Supporting Information

Enantio- and Diastereoselective Synthesis of Hydroxy Bis(boronates) via Cu-Catalyzed Tandem Borylation/1,2-Addition

Jacob C. Green, Matthew V. Joannou, Stephanie A. Murray, Joseph M. Zanghi, and Simon J. Meek*

Department of Chemistry, The University of North Carolina at Chapel Hill, Chapel Hill, North Carolina 27599-3290.

sjmeek@unc.edu

Table of Contents

■ **General:** All reactions were carried out in oven-dried (150 °C) or flame-dried glassware under an inert atmosphere of dried N_2 unless otherwise noted. Analytical thin-layer chromatography was performed on glass plates coated with 0.25 mm of 60 Å mesh silica gel. Plates were visualized by exposure to UV light (254 nm) and/or immersion into $KMnO_4$ or Seebach Stain followed by heating. Column chromatography was performed using silica gel P60 (mesh 230-400) supplied by Silicycle. Deactivated silica gel was prepared by stirring a slurry of the aforementioned silica gel in a 4.5% NaOAc aqueous solution for 15 minutes. The deactivated silica gel was collected by filtration and then dried in a 150 °C oven for 3 days. All solvents were

sparged with argon and then purified under a positive pressure of argon through a SG Water, USA Solvent Purification System. Tetrahydrofuran, toluene, and benzene (OmniSolv) were passed successively through two columns of neutral alumina. The ambient temperature in the laboratory was approximately 22 °C.

■ **Instrumentation:** All ^{1}H NMR spectra were recorded on Bruker Spectrometers (AVANCE-600, AVANCE-500 and AVANCE-400). Chemical shifts are reported in ppm from tetramethylsilane and referenced to the residual protio solvent peak ($CDCl_3$: δ 7.26, C_6D_6: δ 7.16). Data are reported as follows: chemical shift, multiplicity (s = singlet, d = doublet, t = triplet, qu = quartet, quint = quintet, br = broad, m = multiplet, app = apparent), integration, and coupling constants are given in Hz. ^{13}C NMR spectra were recorded on Bruker Spectrometers (AVANCE-600 and AVANCE-400) with carbon and proton decoupling. Chemical shifts are reported in ppm from tetramethylsilane and referenced to the residual protio solvent peak ($CDCl_3$: δ 77.16, C_6D_6: δ 128.06). All IR spectra were recorded on a Jasco 260 Plus Fourier transform infrared spectrometer. Optical rotations were determined using a Jasco P1010 polarimeter and concentrations are reported in g/100mL. Enantiomeric ratios were determined on an Agilent Technologies 1220 Infinity LC using the following columns: Diacel CHIRALPAK IA (4.6 mm x 250 mm x 5 μm), Diacel CHIRALPAK IB (4.6 mm x 250 mm x 5 μm), and Diacel CHIRALPAK IC (4.6 mm x 250 mm x 5 μm). Chiral supercritical fluid chromatography analysis was performed on a Waters Acquity UPC² instrument at 22°C with Phenomenex chiral columns (15 cm) using the conditions detailed for each substrate. Mass Spectrometry samples were analyzed with a hybrid LTQ FT (ICR 7T) (ThermoFisher, Bremen, Germany) mass spectrometer. Samples were introduced *via* a micro-electrospray source at a flow rate of 10 μL/min (solvent composition 10:1 MeOH:H_2O or pure acetonitrile for copper complexes). Xcalibur (ThermoFisher, Breman, Germany) was used to analyze the data. Molecular formula assignments were determined with Molecular Formula Calculator (v 1.2.3). Low-resolution mass spectrometry (linear ion trap) provided independent verification of molecular weight distributions. All observed species were singly charged, as verified by unit *m*/*z* separation between mass spectral peaks corresponding to the ^{12}C and $^{13}C^{12}C_{c-1}$ isotope for each elemental composition.

■ **Reagents:** All liquid aldehydes were distilled from CaH_2 or $CaSO_4$ under reduced pressure and then sparged with dry N_2. Solid aldehydes were purified *via* recrystallization, followed by azeotropic drying with benzene. Tetrakis(acetonitrile)copper hexafluorophosphate was purchased from Sigma Aldrich and kept in an N_2-filled glove box. All chiral phosphine ligands used were purchased from Strem Chemicals Inc. and used as received.

1-(2-allyl-4-fluorophenyl)ethan-1-one was prepared according to a literature procedure[1]

2'-Allylacetophenone was prepared according to a literature procedure[1]

2-Allylbenzaldehyde was prepared according to a literature procedure[1]

4-Anisaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

Bis(pinacolato)diboron was purchased from Frontier Scientific, recrystallized from boiling hexanes, azeotropically dried with benzene three times, and kept in an N_2-filled glovebox

Benzaldehyde was purchased from Alfa-Aesar, vacuum distilled from CaH_2, and then sparged with dry N_2

Benzene-d_6 was purchased from Cambridge Isotope Laboratories and distilled over Na/benzophenone, sparged with dry N_2, and kept in an N_2-filled glove box over 4 Å molecular sieves

Benzoic Anhydride was purchased from Acros and used as received.

Benzylchlorodimethylsilane was purchased from TCI and used as received

1-Bromo-2-methyl-1-propene was purchased from Matrix Scientific and used as recieved

2-Bromobenzaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

2-Bromo-4-chlorobenzaldehyde was purchased from Alfa-Aesar, recrystallized from methanol, azeotropically dried with benzene three times, and then stored in an N_2-filled glovebox

4-Bromobenzaldehyde was purchased from Alfa-Aesar, recrystallized from methanol, azeotropically dried with benzene three times, and then stored in an N_2-filled glovebox

Calcium hydride was purchased from Acros and used without further purification

$CDCl_3$ was purchased from Cambridge Isotope Laboratories and used without further purification

Cyclohexanecarboxyaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

Dibromomethane was purchased from Aldrich and used as received

Dihydrocinnamaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, sparged with dry N_2, and stored at -20 °C

4-Dimethylaminopyridine was purchased from Sigma Aldrich and used as received.

4-Fluorobenzaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

Furan was purchased from Alfa Aesar, dried over CaH_2, distilled under reduced pressure, kept over 4Å molecular sieves and sparged with dry N_2

2-Furylaldehyde was purchased from Acros Organics, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

Geranial was synthesized according to a published literature procedure[2]

Grubb's 1st Generation Catalyst was purchased from Aldrich and used as received

5-Hexen-2-one was purchased from Alfa Aesar and used as received

Hydrogen Peroxide was purchased as a 30% solution in water and stored at -20 °C

Isovaleraldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, sparged with dry N_2, and stored at -20 °C.

Methoxyamine was prepared according to a literature procedure[3]

***n*-Butyllithium** was purchased from Strem and titrated with phenanthroline/*sec*-butanol

N-Boc-3-indolecarboxaldehyde was synthesized according to a published literature procedure[4]

N-Bromosuccinimide was purchased from Aldrich and recrystallized from water before use

Nicotinaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

Palladium(II) Acetate was purchased from Strem Chemicals and used as received

Potassium *tert*-butoxide were purchased from Strem and used as received

RuPhos was purchased from Sigma Aldrich and used as received

Sodium Hydroxide was purchased from Fisher Scientific and used as received

***tert*-Butyl allyl(2-oxopropyl)carbamate** was prepared according to a modified literature procedure[5]

***tert*-Butyldimethylsilyl chloride** was purchased from Sigma-Aldrich and used as received

2-Tolualdehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

3-Tolualdehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

Triethylamine was purchased from Sigma Aldrich, dried over CaH_2, and distilled under N_2.

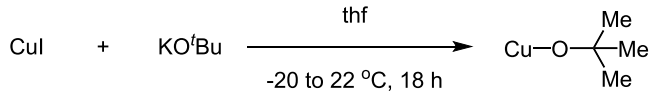
2,4,6-Trimethylbenzaldehyde was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

***trans*-Cinnamaldehyde** was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

***trans*-α-Methylcinnamaldehyde** was purchased from Alfa-Aesar, dried over CaH_2, distilled under reduced pressure, and then sparged with dry N_2

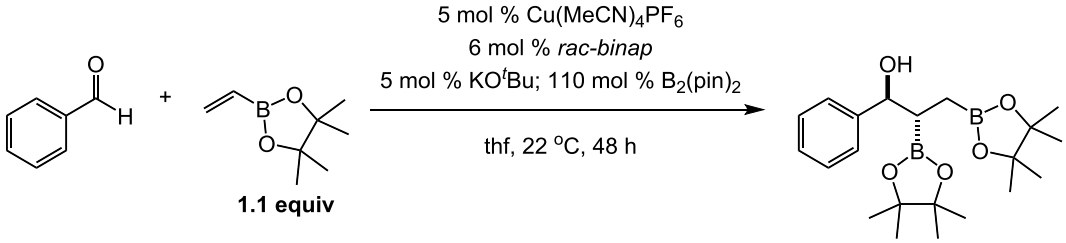
Vinyl boronic acid pinacol ester was purchased from Sigma Aldrich, dried over CaH_2, distilled under reduced pressure, sparged with dry N_2, and stored at -20 °C in an N_2-filled glovebox

■ Synthesis of Copper *tert*-butoxide



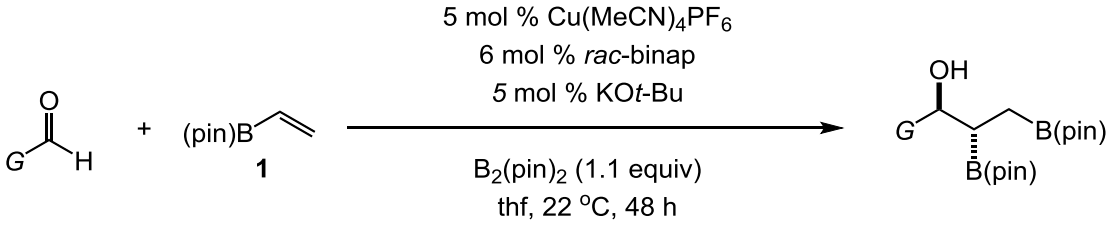
Procedure: Copper *tert*-butoxide was prepared according to a literature procedure.[6] In an N_2-filled glovebox, a -20 °C solution of KO*t*-Bu (295.6 mg, 2.625 mmol) in thf (3.35 mL) was added to a -20 °C suspension of CuI (500.0 mg, 2.625 mmol) in thf (3.35 mL) in a 20 mL scintillation vial. The vial was agitated and allowed to stand at -20 °C for 30 minutes. The reaction was then allowed to stir at ambient temperature for 18 hours. The heterogeneous reaction was allowed to settle and the supernatant was removed and filtered over Celite®. The filtrate was concentrated to afford CuO*t*-Bu as a tan/yellow powder in 75% yield (269 mg). **^{1}H NMR** (600 MHz, C_6D_6): δ 1.31 (s, 9H). **^{13}C NMR** (151 MHz, C_6D_6): δ 72.3, 35.5.

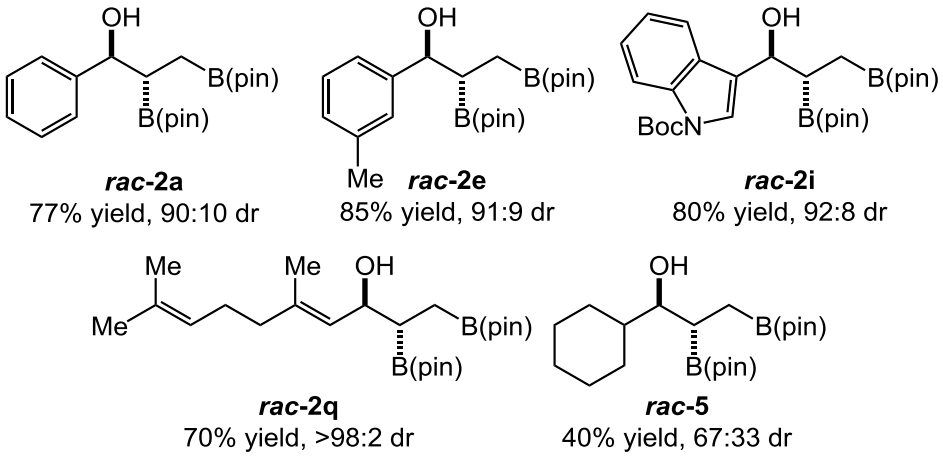
■ General Procedure (I) for the Diastereoselective Multicomponent Borylation/1,2-Addition Reaction



Procedure: In an N_2-filled glovebox, an 8-mL vial equipped with a magnetic stir bar was charged with $Cu(MeCN)_4PF_6$ (1.9 mg, 0.0050 mmol) and *rac*-binap (3.7 mg, 0.0060 mmol) and dissolved in 400 μL of thf. The reaction was allowed to stir at ambient temperature for 60 minutes, after which time the solution was transferred to an 8-mL vial containing KO^{t}Bu (0.6 mg, 0.0050 mmol). The original vial was washed with 200 μL of thf and the reaction mixture allowed to stir at ambient temperature for 30 minutes. Bis(pinacolato)diboron (27.9 mg, 0.110 mmol) was added to the vial as a solution in thf (200 μL). Vinyl boronic acid pinacol ester (18.7 μL, 0.110 mmol) and the aldehyde (0.1 mmol) were added sequentially via syringe. The reaction was capped with a Teflon-lined lid, sealed with electrical tape, removed from the glovebox, and allowed to stir at ambient temperature for 48 hours. The reaction was quenched with 2 mL of a saturated aqueous solution of NH_4Cl and allowed to stir vigorously at 22 °C for 30 minutes. The aqueous layer was extracted three times with diethyl ether, and the combined organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. Conversions and diastereomeric ratios were determined by ^{1}H NMR, using hexamethyldisiloxane as an internal standard.

Scheme S1. Diastereoselective Multicomponent Borylation/1,2-Addition of Vinylboron **1** and Aldehydes[a-c]





***rac*-2a**
77% yield, 90:10 dr

***rac*-2e**
85% yield, 91:9 dr

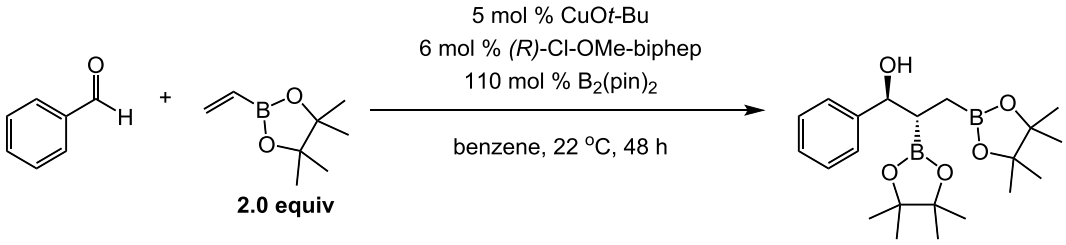
***rac*-2i**
80% yield, 92:8 dr

***rac*-2q**
70% yield, >98:2 dr

***rac*-5**
40% yield, 67:33 dr

[a]Reactions performed under an N_2 atmosphere. [b]Diastereoselectivity determined using ^{1}H NMR spectroscopy on the crude reaction mixture. [c]Isolated yields correspond to the anti diastereomer

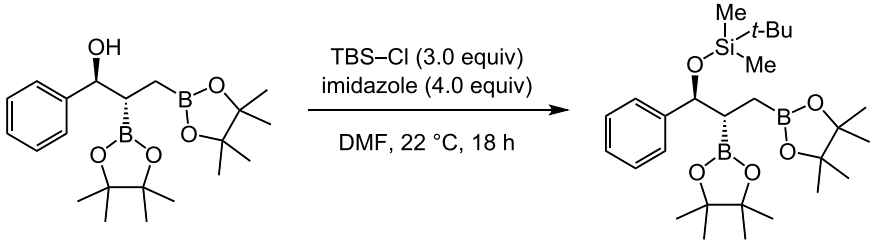
■ **General Procedure (II) for the Enantio- and Diastereoselective Multicomponent Borylation/1,2-Addition Reaction**



Procedure: In an N_2-filled glovebox, an 8-mL vial equipped with a magnetic stir bar was charged with CuO*t*-Bu (1.4 mg, 0.010 mmol) and *(R)*-Cl-OMe-biphep (7.2 mg, 0.011 mmol) and dissolved in 400 μL of benzene. The reaction was allowed to stir at ambient temperature for 60 minutes. Bis(pinacolato)diboron (27.9 mg, 0.110 mmol) was added to the vial as a solution in benzene (200 μL), followed by vinyl boronic acid pinacol ester (18.7 μL, 0.110 mmol), and the aldehyde (0.1 mmol) neat via syringe. The reaction was capped with a Teflon-lined lid, sealed with electrical tape, removed from the glovebox, and allowed to stir at ambient temperature for 48 hours. The reaction was quenched with 2 mL of a saturated aqueous solution of NH_4Cl and allowed to stir vigorously at 22 °C for 30 minutes. The aqueous layer was extracted three times with diethyl ether, and the combined organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. Conversions and diastereomeric ratios were determined by ^1H NMR, using hexamethyldisiloxane as an internal standard.

For determination of the enantioselectivity of alkyl aldehyde addition products without a UV absorbing group (aryl ring, alkene, etc.), the 1-hydroxy-2,3-bisboroantes were oxidized to the triol and subsequently benzoylated to afford the 1,2,3-tris-benzoate products, which were assayed via HPLC.

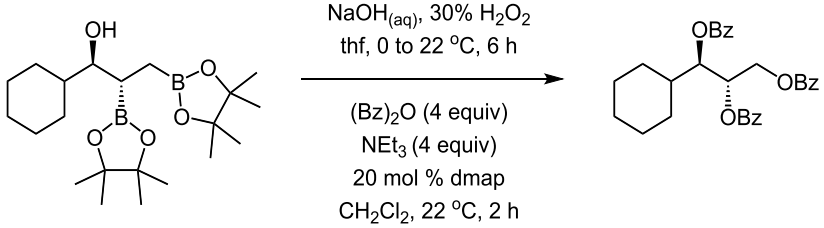
■ **General Procedure (III) for the TBS-Protection of 1-Hydroxy-2,3-bisboronate Products**



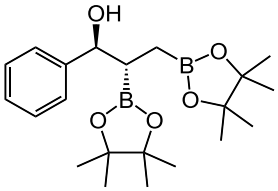
A crude reaction mixture of 1-hydroxy-2,3-bisboronate was charged with imidazole (4.0 equivalents) and a magnetic stir bar and dried under vacuum for 20 minutes. TBSCl (3.0

equivalents) was then added to the vial and purged with N_2 for 5 minutes. Anhydrous dmf (0.15M) was then added via syringe under N_2 and the reaction was purged for an additional 5 minutes and then allowed to stir at ambient temperature for 18 hours. The reaction was quenched by addition of 1 mL of a saturated aqueous solution of NH_4Cl. The mixture was extracted 3X with diethyl ether and the combined organic extracts were washed with a saturated aqueous solution of $NaHCO_3$, followed by brine. The washed organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude reaction mixture was purified *via* silica gel chromatography (20:1 hexanes:Et_2O, Seebach Stain visualization) to yield the TBS-protected products.

■ **Supplementary Procedure A: Oxidation/Benzoylation of Alkyl Aldehyde Addition Products**



A vial containing **2p** (7.9 mg, 0.2 mmol) was charged with thf (800 μL) and allowed to cool to 0 °C (ice/water bath). The reaction was charged with 3M NaOH (400 μL, 1.2 mmol) and then 30% H_2O_2 (400 μL, 4.0 mmol) dropwise. The reaction was allowed to slowly warm up to ambient temperature over 2 hours, followed by 4 hours of additional stirring at that temperature. The reaction was allowed to cool to 0 °C and quenched by dropwise addition of 1M $Na_2S_2O_3$. The reaction was diluted with water and then extracted 6X with EtOAc. The combined organic extracts were dried over Na_2SO_4, filtered, and then concentrated *in vacuo*. The crude oxidation mixture was taken up in 1:1 hexanes:EtOAc and passed through a column of silica gel (to remove pinacol) and then flushed thoroughly with pure EtOAc to isolate the product. The purified triol (9.4 mg, 0.054 mmol), benzoic anhydride (48.8 mg, 0.216 mmol), and 4-dimethylaminopyridine (1.3 mg, 0.0108 mmol) were added to an 8 mL vial equipped with a stir bar and then dried *in vacuo* for 10 minutes. The vial was purged with N_2 for 10 minutes and then charged with CH_2Cl_2 (500 μL) followed by NEt_3 (30.1 μL, 0.216 mmol). The reaction was allowed to stir at ambient temperature for 2 hours and then quenched with a saturated aqueous solution of NH_4Cl. The biphasic mixture was extracted 3X with diethyl ether, dried over $MgSO_4$, filtered, and then concentrated *in vacuo*. The product was purified via silica gel chromatography (5:1 pentane:Et_2O) to afford the product.



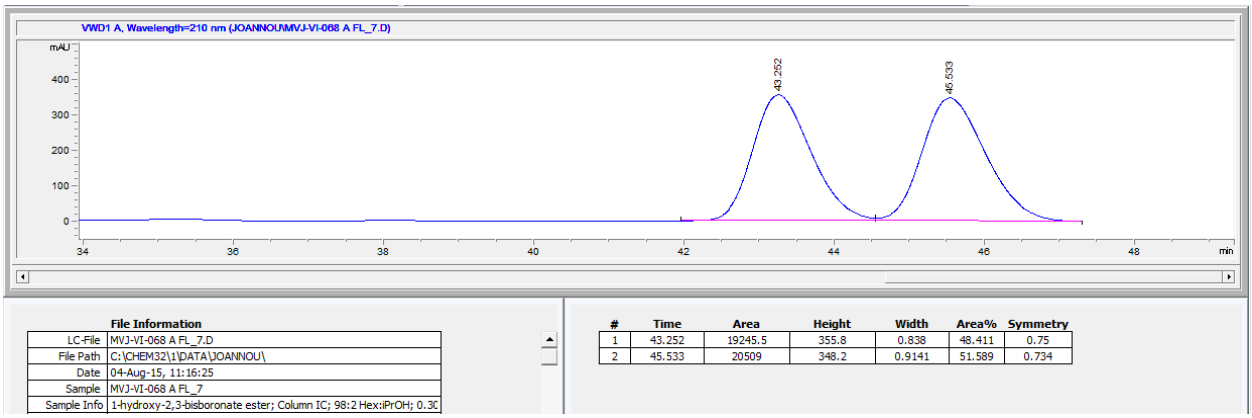
2a

1-phenyl-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2a). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 74% yield (28.7 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.39 – 7.35 (m, 2H), 7.32 (t, *J* = 7.6 Hz, 2H), 7.26 – 7.22 (m, 1H), 4.72 (dd, *J* = 7.6, 3.7 Hz, 1H), 3.11 (d, *J* = 4.7 Hz, 1H), 1.66 (ddd, *J* = 8.9, 7.5, 5.7 Hz, 1H), 1.25 (d, *J* = 2.2 Hz, 24H), 0.88 – 0.74 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 144.3, 128.1, 127.1, 126.4, 83.5, 83.1, 28.4, 24.9, 24.8, 24.8, 24.8, 9.6. **IR** (υ/cm^{-1}): 3481 (s, br), 3080 (w), 2976 (s), 2941 (m), 2875 (m), 1489 (w), 1465 (m), 1330 (m), 1249 (w), 1230 (w), 1113 (w), 1111 (w). **HRMS** (ESI$^+$) calcd for $C_{21}H_{34}B_2O_5Na^+$ 411.2490, found: [M+Na$^+$] 411.2485. **[α]$_D^{22}$** = —20.6 (*c* = 5.45, CH_2Cl_2, *l* = 100 mm).

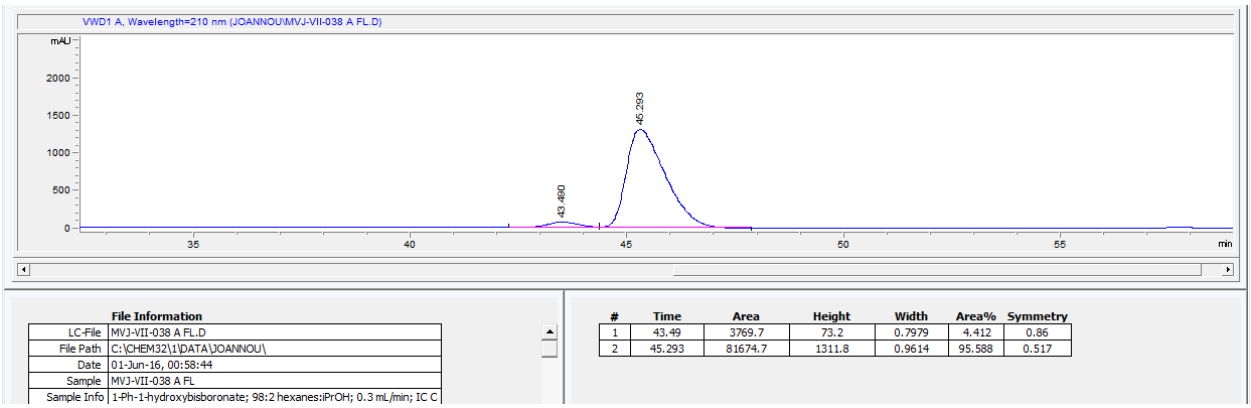
The absolute stereochemistry and diastereoselectivity of the product was determined by [α]$_D$ analysis of the oxidized product (1,2,3-triol) which has been previously characterized (found **[α]$_D^{22}$** = —71.67 (*c* = 2.95, CH_2Cl_2, *l* = 100 mm), lit: **[α]$_D^{21}$** = —89.73 (*c* = 0.66, $CHCl_3$).[6]

For all 1-hydroxy-2,3-bisboronate products, the ^{13}C NMR signals for the carbons bound to each boronate ester are highly broadened and sometimes absent, likely due to quadrupolar relaxation of the $^{10/11}$B nucleus coupled to ^{13}C nucleus.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm

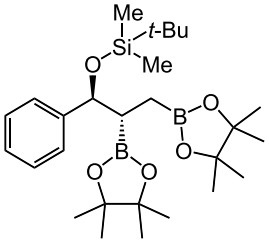


Racemic Material



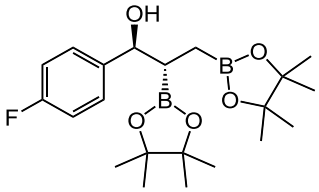
Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 43.4 min; (1*S*,2*S*) enantiomer: 45.3 min: 96:4 e.r.



10

tert-butyldimethyl(1-phenyl-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propoxy)silane (10). Following General Procedure III, the crude reaction mixture was purified *via* silica gel chromatography (25:1 pentane:Et_2O, Seebach Stain visualization) to yield the TBS-protected product in 62% yield (over two steps) in 84:16 d.r. (155.6 mg). ***Anti* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.34 – 7.30 (m, 2H), 7.25 (dd, *J* = 8.3, 6.8 Hz, 2H), 7.20 – 7.16 (m, 1H), 4.78 (d, *J* = 6.5 Hz, 1H), 1.63 – 1.58 (m, 1H), 1.25 (s, 6H), 1.23 (s, 6H), 1.21 (s, 6H), 1.21 (s, 6H), 0.88 (s, 9H), 0.78 – 0.74 (m, 2H), 0.03 (s, 3H), -0.27 (s, 3H). ***Syn* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.34 – 7.31 (m, 2H), 7.25 (t, *J* = 7.6 Hz, 2H), 7.20 – 7.16 (m, 1H), 4.62 (d, *J* = 8.7 Hz, 1H), 1.54 (ddd, *J* = 12.4, 8.7, 3.6 Hz, 1H), 1.25 (s, 6H), 1.23 (s, 6H), 1.21 (s, 6H), 1.21 (s, 6H), 0.84 (s, 9H), 0.78 – 0.74 (m, 2H), 0.02 (s, 3H), -0.27 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 145.5, 145.1, 127.6, 127.5, 127.2, 127.0, 126.8, 126.6, 82.9, 82.9, 82.8, 82.8, 78.0, 77.9, 30.1, 26.0, 25.9, 25.2, 25.0, 25.0, 25.0, 24.9, 24.8, 24.8, 24.7, 18.2, 8.9, -4.5, -4.7. **IR** (ν/cm^{-1}): 2985 (m), 2945 (m), 2879 (m), 2843 (m), 1416 (m), 1402 (w), 1379 (m), 1371 (m). **HRMS** (ESI$^+$): calcd for $C_{27}H_{48}B_2O_5SiNa^+$ 525.3355, found [M+Na$^+$] 525.3350. **[α]$_D^{22}$** = —37.2 (*c* = 7.92, CH_2Cl_2, *l* = 100 mm).

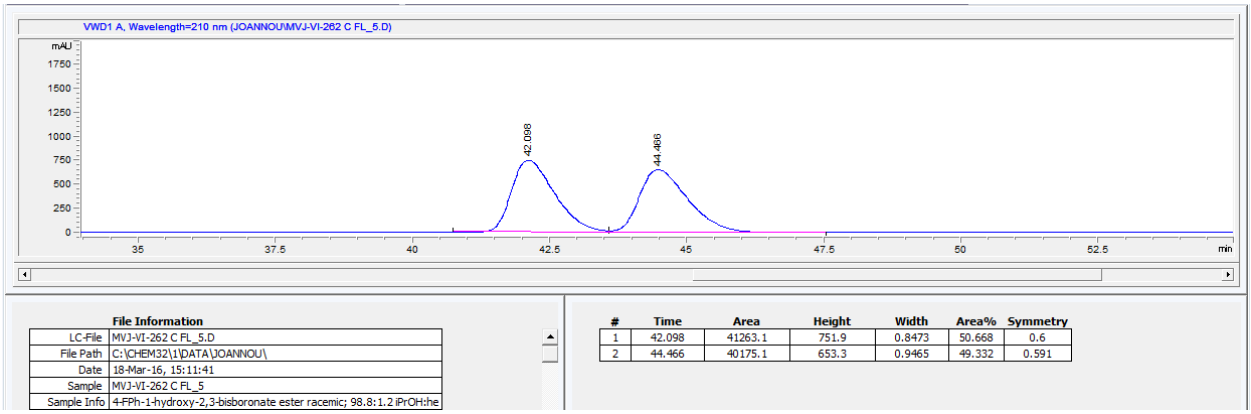


2b

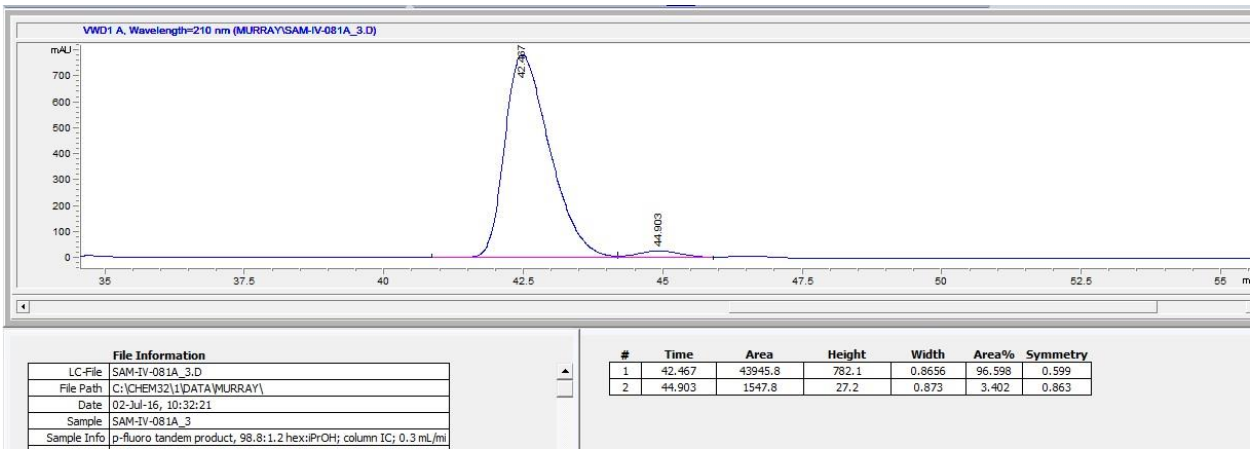
1-(4-fluorophenyl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2b). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 70% yield (28.4 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.36 – 7.31 (m, 2H), 7.00 (t, *J* = 8.7 Hz, 2H), 4.70 (dd, *J* = 7.7, 2.9 Hz, 1H), 3.18 (d, *J* = 4.6 Hz, 1H), 1.65 – 1.57 (m, 1H), 1.25 (d, *J* = 1.5 Hz, 24H), 0.78 (qd, *J* = 16.1, 7.2 Hz, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 162.4 (d, *J* = 244.2 Hz), 140.1 (d, *J* = 3.1 Hz), 128.0 (d, *J* = 8.0 Hz), 114.8 (d, *J* = 21.2 Hz), 83.6, 83.2, 76.6, 28.5, 24.9, 24.8, 24.8, 24.8, 9.5. **IR** (υ/cm^{-1}): 3506 (s, br), 3080 (w), 2890 (m), 1510 (w), 1499 (m), 1340 (m), 1199 (w). **HRMS** (ESI$^+$) calcd for $C_{21}H_{33}O_5B_2FNa^+$ 429.2396, found: [M+Na] 429.2391. **[α]$_D^{22}$** = — 39.4 (*c* = 5.40, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98.8:1.2 hexanes:iPrOH; 0.3 mL/min; 210 nm

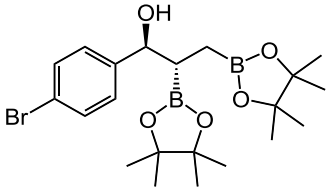


Racemic Material



Enantioenriched Material

***Anti* diastereomer:** (1*S*,2*S*) enantiomer**:** 42.5 min; (1*R*,2*R*) enantiomer: 44.9 min: 96:4 e.r.

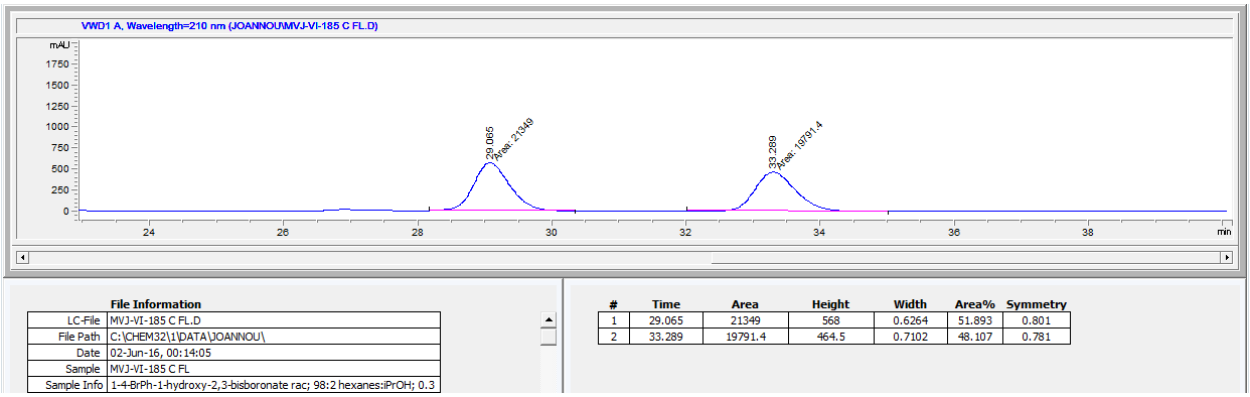


2c

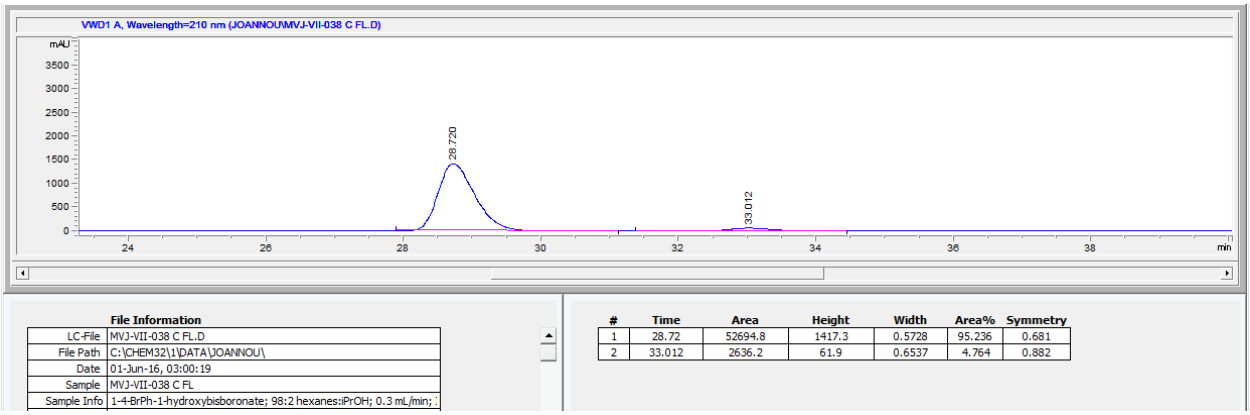
1-(4-bromophenyl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2c). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 68% yield (31.8 mg) and a 5.7:1 anti:syn diastereomeric ratio. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 7.47 – 7.40 (m, 2H), 7.26 – 7.22 (m, 2H), 4.68 (d, *J* = 7.3 Hz, 1H), 3.22 (s, 1H), 1.63 – 1.56 (m, 1H), 1.25 (s, 24H), 0.80 (ddd, *J* = 14.9, 7.5, 5.7 Hz, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 143.4, 131.1, 128.2, 120.8, 83.6, 83.2, 76.7, 28.3, 24.9, 24.8, 24.8, 24.8, 9.6. **IR** (υ/cm^{-1}): 3400 (s, br), 2988 (w), 2850 (m), 1599 (w), 1511 (m), 1329 (m). **HRMS** (ESI$^+$) calcd for $C_{21}H_{33}O_5B_2BrNa^+$ 489.1595, found: [M+Na] 489.1593. **[α]$_D^{22}$** = —19.3 (*c* = 6.05, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm

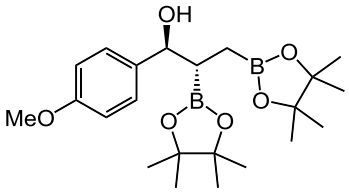


Racemic Material



Enantioenriched Material

***Anti* diastereomer:** (1*S*,2*S*) enantiomer**:** 28.7 min; (1*R*,2*R*) enantiomer: 33.0 min: 95:5 e.r.

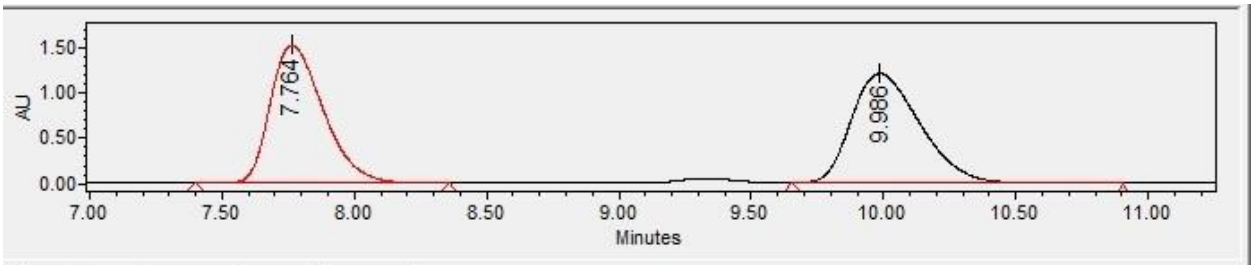


2d

1-(4-methoxyphenyl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2d). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 70% yield (29.3 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.31 – 7.26 (m, 2H), 6.88 – 6.84 (m, 2H), 4.66 (dd, *J* = 7.9, 2.7 Hz, 1H), 3.80 (s, 3H), 3.04 (d, *J* = 4.3 Hz, 1H), 1.62 (ddd, *J* = 9.0, 7.9, 5.7 Hz, 1H), 1.26 (s, 12H), 1.23 (s, 12H), 0.81 – 0.70 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 158.7, 136.5, 127.6, 113.4, 83.5, 83.1, 76.9, 55.3, 28.4, 24.9, 24.9, 24.8, 24.8, 9.6. **IR** (υ/cm^{-1}): 3489 (s, br), 2921 (m), 1567 (m), 1482 (w), 1289 (m). **HRMS** (ESI^+) calcd for $C_{22}H_{36}O_6B_2Na^+$ 441.2596, found: [M+Na] 441.2590. **[α]$_D^{22}$** = —27.8 (*c* = 5.56, CH_2Cl_2, *l* = 100 mm).

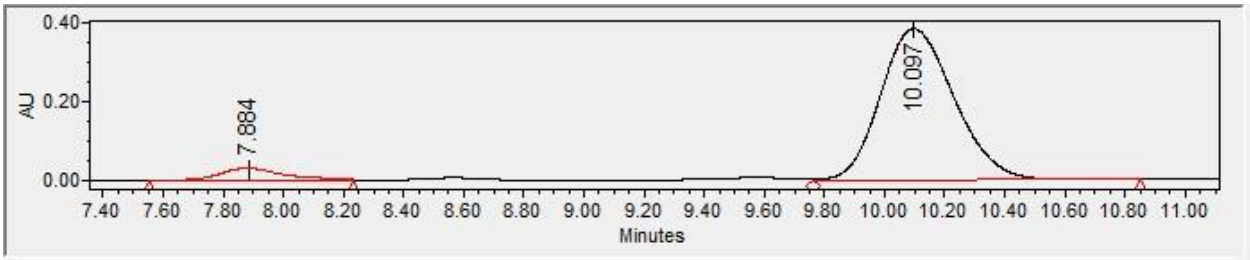
Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Phenomenex Amylose-1 Column; 90:10 CO_2:iPrOH; 1.0 mL/min; 35 °C; 220 nm



	Retention Time (min)	Area (μV*sec)	% Area	Height (μV)
1	7.764	21323254	49.33	1527588
2	9.986	21899645	50.67	1213464

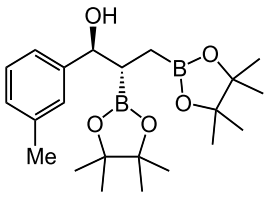
Racemic Material



	Retention Time (min)	Area (μV*sec)	% Area	Height (μV)
1	7.884	426176	6.18	29880
2	10.097	6471047	93.82	381259

Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 7.9 min; (1*S*,2*S*) enantiomer: 10.1 min: 94:6 e.r.



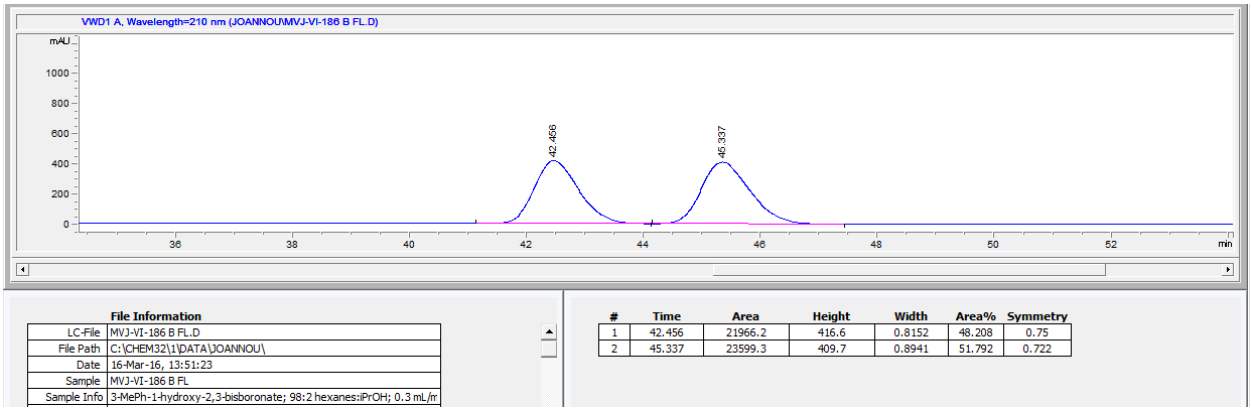
2e

2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1-(3-tolyl)propan-1-ol (2e). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column

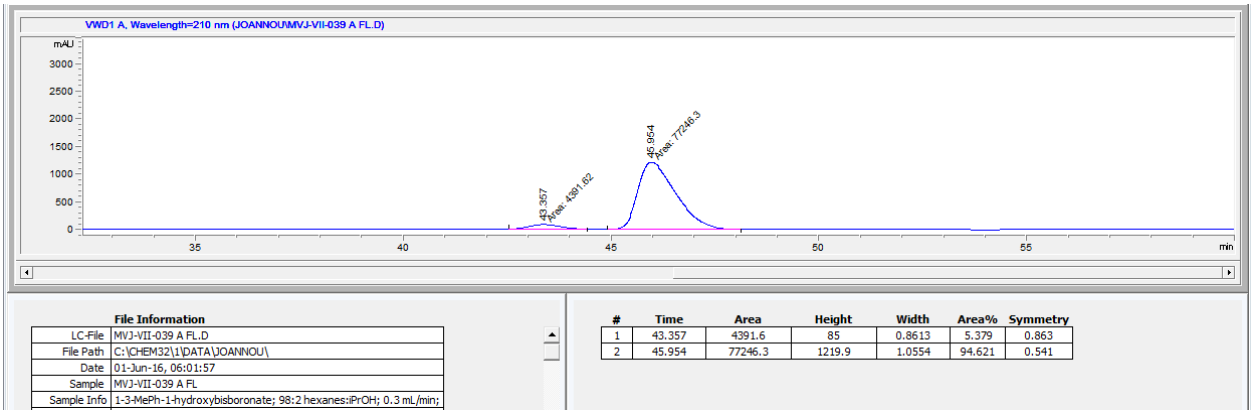
chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 75% yield (30.2 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.22 – 7.18 (m, 3H), 7.16 – 7.13 (m, 1H), 7.05 (dd, *J* = 7.9, 1.1 Hz, 1H), 4.68 (d, *J* = 7.5 Hz, 1H), 3.09 (s, 1H), 2.34 (s, 3H), 1.67 – 1.61 (m, 1H), 1.25 (d, *J* = 5.3 Hz, 24H), 0.87 – 0.74 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 144.3, 137.5, 127.9, 127.8, 127.1, 123.6, 83.5, 83.1, 77.3, 28.4, 24.9, 24.9, 24.8, 24.8, 21.5, 9.7. **IR** (υ/cm^{-1}): 3356 (s, br), 2879 (m), 1603 (m), 1594 (w), 1392 (m), 1303 (w). **HRMS** (ESI^+) calcd for $C_{22}H_{36}O_5B_2Na^+$ 425.2647, found: [M+Na] 425.2642. **[α]$_D^{22}$** = —30.2 (*c* = 5.73, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm

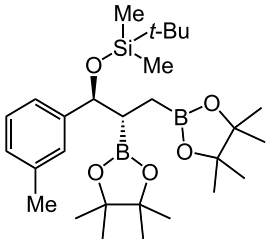


Racemic Material



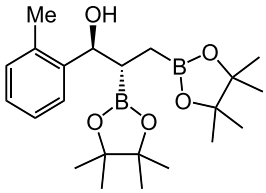
Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 43.4 min; (1*S*,2*S*) enantiomer: 46.0 min: 95:5 e.r.



S1

((1*S*,2*S*)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1-(*m*-tolyl)propoxy)(*tert*-butyl)dimethylsilane (S1). Following General Procedure III, the crude reaction mixture was purified *via* silica gel chromatography (25:1 pentane:Et_2O, Seebach Stain visualization) to yield the TBS-protected product in 77% yield (over two steps) in 3.6:1 d.r. (39.5 mg). ***Anti* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.14 – 7.07 (m, 4H), 4.74 (d, *J* = 6.4 Hz, 1H), 2.29 (s, 3H), 1.57 (ddd, *J* = 11.2, 6.2, 4.8 Hz, 1H), 1.22 (s, 6H), 1.20 (s, 6H), 1.19 (s, 6H), 1.18 (s, 6H), 0.85 (s, 9H), 0.00 (s, 3H), -0.28 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 145.0, 136.7, 127.7, 127.3, 127.2, 124.1, 82.9, 82.8, 77.9, 26.0, 25.2, 25.0, 25.0, 24.7, 21.5, 18.2, -4.5, -4.7. ***Syn* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) 6.96 (m, 4H), 4.57 (d, *J* = 8.6 Hz, 1H), 2.29 (s, 3H), 1.49 (ddd, *J* = 12.4, 8.6, 3.6 Hz, 1H), 1.22 (s, 6H), 1.21 (s, 6H), 1.12 (s, 6H), 0.99 (s, 6H), 0.82 (s, 9H), -0.01 (s, 3H), -0.29 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 145.4, 136.7, 127.8, 127.5, 127.4, 124.2, 82.8, 82.8, 77.9, 26.0, 24.9, 24.8, 24.8, 24.7, 21.5, 18.2, -4.4, -4.8. **IR** (ν/cm^{-1}): 2977.55 (s), 2928.38 (m), 2856.06 (m), 1471.42 (s), 1371.14 (m), 1316.18 (m), 1144.55 (s). **HRMS** (ESI$^+$): calcd for $C_{28}H_{50}B_2O_5SiNa^+$ 539.3511, found [M+Na$^+$] 539.3499. **[α]$_D^{22}$** = + 5.6 (*c* = 1.98, CH_2Cl_2, *l* = 100 mm).



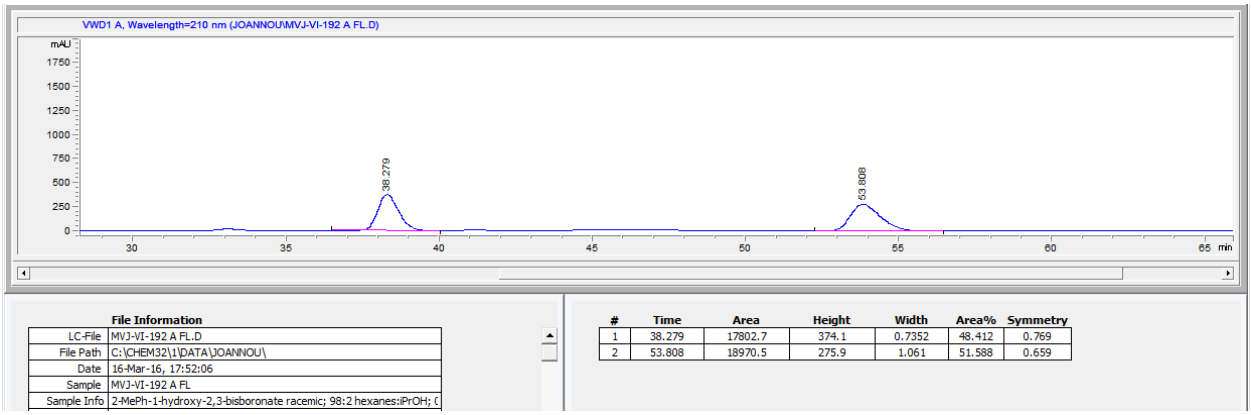
2f

2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1-(2-tolyl)propan-1-ol (2f). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 81% yield (32.6 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.48 (dd, *J* = 7.7, 1.4 Hz, 1H), 7.20 (td, *J* = 7.4, 1.6 Hz, 1H), 7.16 – 7.08 (m, 2H), 4.91 (d, *J* = 6.8 Hz, 1H), 3.21 (s, 1H), 2.37 (s, 3H), 1.67 (dt, *J* = 8.7, 6.5 Hz, 1H), 1.26 (m, 12H), 1.25 (s, 12H), 0.92 – 0.81 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 142.7, 135.3, 130.1, 126.8, 125.9, 125.6, 83.5, 83.1, 74.0, 24.9, 24.9, 24.8, 19.5,

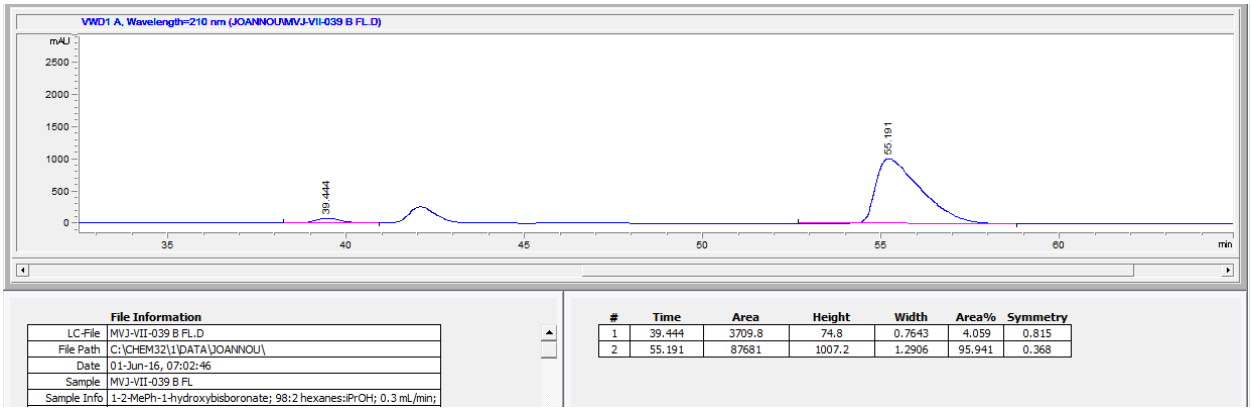
10.2. **IR** (υ/cm^{-1}): 3892 (s, br), 2899 (m), 2657 (m), 1455 (w), 1515 (w) 1301 (m). **HRMS** (ESI$^+$) calcd for $C_{22}H_{36}O_5B_2Na^+$ 425.2647, found: [M+Na] 425.2643. **[α]$_D^{22}$** = —39.2 (*c* = 6.19, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm



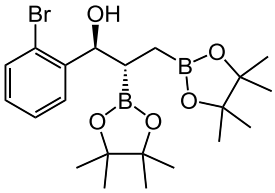
Racemic Material



Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 39.4 min; (1*S*,2*S*) enantiomer: 55.2 min: 96:4 e.r.

The peak at 42 min is the major enantiomer of the minor diastereomer, which was not present in the racemic product. It fluoresces more intensely than the *anti* diastereomer.

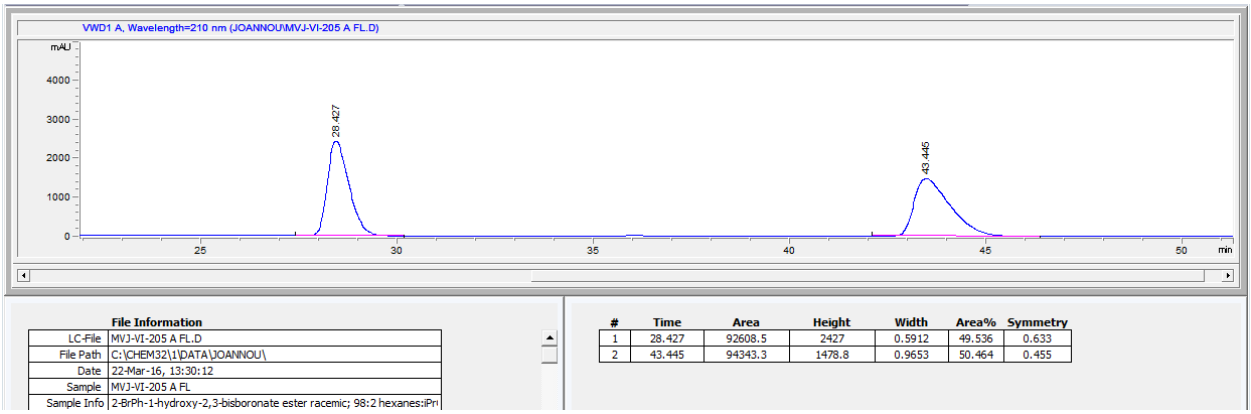


2g

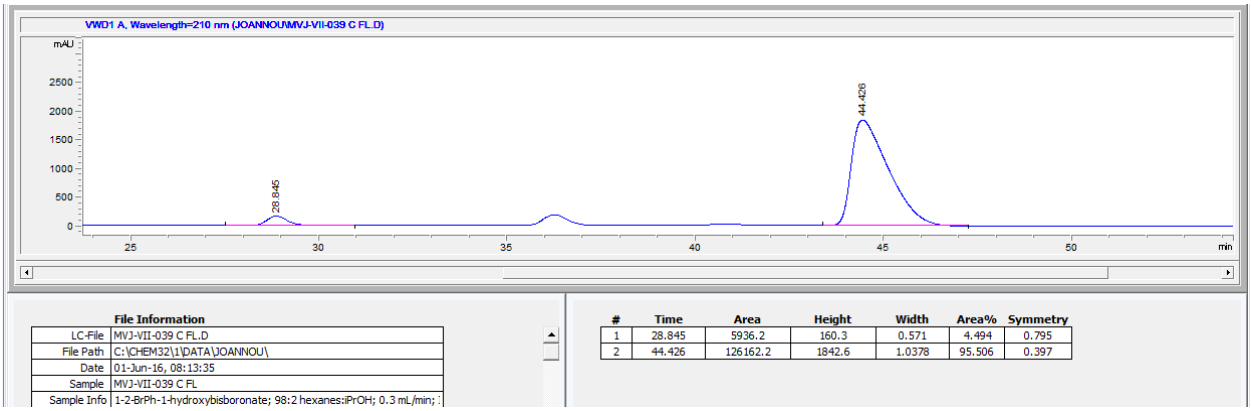
1-(2-bromophenyl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2g). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 83% yield (38.8 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.58 (dd, *J* = 7.8, 1.7 Hz, 1H), 7.50 (dd, *J* = 8.0, 1.2 Hz, 1H), 7.33 – 7.29 (m, 1H), 7.09 (ddd, *J* = 7.9, 7.3, 1.7 Hz, 1H), 5.03 (dd, *J* = 6.5, 3.2 Hz, 1H), 3.65 (d, *J* = 4.8 Hz, 1H), 1.76 (dt, *J* = 9.4, 5.4 Hz, 1H), 1.27 (d, *J* = 3.9 Hz, 24), 1.05 (dd, *J* = 15.9, 9.2 Hz, 1H), 0.90 (dd, *J* = 16.0, 5.0 Hz, 1H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 143.6, 132.4, 128.4, 127.9, 127.2, 123.0, 83.5, 83.2, 76.6, 27.5, 25.0, 24.9, 24.9, 24.8, 10.7. **IR** (υ/cm^{-1}): 3545 (s, br), 2923 (m), 1525 (m), 1359 (m), 1189 (w). **HRMS** (ESI$^+$) calcd for $C_{21}H_{33}O_5B_2BrNa^+$ 489.1595, found: [M+Na] 489.1590. **[α]$_D^{22}$** = —41.1 (*c* = 7.38, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm

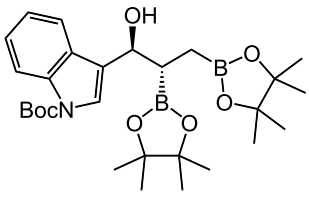


Racemic Material



Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 28.8 min; (1*S*,2*S*) enantiomer: 44.4 min: 96:4 e.r.
The peak at 36 min is the major enantiomer of the minor diastereomer, which was not present in the racemic product. It fluoresces more intensely than the *anti* diastereomer.

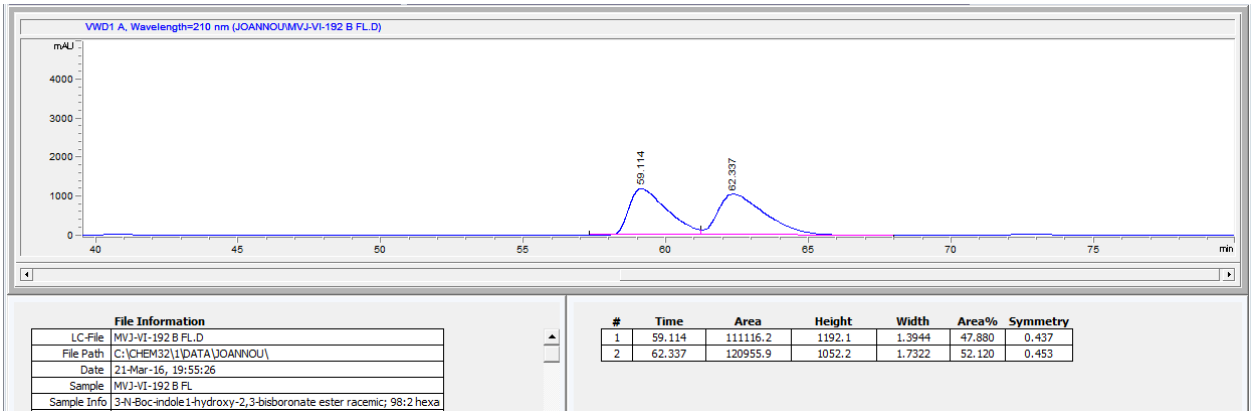


2h

tert-butyl 3-(1-hydroxy-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)-1H-indole-1-carboxylate (2h). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 63% yield (33.2 mg) and a 3:1 *anti*:*syn* diastereomeric ratio. ***Anti* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.79 (dt, *J* = 7.9, 1.0 Hz, 1H), 7.52 (s, 1H), 7.34 – 7.29 (m, 1H), 7.22 (ddd, *J* = 8.1, 7.2, 1.1 Hz, 1H), 4.99 (t, *J* = 5.9 Hz, 1H), 3.20 (s, 1H), 1.90 (dt, *J* = 8.3, 6.5 Hz, 1H), 1.66 (s, 9H), 1.27 (d, *J* = 3.6 Hz, 12H), 1.26 – 1.25 (m, 12H), 1.00 (dd, *J* = 16.2, 6.2 Hz, 1H), 0.91 (dd, *J* = 16.2, 8.3 Hz, 1H). ***Syn* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) δ 8.15 (s, 1H), 7.79 (dt, *J* = 7.9, 1.0 Hz, 1H), 7.52 (s, 1H), 7.34 – 7.29 (m, 1H), 7.22 (ddd, *J* = 8.1, 7.2, 1.1 Hz, 1H), 5.18 (d, *J* = 6.5 Hz, 1H), 1.96 – 1.91 (m, 1H) 1.21 (s, 12H), 1.20 (s, 12H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 149.7, 129.1, 129.0, 124.2, 124.1, 123.8, 122.7, 122.4, 120.5, 120.0, 115.1, 83.5, 83.4, 83.3, 83.2, 75.0, 71.2, 69.7, 28.2, 26.7, 25.0, 24.9, 24.9, 24.9, 24.8, 24.8, 24.7, 24.7, 10.0. **IR** (ν/cm^{-1})**:** 3499 (s, br), 2998 (s), 2867 (w), 1732 (s), 1480 (s), 1354 (s), 1319 (m), 1267 (m). **HRMS** (ESI$^+$) calcd for $C_{28}H_{43}O_7NB_2Na^+$ 550.3123, found: [M+Na] 550.3118. **[α]$_D^{22}$** = —9.7 (*c* = 5.80, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

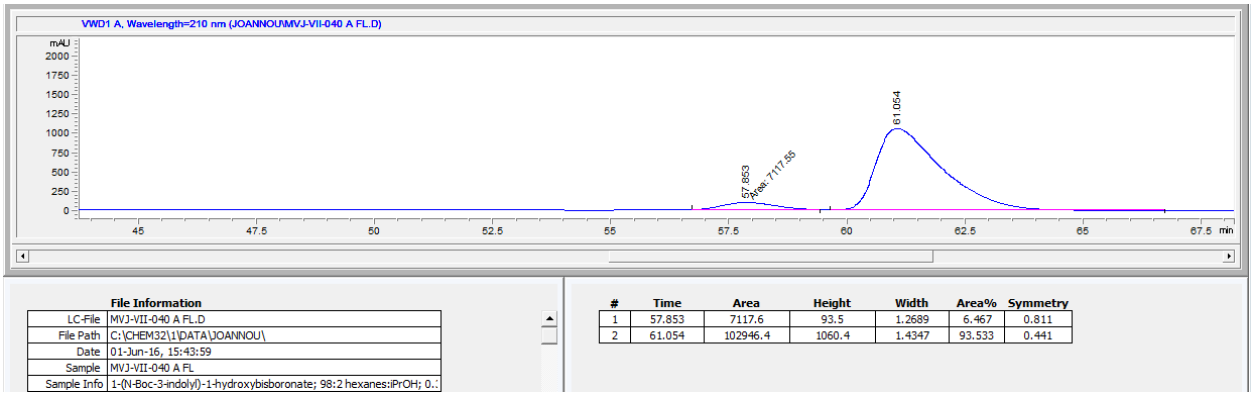
Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm



File Information	
LC-File	MVJ-VI-192 B FL.D
File Path	C:\CHEM32\1\DATA\JOANNOU\
Date	21-Mar-16, 19:55:26
Sample	MVJ-VI-192 B FL
Sample Info	3-N-Boc-indole1-hydroxy-2,3-bisboronate ester racemic; 98:2 hexa

#	Time	Area	Height	Width	Area%	Symmetry
1	59.114	111116.2	1192.1	1.3944	47.880	0.437
2	62.337	120955.9	1052.2	1.7322	52.120	0.453

Racemic Material (anti)

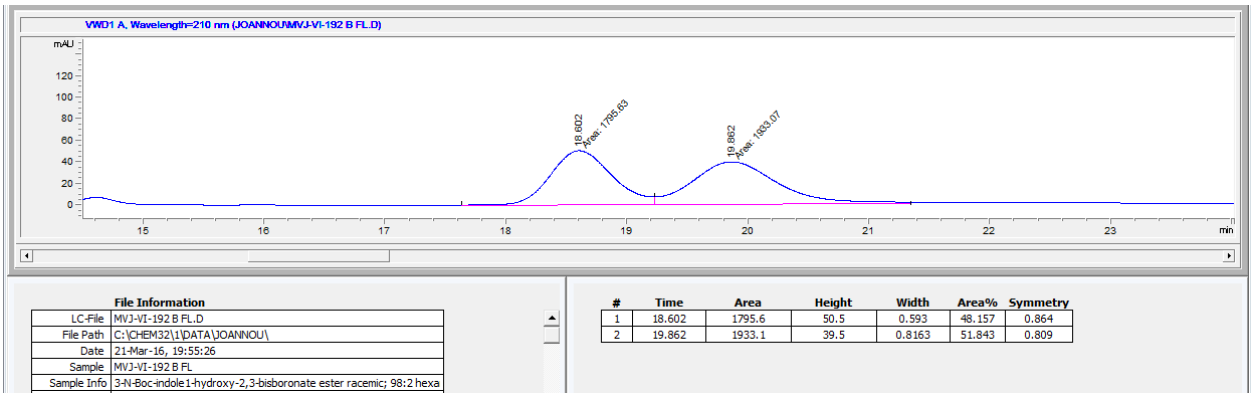


File Information	
LC-File	MVJ-VII-040 A FL.D
File Path	C:\CHEM32\1\DATA\JOANNOU\
Date	01-Jun-16, 15:43:59
Sample	MVJ-VII-040 A FL
Sample Info	1-(N-Boc-3-indolyl)-1-hydroxybisboronate; 98:2 hexanes:iPrOH; 0.:

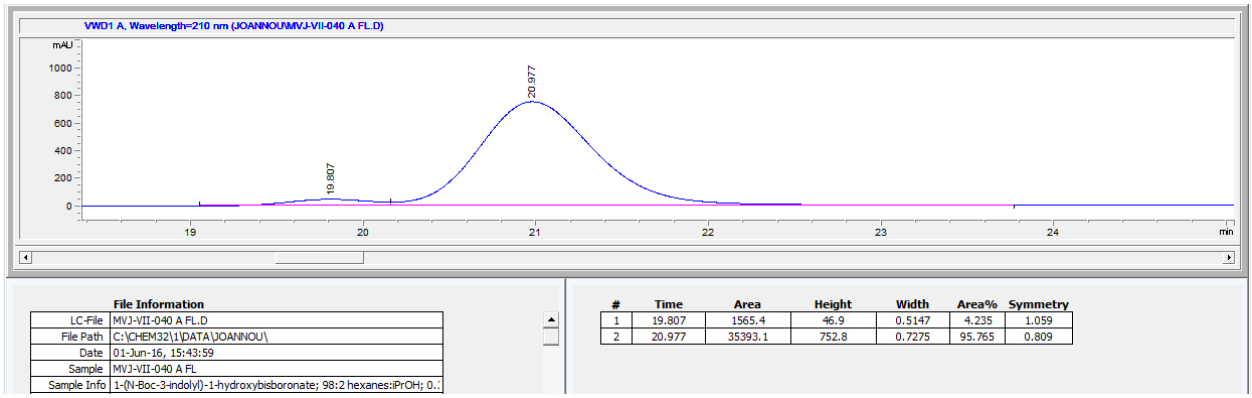
#	Time	Area	Height	Width	Area%	Symmetry
1	57.853	7117.6	93.5	1.2689	6.467	0.811
2	61.054	102946.4	1060.4	1.4347	93.533	0.441

Enantioenriched Material (anti)

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 58.9 min; (1*S*,2*S*) enantiomer: 61.1 min: 94:6 e.r.

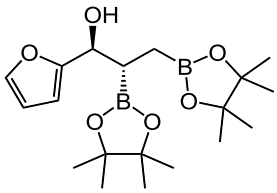


Racemic Material (syn)



Enantioenriched Material (syn)

***Syn* diastereomer:** Minor enantiomer**:** 19.8 min; Major enantiomer: 21.0 min: 96:4 e.r.



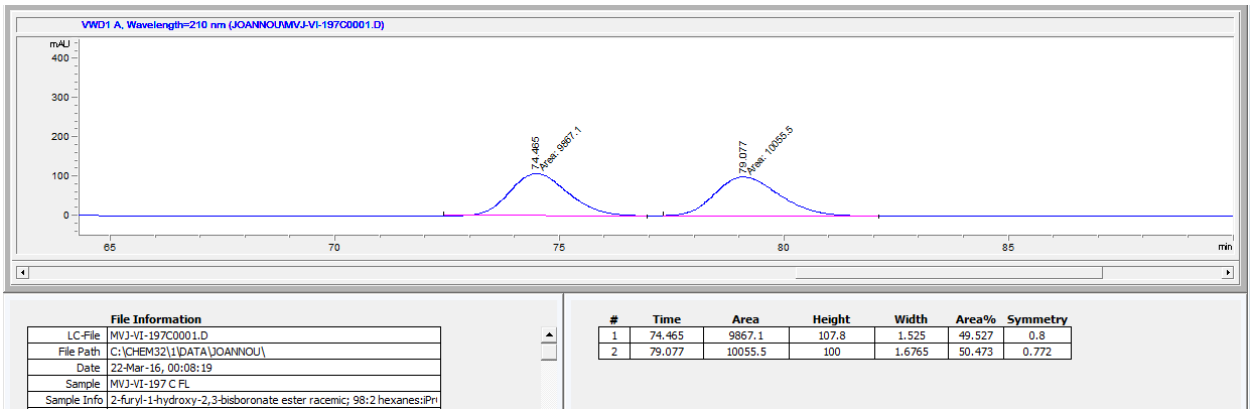
2i

1-(furan-2-yl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2i). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 52% yield (19.7 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.35 (dd, *J* = 1.8, 0.9 Hz, 1H), 6.30 (dd, *J* = 3.2, 1.8 Hz, 1H), 6.23 (dt, *J* = 3.2, 0.8 Hz, 1H), 4.76 (t, *J* = 6.0 Hz, 1H), 3.18 (d, *J* = 6.8 Hz, 1H), 1.81 (dt, *J* = 8.7, 6.1 Hz, 1H), 1.27 – 1.24 (m, 24H), 0.94 – 0.83 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 156.8, 141.5, 109.9, 106.1, 83.5, 83.2, 71.1, 25.5, 24.9, 24.8, 24.7, 9.3. **IR** (ν/cm^{-1}):

3546 (s, br), 2984 (s), 2916 (m), 1458 (m), 1381 (s), 1312 (m), 1182 (s). **HRMS** (ESI$^+$) calcd for $C_{19}H_{32}O_6B_2Na^+$ 401.2283, found: [M+Na] 401.2279. $[\alpha]_D^{22}$ = —16.7 (*c* = 6.04 CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

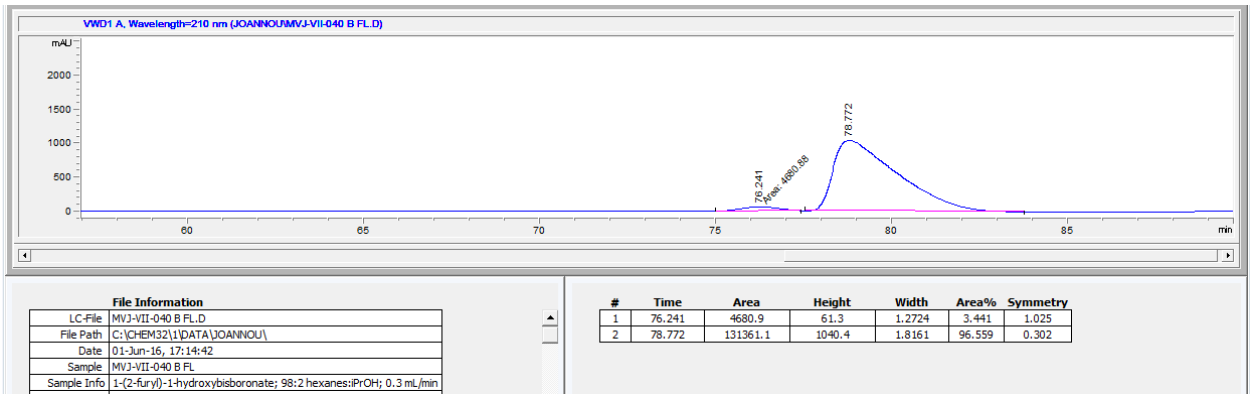
Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm



File Information	
LC-File	MVJ-VI-197C0001.D
File Path	C:\CHEM32\1\DATA\JOANNOU\
Date	22-Mar-16, 00:08:19
Sample	MVJ-VI-197 C FL
Sample Info	2-furyl-1-hydroxy-2,3-bisboronate ester racemic; 98:2 hexanes:iPr

#	Time	Area	Height	Width	Area%	Symmetry
1	74.465	9867.1	107.8	1.525	49.527	0.8
2	79.077	10055.5	100	1.6765	50.473	0.772

Racemic Material

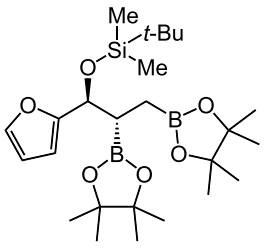


File Information	
LC-File	MVJ-VII-040 B FL.D
File Path	C:\CHEM32\1\DATA\JOANNOU\
Date	01-Jun-16, 17:14:42
Sample	MVJ-VII-040 B FL
Sample Info	1-(2-furyl)-1-hydroxybisboronate; 98:2 hexanes:iPrOH; 0.3 mL/min

#	Time	Area	Height	Width	Area%	Symmetry
1	76.241	4680.9	61.3	1.2724	3.441	1.025
2	78.772	131361.1	1040.4	1.8161	96.559	0.302

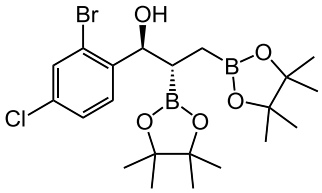
Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 76.2 min; (1*S*,2*S*) enantiomer: 78.8 min: 97:3 e.r.



S2

***tert*-butyl((1*S*,2*S*)-1-(furan-2-yl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propoxy)dimethylsilane (S2).** Following General Procedure III, the crude reaction mixture was purified *via* silica gel chromatography (25:1 pentane:Et_2O, Seebach Stain visualization) to yield the TBS-protected product in 57% yield (over two steps) in 3.5:1 d.r. (28.2 mg). ***Anti* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.26 (s, 1H), 6.24 (dd, *J* = 3.1, 1.8 Hz, 1H), 6.14 (d, *J* = 3.2 Hz, 1H), 4.85 (d, *J* = 6.3 Hz, 1H), 1.71 – 1.66 (m, 1H), 1.22 (s, 6H), 1.21 (s, 6H), 1.20 (s, 12H), 0.86 (s, 9H), 0.01 (s, 3H), -0.13 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 157.2, 140.6, 109.8, 106.5, 83.0, 82.8, 71.7, 25.9, 25.0, 25.0, 24.8, 24.7, 18.2, -4.9, -5.0. ***Syn* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.28 (d, *J* = 1.0 Hz, 1H), 6.24 (dd, *J* = 3.1, 1.8 Hz, 1H), 6.15 (d, *J* = 3.2 Hz, 1H), 4.67 (d, *J* = 9.3 Hz, 1H), 1.73 – 1.65 (m, 1H), 1.22 (s, 6H), 1.22 (s, 6H), 1.12 (s, 6H), 1.09 (s, 6H), 0.82 (s, 9H), 0.01 (s, 3H), -0.18 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 157.7, 140.7, 109.8, 106.1, 82.9, 82.9, 70.6, 25.9, 25.0, 24.9, 24.8, 24.7, 18.3, -4.9, -5.0. **IR** (ν/cm^{-1}): 2978.52 (s), 2929.34 (m), 2857.02 (m), 1371.14 (m), 1256.4 (m), 1164.79 (m). **HRMS** (ESI$^+$): calcd for $C_{25}H_{46}B_2O_6SiNa^+$ 515.3148, found [M+Na$^+$] 515.3163. **[α]$_D^{22}$** = + 5.6 (*c* = 2.67, CH_2Cl_2, *l* = 100 mm).

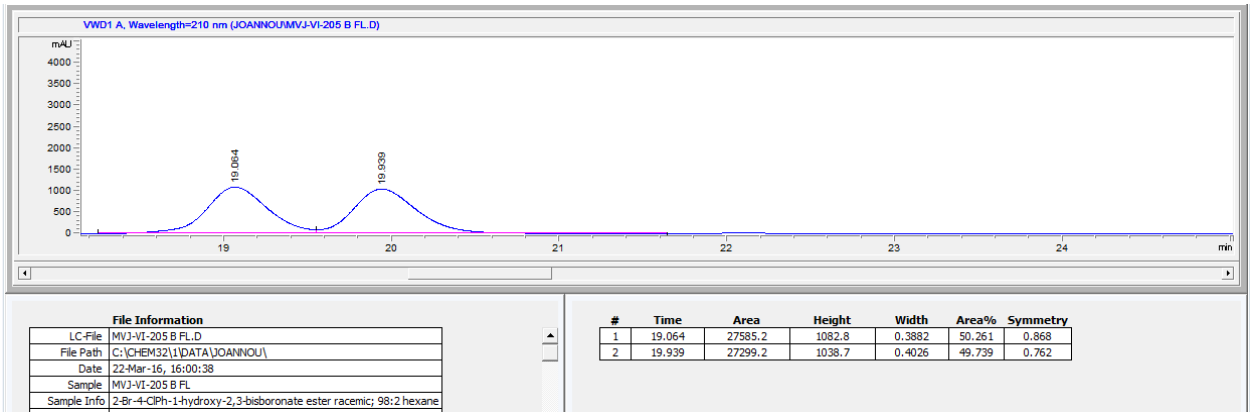


2j

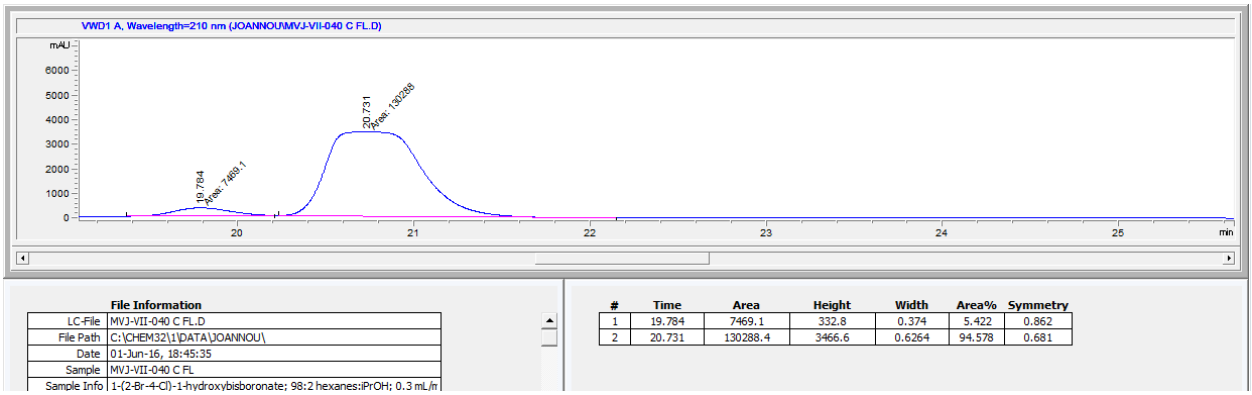
1-(2-bromo-4-chlorophenyl)-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2j). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 71% yield (35.5 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.57 – 7.49 (m, 2H), 7.31 – 7.28 (m, 1H), 4.98 (dd, *J* = 5.7, 2.1 Hz, 1H), 3.81 (d, *J* = 4.2 Hz, 1H), 1.71 (dt, *J* = 8.9, 5.2 Hz, 1H), 1.28 – 1.25 (m, 24H), 1.10 – 0.98 (m, 1H), 0.91 (dd, *J* = 15.9, 5.2 Hz, 1H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 142.3, 133.1, 131.8, 128.9, 127.4, 123.1, 83.6, 83.3, 76.2, 27.7, 24.9, 24.9, 24.9, 24.81, 11.0. **IR** (ν/cm^{-1}): 3589 (s, br), 2834 (s), 2865 (w), 1564 (m), 1355 (s), 1314 (s), 1147 (s). **HRMS** (ESI$^+$) calcd for $C_{21}H_{32}O_5B_2BrClNa^+$ 523.1205, found: [M+Na] 523.1203. **[α]$_D^{22}$** = +10.1 (*c* = 5.80, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm

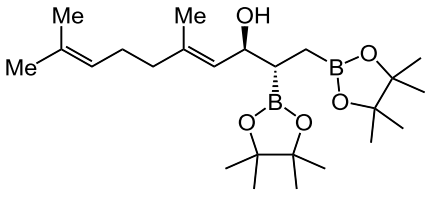


Racemic Material



Enantioenriched Material

***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 19.8 min; (1*S*,2*S*) enantiomer: 20.7 min: 95:5 e.r.



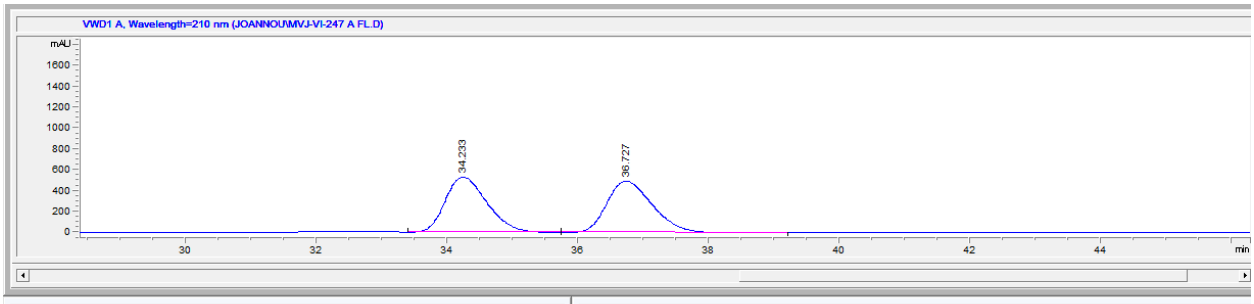
2l

***E*-5,9-dimethyl-1,2-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)deca-4,8-dien-3-ol (2l).** Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 78% yield (33.9 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 5.19 (dq, *J* = 8.9, 1.3 Hz, 1H), 5.13 – 5.08 (m, 1H), 4.38 (dd, *J* = 8.9, 7.3 Hz, 1H), 2.54 (s, 1H), 2.10 (td, *J* = 8.7, 7.9, 4.7 Hz, 2H), 2.04 – 1.98 (m, 2H), 1.69 (dd, *J* = 4.5, 1.4 Hz, 6H), 1.61 (d, *J* = 1.3 Hz, 3H), 1.27 (s, 12H), 1.25 (s, 12H), 0.91 (dd, *J* = 16.1, 5.5 Hz, 1H), 0.83 (dd, *J* = 16.0, 9.5 Hz, 1H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 138.1, 131.5, 127.8, 124.2, 83.3, 83.0, 71.6, 39.7, 26.4, 25.7, 25.0, 24.9, 24.9, 24.8, 17.7, 16.8, 9.0. **IR** (ν/cm^{-1}): 3600 (s), 2967 (m), 2897 (m), 2092 (m), 1567 (s), 1345 (m), 1274 (w), 1201 (m). **HRMS**

(ESI⁺) calcd for $C_{24}H_{44}O_5B_2Na^+$ 457.3273, found: [M+Na] 457.3268. $[\alpha]_D^{22}$ = – 41.6 (*c* = 6.44, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

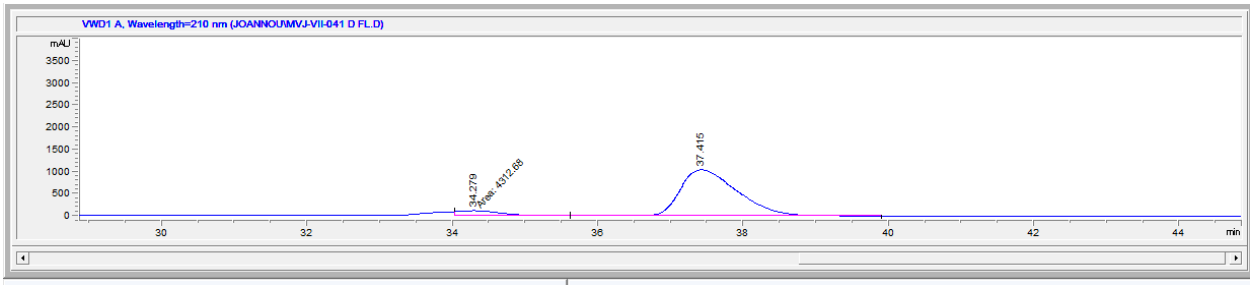
Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 190 nm



File Information	
LC-File	MVJ-VI-247 A FL.D
File Path	C:\CHEM32\1\DATA\JOANNOU\
Date	25-Mar-16, 17:47:08
Sample	MVJ-VI-247 A FL
Sample Info	geranyl-1-hydroxy-2,3-bisboronate racemic; 98:2 hexanes:iPrOH;

#	Time	Area	Height	Width	Area%	Symmetry
1	34.233	23557.3	530.9	0.6907	49.718	0.705
2	36.727	23824.2	492.7	0.7522	50.282	0.689

Racemic Material



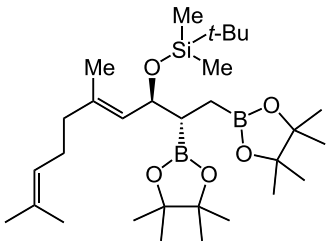
File Information	
LC-File	MVJ-VII-041 D FL.D
File Path	C:\CHEM32\1\DATA\JOANNOU\
Date	01-Jun-16, 14:58:09
Sample	MVJ-VII-041 D FL
Sample Info	1-(geranyl)-1-hydroxybisboronate; 98:2 hexanes:iPrOH; 0.3 mL/mi

#	Time	Area	Height	Width	Area%	Symmetry
1	34.279	4312.7	111.8	0.643	7.165	0.539
2	37.415	55877.3	1036.8	0.8378	92.835	0.552

Enantioenriched Material

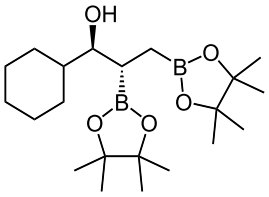
***Anti* diastereomer:** (1*R*,2*R*) enantiomer**:** 34.3 min; (1*S*,2*S*) enantiomer: 37.4 min: 93:7 e.r.

The peak at 34.0 min is the major enantiomer of the minor diastereomer, which was not present in the racemic product. It fluoresces more intensely than the *anti* diastereomer.



S3

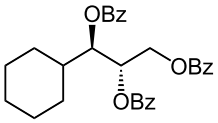
***tert*-butyl(((2S,3S,E)-5,9-dimethyl-1,2-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)deca-4,8-dien-3-yl)oxy)dimethylsilane (S3).** Following General Procedure III, the crude reaction mixture was purified *via* silica gel chromatography (25:1 pentane:Et_2O, Seebach Stain visualization) to yield the TBS-protected product in 36% yield (over two steps) in >20:1 d.r. (19.7 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 5.22 (dd, *J* = 9.2, 1.1 Hz, 1H), 5.10 (ddd, *J* = 7.0, 5.7, 1.3 Hz, 1H), 4.38 (dt, *J* = 10.3, 5.1 Hz, 1H), 2.08 (dd, *J* = 14.9, 7.4 Hz, 2H), 1.99 – 1.94 (m, 2H), 1.67 (s, 3H), 1.61 (d, *J* = 1.1 Hz, 3H), 1.60 (s, 3H), 1.21 (s, 24H), 0.85 (s, 9H), 0.00 (s, 3H), -0.05 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 134.1, 131.3, 129.4, 124.5, 82.8, 82.7, 73.3, 39.7, 26.2, 26.0, 25.7, 25.1, 25.0, 24.9, 24.8, 18.2, 17.7, 16.8, -3.9, -4.5. **IR** (ν/cm^{-1}): 2927.41 (s), 2359.48 (m), 1716.34 (m), 1557.24 (m), 1455.99 (m). **HRMS** (ESI$^+$): calcd for $C_{30}H_{58}B_2O_5SiNa^+$ 571.4137, found [M+Na$^+$] 571.4163. **[α]$_D^{22}$** = + 5.0 (*c* = 0.2, CH_2Cl_2, *l* = 100 mm).



2m

1-cyclohexyl-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propan-1-ol (2m). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 63% yield (24.8 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 3.33 (dd, *J* = 6.3, 4.8 Hz, 1H), 1.92 (dt, *J* = 12.7, 1.9 Hz, 1H), 1.80 – 1.70 (m, 3H), 1.68 – 1.61 (m, 3H), 1.49 (d, *J* = 4.9 Hz, 6H), 1.28 (s, 6H), 1.27 (s, 6H), 1.25 (s, 6H), 1.14 – 0.96 (m, 4H), 0.96 – 0.93 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 83.5, 83.3, 79.8, 42.8, 30.0, 28.0, 26.6, 26.5, 26.3, 25.0, 24.9, 24.9, 24.8, 24.78. **IR** (ν/cm^{-1}): 3501 (s, br), 2978 (m), 2967 (s), 1445 (m), 1379 (s), 1344 (m), 1273 (w), 1199 (w), 1161 (w). **HRMS** (ESI$^+$): calcd for $C_{21}H_{40}O_5B_2Na$ 417.2960, found [M+Na$^+$] 417.2955. **[α]$_D^{22}$** = – 18.5 (*c* = 5.82, CH_2Cl_2, *l* = 100 mm).

Representative Example of tribenzoate:

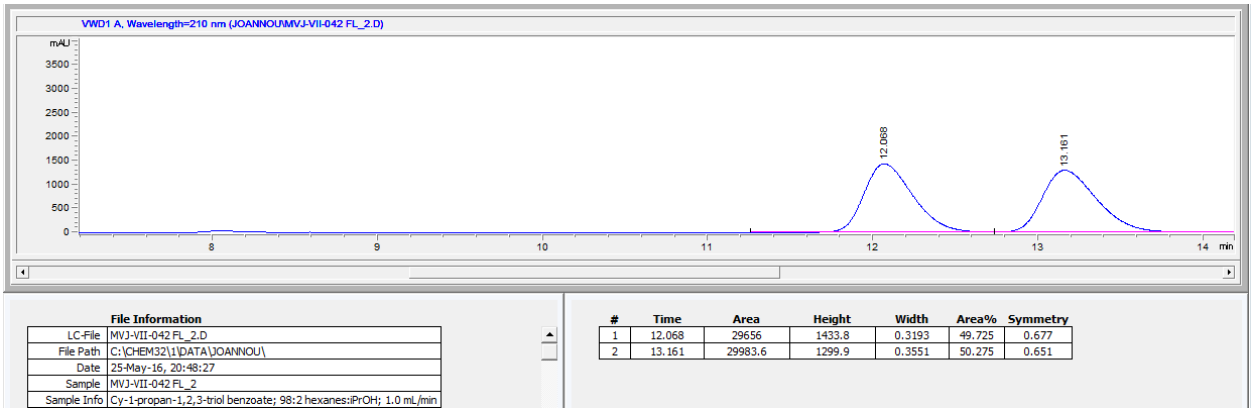


S4

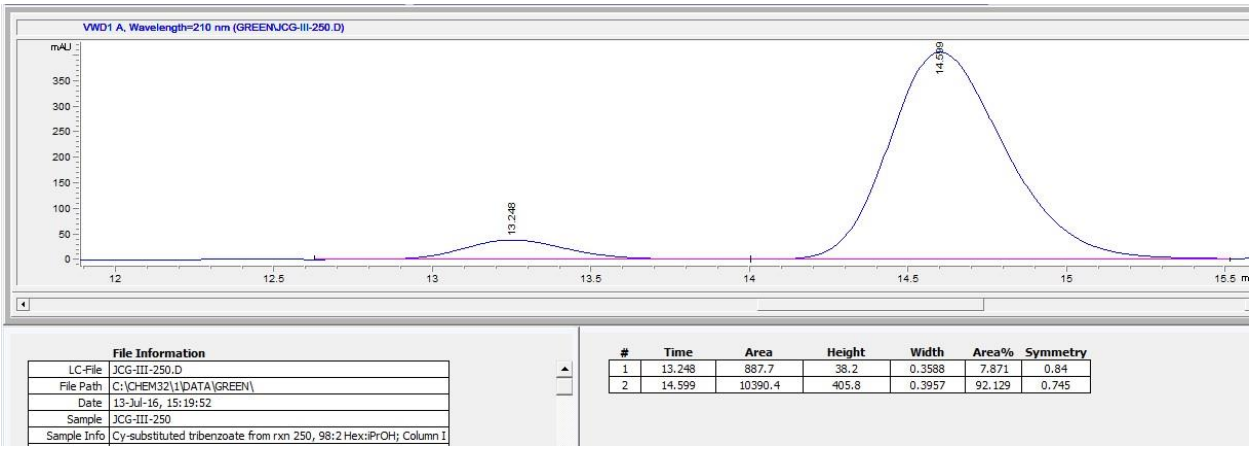
1-cyclohexylpropane-1,2,3-triyl tribenzoate (S4). Following the General Oxidation/Benzoylation Procedure, the tribenzoate was purified *via* silica gel chromatography (10:1 to 5:1 pentane:Et_2O, $KMnO_4$ visualization) and isolated as a colorless oil in 90% yield (23.6 mg) in 12:1 d.r. **^{1}H NMR** (400 MHz, $CDCl_3$) δ 8.24 – 7.95 (m, 5H), 7.74 – 7.37 (m, 10H), 5.88 (tq, *J* = 4.6, 2.1 Hz, 1H), 5.56 (t, *J* = 6.0 Hz, 1H), 4.89 (dt, *J* = 12.2, 2.3 Hz, 1H), 4.60 (dd, *J* = 12.1, 7.4 Hz, 1H), 2.02 – 1.55 (m, 6H), 1.26 (dt, *J* = 36.5, 8.4 Hz, 5H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 166.4, 165.8, 165.7, 162.4, 134.6, 133.3, 133.2, 133.2, 130.6, 129.8, 129.8, 129.7, 128.9, 128.8, 128.6, 128.4, 128.4, 76.3, 71.0, 62.9, 39.0, 29.4, 28.2, 26.1, 25.9, 25.7. **IR** (ν/cm^{-1}): 3350 (m), 2895 (m), 2870 (m), 1650 (s), 1625 (s), 1546 (m), 1201 (m). **HRMS** (ESI$^+$): calcd for $C_{30}H_{30}O_6Na^+$ 509.1940, found [M+ Na^+] 509.1935. **[α]$_D^{22}$** = – 95.2 (*c* = 2.86, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 1.0 mL/min; 210 nm

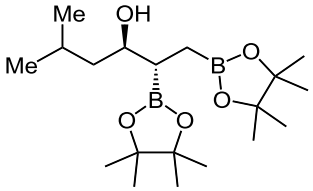


Racemic Material



Enantioenriched Material

***Anti* diastereomer:** (1*S*,2*R*) enantiomer**:** 13.2 min; (1*R*,2*S*) enantiomer: 14.6 min: 92:8 e.r.

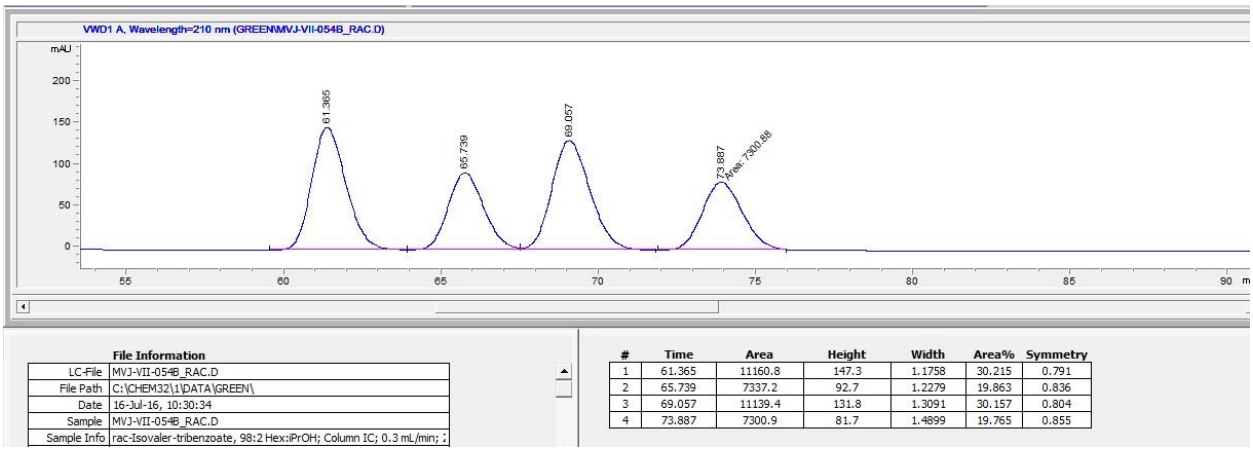


2n

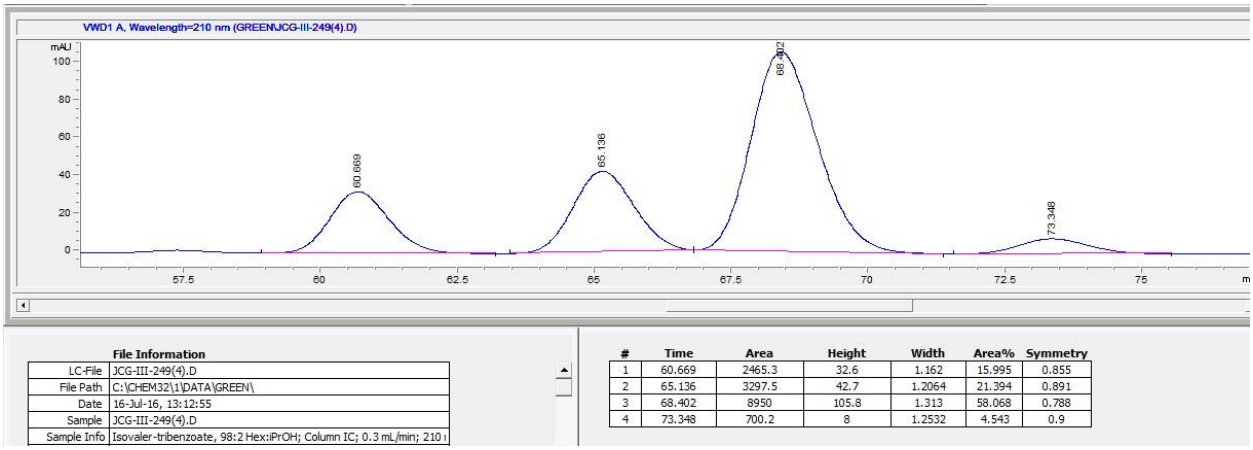
5-methyl-1,2-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)hexan-3-ol (2n). Following General Procedure II, the crude reaction mixture was purified *via* silica gel column chromatography (NaOAc deactivated silica gel, 5:1 to 2:1 pentane:Et_2O, Seebach Stain visualization) to yield the 1-hydroxy-2,3-bisboronate ester as a colorless oil in 48% yield (17.7 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 3.70 (ddd, *J* = 8.9, 4.8, 3.8 Hz, 1H), 1.82 (dqd, *J* = 9.0, 6.7, 5.0 Hz, 1H), 1.42 (ddd, *J* = 14.1, 9.3, 5.0 Hz, 1H), 1.37 – 1.29 (m, 1H), 1.26 (s, 12H), 1.25 (s, 12H), 0.96 – 0.94 (m, 2H), 0.91 (dd, *J* = 10.7, 6.7 Hz, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 83.3, 83.1, 73.2, 46.2, 24.9, 24.8, 24.8, 24.7, 23.7, 22.0. **IR** (ν/cm^{-1}): 3605 (s, br), 3001 (m), 1515 (m), 1410 (s), 1279 (w), 1210 (w). **HRMS** (ESI$^+$): calcd for $C_{19}H_{38}O_5B_2Na^+$ 391.2803, found [M+Na$^+$] 391.2798. **[α]$_D^{22}$** = – 27.6 (*c* = 3.23, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IC Column; 98:2 hexanes:iPrOH; 0.3 mL/min; 210 nm



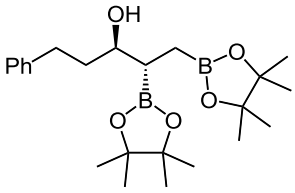
Racemic Material (anti + syn)



Enantioenriched Material (anti + syn)

***Anti* diastereomer:** (2*R*,3*S*) enantiomer**:** 60.7 min; (2*S*,3*R*) enantiomer: 68.4 min: 78:22 e.r.

***Syn* diastereomer:** Major enantiomer**:** 65.1 min; Minor enantiomer: 73.3 min: 82:18 e.r.



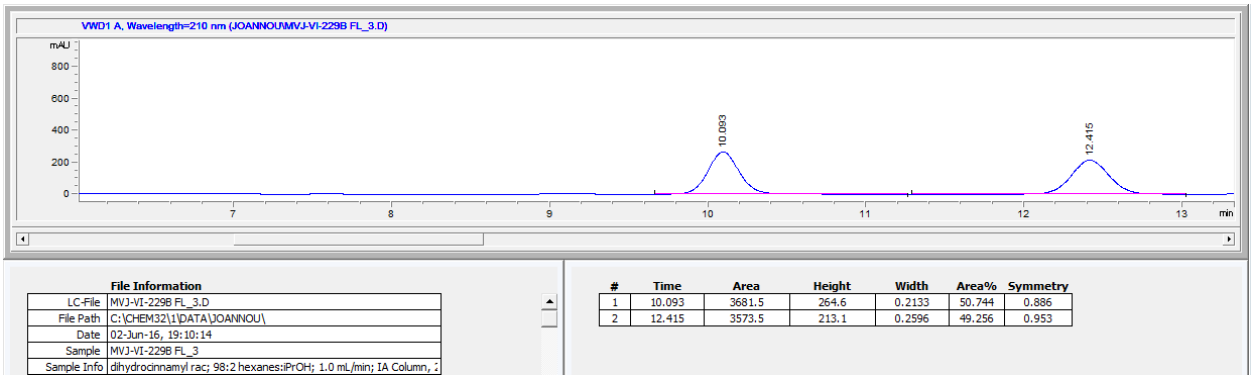
2o

5-phenyl-1,2-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)pentan-3-ol (2o). Following General Procedure II, the desired 1-hydroxy-2,3-bisboronate ester was produced in 70% NMR yield. Purification of compound **2o** (deactivated silica gel, 5:1 pentane:Et_2O) gave an inseparable mixture of product and ligand. Simple silyl-protection of the crude reaction mixture allowed for

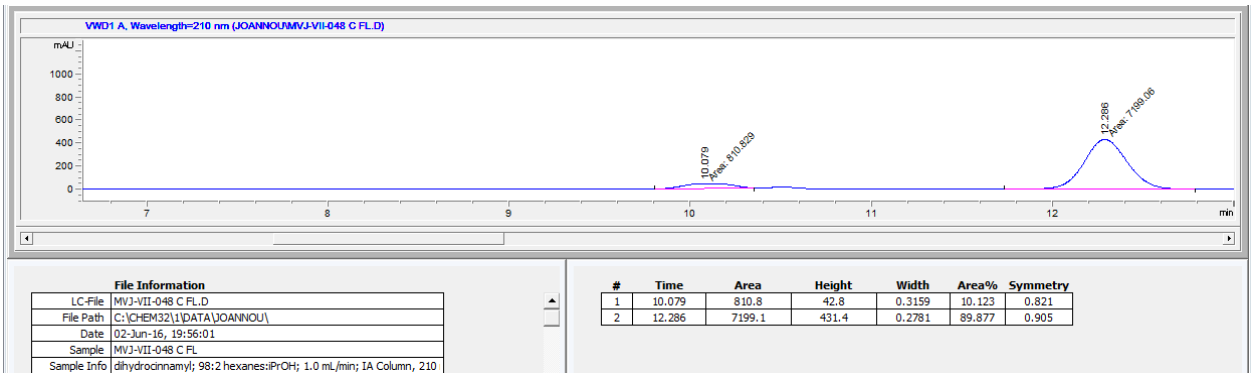
isolation of clean product (*vide infra*). ***Anti* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.32 – 7.14 (m, 5H), 3.65 (dt, *J* = 8.8, 4.5 Hz, 1H), 2.86 (ddd, *J* = 13.6, 9.6, 5.5 Hz, 1H), 2.71 – 2.64 (m, 1H), 1.81 (dtd, *J* = 9.8, 8.3, 7.7, 4.7 Hz, 2H), 1.42 – 1.36 (m, 1H), 1.26 (d, *J* = 0.7 Hz, 12H), 1.24 (d, *J* = 2.1 Hz, 14H), 0.95 (dd, *J* = 7.1, 3.6 Hz, 2H). ***Syn* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.32 – 7.14 (m, 5H), 3.71 (t, *J* = 6.5 Hz, 1H), 3.02 – 2.90 (m, 1H), 2.79 – 2.72 (m, 1H), 1.97 – 1.87 (m, 2H), 1.41 – 1.36 (m, 1H), 1.28 (s, 24H), 1.03 (dd, *J* = 18.9, 7.5 Hz, 1H), 0.88 – 0.83 (m, 1H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 142.7, 128.5, 128.5, 128.44, 128.4, 128.3, 125.5, 83.5, 83.4, 83.1, 75.1, 74.7, 38.5, 32.5, 30.3, 29.7, 25.0, 24.9, 24.8, 24.8, 24.8, 24.8, 24.7, 24.7. **HRMS** (ESI^+): calcd for $C_{23}H_{38}O_5B_2Na^+$ 439.2803, found [M+Na^+] 439.2802. **[α]$_D^{22}$** = –15.6 (*c* =5.66, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **2a**.

Diacel CHIRALPAK IA Column; 98:2 hexanes:iPrOH; 1.0 mL/min; 210 nm

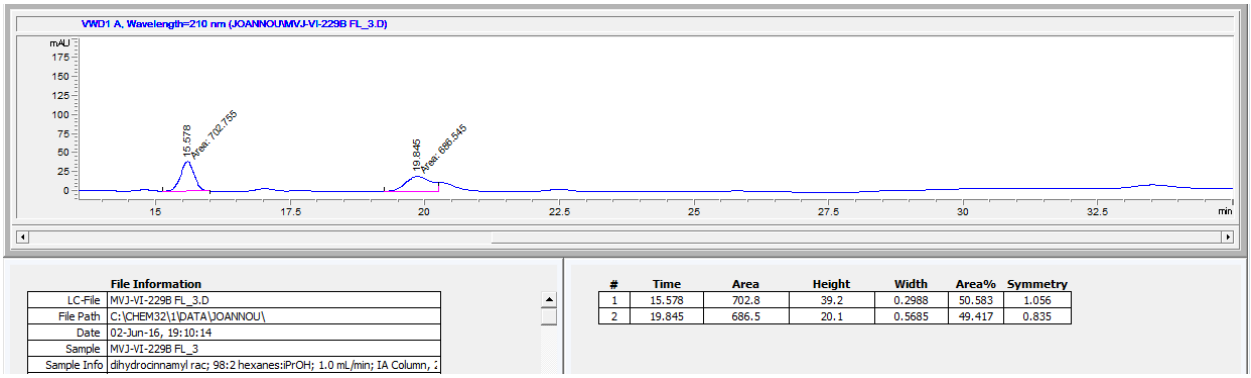


Racemic Material (anti)

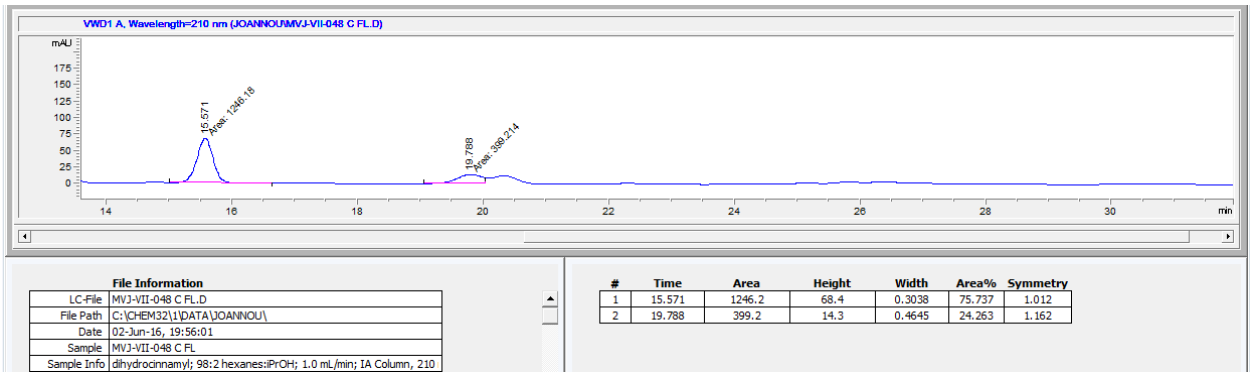


Enantioenriched Material (anti)

***Anti* diastereomer:** (2*R*,3*S*) enantiomer**:** 10.1 min; (2*S*,3*R*) enantiomer: 12.9 min: 90:10 e.r.

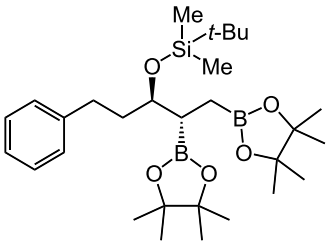


Racemic Material (syn)



Enantioenriched Material (syn)

***Syn* diastereomer:** Major enantiomer**:** 15.6 min; Minor enantiomer: 19.8 min: 76:24 e.r.

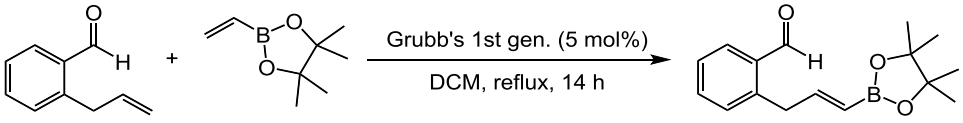


S5

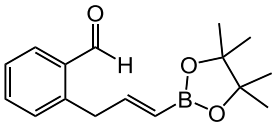
***tert*-butyldimethyl(((2S,3R)-5-phenyl-1,2-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)pentan-3-yl)oxy)silane (S5).** Following General Procedure III, the crude reaction mixture was purified *via* silica gel chromatography (25:1 pentane:Et_2O, Seebach Stain visualization) to yield the TBS-protected product in 52% yield (over two steps) in 2.7:1 d.r. (27.8 mg). ***Anti* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.28 – 7.24 (m, 2H), 7.20 – 7.17 (m, 3H), 3.80 – 3.75 (m, 1H), 2.77 (td, *J* = 12.7, 5.1 Hz, 1H), 2.64 – 2.58 (m, 1H), 1.89 – 1.82 (m, 1H), 1.83 – 1.76 (m, 1H), 1.52-1.43 (m, 1H), 1.23 (s, 12H), 1.21 (s, 6H), 1.19 (s, 6H), 1.04 – 0.93 (m, 1H), 0.92 (s, 9H), 0.78 (dd, J = 15.9, 11.4 Hz, 1H), 0.09 (s, 3H), 0.07 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 143.6, 128.5, 128.2, 125.4, 82.9, 82.9, 74.7, 38.3, 33.1, 31.0, 26.1, 25.1, 25.0, 24.8, 24.8, 18.3, -4.1, -4.2. ***Syn* diastereomer: ^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.28 – 7.24 (m, 2H), 7.17 – 7.13 (m, 3H), 3.85 – 3.81

(m, 1H), 2.68 (ddd, *J* = 13.6, 10.7, 5.5 Hz, 1H), 2.60 – 2.56 (m, 1H), 1.82 – 1.76 (m, 1H), 1.76 – 1.70 (m, 1H), 1.51-1.43 (m, 2H), 1.24 (s, 6H), 1.23 (s, 6H), 1.23 (s, 6H), 1.21 (s, 6H), 1.02 – 0.91 (m, 1H), 0.89 (s, 9H), 0.87-0.83 (m, 1H), 0.05 (s, 3H), 0.04 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 143.1, 128.4, 128.2, 125.4, 82.8, 82.7, 75.3, 38.0, 33.1, 26.0, 25.1, 25.0, 24.7, 24.6, 18.2, -4.3, -4.4. **IR** (ν/cm^{-1}): 2977.55 (s), 2928.38 (m), 2856.06 (m), 1471.42 (s), 1371.14 (s), 1315.21 (m), 1144.55 (m). **HRMS** (ESI$^+$): calcd for $C_{29}H_{52}B_2O_5SiNa^+$ 553.3668, found [M+Na$^+$] 553.3685. **[α]$_D^{22}$** = + 2.0 (*c* = 1.0, CH_2Cl_2, *l* = 100 mm).

■ General Procedure (IV) for the Synthesis of Intramolecular Alkenylboron Substrates

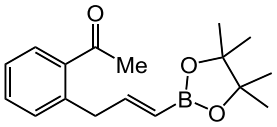


Metathesis reactions for the 5 intramolecular substrates were performed based on a reported procedure.[7] To an oven-dried flask equipped with a magnetic stir bar was added Grubb's 1st generation catalyst (5 mol%). A reflux condenser was attached, and the system was evacuated and backfilled with N_2. The catalyst was dissolved in 15 mL dry dichloromethane (DCM). A solution of olefin in 15 mL dry DCM was added, followed by vinyl boronic acid pinacol ester. The condenser was washed with dry DCM, and the reaction heated at reflux for 40 hours. The reaction was cooled to room temperature and concentrated by rotary evaporation.



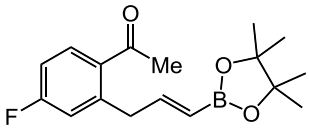
3a

(E)-2-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)allyl)benzaldehyde (3a). Following General Procedure IV using 2-allylbenzaldeyde (949 mg, 6.49 mmol) and vinyl boronic acid pinacol ester (1.10 mL, 6.49 mmol), the crude reaction mixture was purified *via* silica gel chromatography (85:15 hexanes:Et_2O, $KMnO_4$ visualization) to yield the desired alkenylboron product in 49% yield (860 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 10.20 (s, 1H), 7.84 (dd, *J* = 7.7, 1.2 Hz, 1H), 7.51 (ddd, *J* = 15.0, 7.6, 1.5 Hz, 1H), 7.38 (t, *J* = 7.5 Hz, 1H), 7.25 (d, *J* = 7.6 Hz, 1H), 6.80 (dt, *J* = 17.9, 5.8 Hz, 1H), 5.35 – 5.28 (m, 1H), 3.91 (dd, *J* = 5.8, 1.6 Hz, 2H), 1.23 (s, 12H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 192.2, 151.6, 141.3, 134.0, 133.9, 131.6, 131.4, 127.1, 83.2, 38.4, 24.8. **IR** (ν/cm^{-1}): 2978.52 (s), 2930.31 (m), 2359.48 (m), 1697.05 (s), 1635.34 (m), 1599.66 (s), 1361.50 (m), 1324.86 (m). **HRMS** (ESI$^+$): calcd for $C_{16}H_{21}O_3BNa^+$ 295.1481, found [M+Na$^+$] 295.1477.



3b

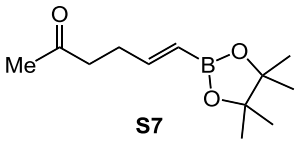
(E)-1-(2-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)allyl)phenyl)ethan-1-one (3b). Following General Procedure IV using 2′-allylacetophenone (467 mg, 2.914 mmol) and vinyl boronic acid pinacol ester (519 μL, 3.06 mmol), the crude reaction mixture was dissolved in dimethylsulfoxide (517 μL, 7.285 mmol, 50 equiv relative to Grubb's catalyst) and 2.5 mL DCM and stirred 18 h at room temperature to help complex ruthenium impurities. The DCM was removed by rotary evaporation, and the DMSO removed by extraction with water and diethyl ether. The aqueous layer was extracted 3xEt_2O, and the combined organic layers were dried over $MgSO_4$. The solvent was removed by rotary evaporation and the dark residue subjected to silica gel flash chromatography (90:10 hexanes:Et_2O, $KMnO_4$ visualization) to yield the desired alkenylboron product in 35% yield (293 mg). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.65 (d, *J* = 7.7 Hz, 1H), 7.40 (t, *J* = 7.6 Hz, 1H), 7.28 (t, *J* = 7.6 Hz, 1H), 7.24 (d, *J* = 7.7 Hz, 1H), 6.77 (dt, *J* = 17.9, 6.0 Hz, 1H), 5.33 (d, *J* = 17.9 Hz, 1H), 3.77 (d, *J* = 5.9 Hz, 2H), 2.56 (s, 3H), 1.23 (s, 12H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 201.9, 152.5, 138.8, 138.0, 131.8, 131.6, 129.2, 126.3, 83.1, 65.9, 39.8, 29.8, 29.7, 24.8, 15.3. **IR** (ν/cm^{-1}): 2978.52 (s), 2929.34 (m), 2362.37 (m), 1716.34 (s), 1684.52 (m), 1635.34 (m), 1361.50 (m). **HRMS** (ESI$^+$): calcd for $C_{17}H_{23}O_3BNa^+$ 309.1638, found [M+Na$^+$] 309.1633.



S6

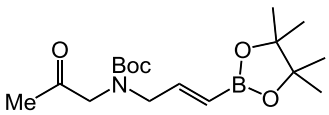
(E)-1-(4-fluoro-2-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)allyl)phenyl)ethan-1-one (S6). Following General Procedure IV using 1-(2-allyl-4-fluorophenyl)ethan-1-one (325 mg, 1.824 mmol) and vinyl boronic acid pinacol ester (340 μL, 2.01 mmol), the crude reaction mixture was dissolved in 324 μL DMSO and diluted with 2 mL DCM . This mixture was stirred for 2 days to complex Ru compounds. The DCM was removed by rotary evaporation, and the DMSO was removed by extraction (H_2O and diethyl ether). The combined organic layers were dried with $MgSO_4$, filtered and concentrated by rotary evaporation. The solvent was removed by rotary evaporation and the dark residue subjected to silica gel flash chromatography (90:10 hexanes:Et_2O to 100% Et_2O, $KMnO_4$ visualization) to yield 226 mg of a viscous oil. ^{1}H NMR determined the oil to be a 9:1 ratio of (*E*)-1-(4-fluoro-2-(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)allyl)phenyl)ethan-1-one to the homodimer of vinyl boronic acid pinacol ester [(*E*)-1,2-Bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethene].[8] **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.71 (dd, *J* = 8.4, 5.9 Hz, 1H), 6.99 – 6.92 (m, 2H), 6.73 (dt, *J* = 17.9, 6.0 Hz, 1H), 5.35 (dd,

J = 17.9, 1.3 Hz, 1H), 3.79 (d, *J* = 6.0 Hz, 2H), 2.55 (s, 3H), 1.24 (s, 12H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 200.0, 164.2 (d, *J* = 253.4 Hz), 151.4, 143.0 (d, *J* = 8.2 Hz), 133.8 (d, *J* = 3.0 Hz), 132.0 (d, *J* = 9.25 Hz), 118.6 (d, *J* = 21.31 Hz), 113.1 (d, *J* = 21.41 Hz), 83.2, 39.9, 29.6, 24.8. **IR** (ν/cm^{-1}): 2978.52 (s), 2930.31 (m), 1685.48 (s), 1635.34 (m), 1606.41 (m), 1583.27 (m), 1369.50 (m). **HRMS** (ESI$^+$): calcd for $C_{17}H_{22}O_3BFNa^+$ 327.1544, found [M+Na$^+$] 327.1539.



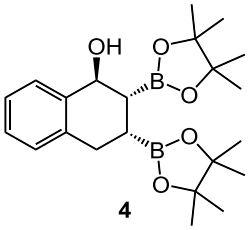
S7

(E)-6-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)hex-5-en-2-one (S7). Following General Procedure IV using 5-hexene-2-one (1.18 mL, 10.19 mmol) and vinyl boronic acid pinacol ester (1.81 mL, 10.69 mmol), the crude reaction mixture was purified *via* silica gel chromatography (90:10 hexanes:Et_2O, $KMnO_4$ visualization) to yield the desired alkenylboron product in 44% yield (1.0 g). **^{1}H NMR** (600 MHz, $CDCl_3$) δ 6.60 (dt, *J* = 18.0, 6.1 Hz, 1H), 5.43 (d, *J* = 18.0 Hz, 1H), 2.56 (t, *J* = 7.4 Hz, 2H), 2.42 (q, *J* = 7.2 Hz, 2H), 2.15 (s, 3H), 1.25 (s, 12H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 207.9, 152.1, 83.2, 41.9, 30.0, 29.4, 24.8. **IR** (ν/cm^{-1}): 2978.52 (s), 2930.31 (m), 2360.44 (m), 2341.16 (m), 1717.30 (s), 1639.20 (m), 1363.43, (m), 1322.93 (m). **HRMS** (ESI$^+$): calcd for $C_{12}H_{21}BO_3Na^+$ 247.1481, found [M+Na$^+$] 247.1477.



S8

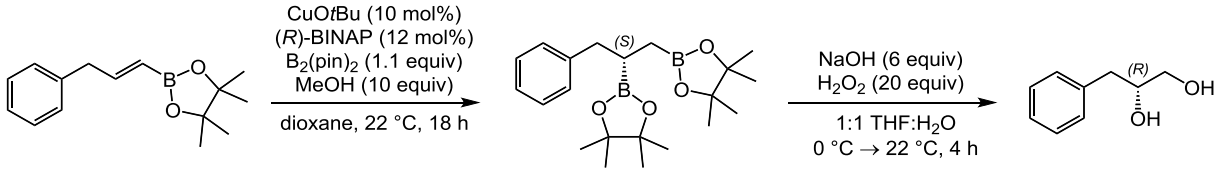
tert-butyl (E)-(2-oxopropyl)(3-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)allyl)carbamate (S8). Following General Procedure IV using *tert*-butyl allyl(2-oxopropyl)carbamate (421 mg, 2.0 mmol) and vinyl boronic acid pinacol ester (351 μL, 2.1 mmol) the crude reaction mixture was purified *via* silica gel chromatography (10:1 to 5:1 hexanes:Et_2O, $KMnO_4$ visualization) to yield the desired alkenylboron product in 28% yield (201.2 mg). NOTE: Purified material contained an inseparable amount of (E)-1,2-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethene (8%).[8] **^{1}H NMR** (600 MHz, $CDCl_3$) δ 6.48 (ddt, *J* = 22.9, 18.0, 4.9 Hz, 1H), 5.49 (dd, *J* = 17.8, 16.5 Hz, 1H), 4.01 (d, *J* = 4.7 Hz, 1H), 3.96 (s, 1H), 3.93 (d, *J* = 4.8 Hz, 1H), 3.84 (s, 1H), 2.10 (d, *J* = 7.2 Hz, 3H), 1.45 – 1.40 (m, 9H), 1.27 (s, 6H), 1.26 (s, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 204.5, 155.6, 155.0, 148.0, 83.4, 83.4, 80.5, 65.9, 56.5, 55.9, 51.8, 51.4, 30.3, 28.3, 28.2, 27.0, 26.8, 24.9, 24.8, 15.3. **IR** (ν/cm^{-1}): 2978.52 (s), 2931.27 (m), 2360.44 (m), 2341.16 (m), 1736.58 (s), 1698.02 (s), 1643.05 (m), 1366.32 (m), 1331.61 (m), 1162.87 (m). **HRMS** (ESI$^+$): calcd for $C_{17}H_{30}BNO_5Na^+$ 362.2115, found [M+Na$^+$] 362.2108.



4

2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1,2,3,4-tetrahydronaphthalen-1-ol (4). In an N_2-filled glovebox, an 8-mL vial equipped with a magnetic stir bar was charged with Cu*O*t*Bu (1.4 mg, 0.010 mmol, 10 mol%) and (*R*)-Cl-OMe-biphep (7.8 mg, 0.012 mmol, 12 mol%), followed by 400 μL toluene. The reaction was capped with a Teflon-lined septum cap and allowed to stir at ambient temperature for 30 minutes, after which time a solution of $B_2(pin)_2$ (27.9 mg, 0.11 mmol, 1.1 equiv) in 200 μL toluene was added. After stirring for 10 minutes, the vial was sealed with electrical tape and removed from the glovebox. In a separate 8 mL vial, a solution of **3a** (32.6 mg, 0.12 mmol) in 240 μL toluene was prepared in the glovebox. This solution was sealed with electrical tape and a Teflon-lined septum cap and removed from the glovebox. Both vials were then cooled to 4 °C in a cryobath, and a 200 μL aliquot of the substrate solution was added to the reaction vial. The reaction was allowed to stir at 4 °C for 48 hours. The reaction was quenched with 2 mL of saturated aqueous NH_4Cl at 4 °C, and allowed to stir vigorously at 22 °C for 30 minutes. The aqueous layer was extracted three times with diethyl ether, and the combined organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude reaction mixture was purified *via* silica gel column chromatography to yield 1-hydroxy-2,3-bisboronate **4** as a colorless oil in 49% yield (19.6 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.44 – 7.39 (m, 1H), 7.16 – 7.10 (m, 2H), 7.10 – 7.06 (m, 1H), 4.98 (d, *J* = 6.0 Hz, 1H), 2.96 – 2.87 (m, 2H), 2.43 (s, 1H), 1.85 (td, *J* = 7.0, 3.5 Hz, 1H), 1.70 (dd, *J* = 6.0, 3.4 Hz, 1H), 1.20 (s, 6H), 1.18 (s, 6H), 1.17 (s, 6H), 1.14 (s, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 138.5, 137.6, 128.9, 128.8, 127.1, 125.7, 83.4, 83.2, 69.2, 30.1, 24.9, 24.7, 24.7, 24.7. **IR** (υ/cm^{-1}): 3430.74 (br), 2977.55 (s), 2930.31 (m), 1643.05 (m), 1379.82 (m), 1313.29 (m), 1143.58 (m). **HRMS** (ESI$^+$): calcd for $C_{44}H_{68}O_{10}B_4Na^+$ 823.5082, found [2M+Na$^+$] 823.5097. **[*α*]$_D^{22}$** = + 6.1 (*c* = 0.39, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Relative stereochemistry was established via oxidation of **4** to the corresponding triol (see Supplementary Procedure B) and comparison to literature spectra.[9] Absolute stereochemistry was assigned by independent analysis of Cu-B(pin) insertion component through copper-catalyzed enantioselective hydroboration.[10]



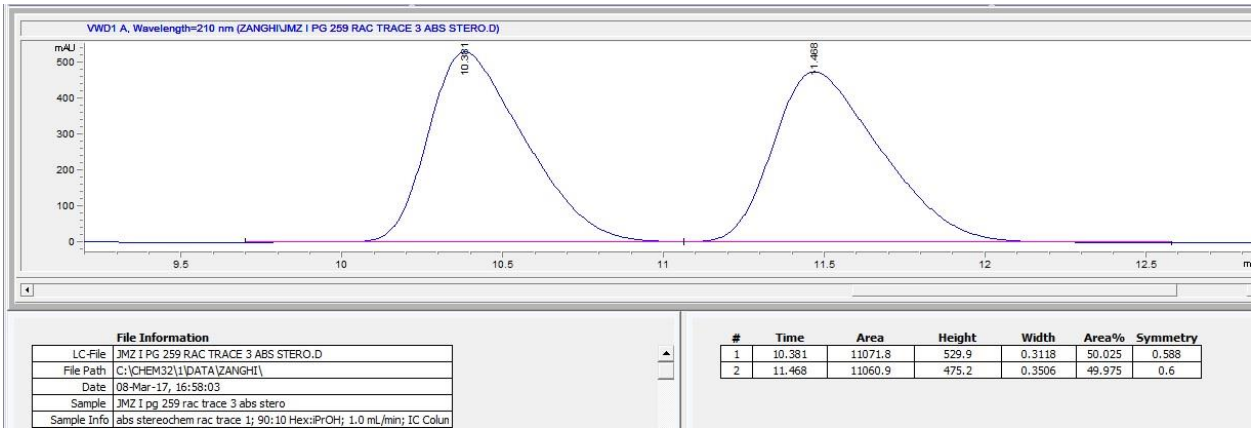
In an N_2-filled glovebox, an 8-mL vial equipped with a magnetic stir bar was charged with CuO*t*Bu (1.4 mg, 0.010 mmol) and (*R*)-BINAP (7.5 mg, 0.012 mmol), followed by 400 μL 1,4-dioxane. The reaction was capped with a Teflon-lined septum cap and allowed to stir at ambient temperature for 30 minutes, after which time a solution of $B_2(pin)_2$ (27.9 mg, 0.11 mmol) in 200 μL dioxane was added. After stirring for 10 minutes, a solution of (*E*)-4,4,5,5-tetramethyl-2-(3-phenylprop-1-en-1-yl)-1,3,2-dioxaborolane (24.4 mg, 0.10 mmol) in 200 μL dioxane was added. The vial was sealed with electrical tape and removed from the glovebox. Dry, freshly-sparged methanol (40.5 μL, 1.0 mmol) was then added by syringe. The reaction was allowed to stir 18 hours at 22 °C. The reaction was quenched with 2 mL of saturated aqueous NH_4Cl and allowed to stir vigorously at 22 °C for 30 minutes. The aqueous layer was extracted three times with diethyl ether, and the combined organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*.

The oxidation was performed according to Supplementary Procedure B. Silica gel flash chromatography (1:1 hexanes:EtOAc → 100% EtOAc; R_f=0.35 in 100% EtOAc) afforded 9.8 mg (0.064 mmol, 64%) of (*R*)-3-phenylpropane-1,2-diol.

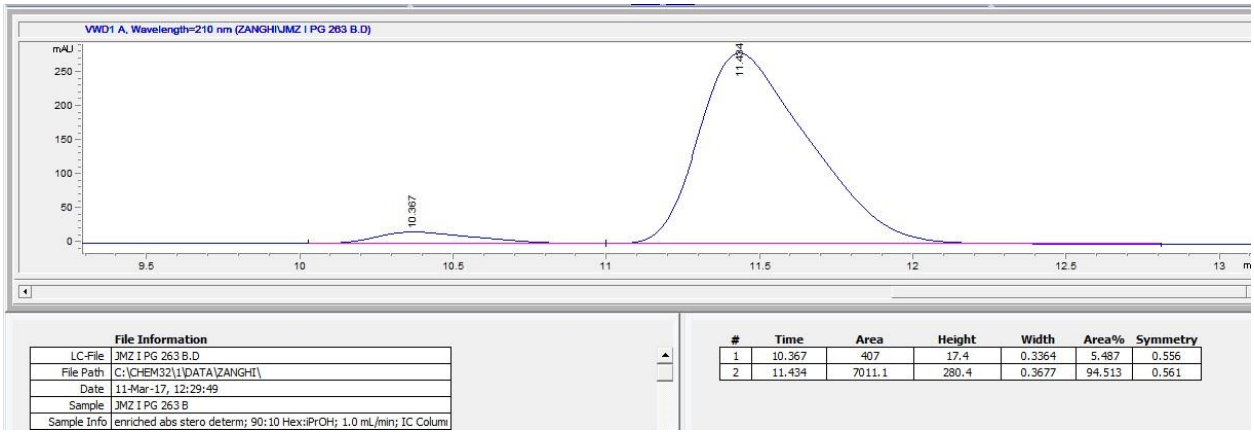
^{1}H NMR (400 MHz, $CDCl_3$): δ 7.33-7.29 (2H, m); 7.23-7.21 (3H, m); 3.94 (1H, m); 3.67 (1H, d); 3.50 (1H, m); 2.76 (2H, m); 2.42 (2H, m). ^{1}H NMR in accordance with literature values.[10]

HPLC Traces: 3-phenylpropane-1,2-diol

Diacel CHIRALPAK IC Column; 90:10 hexanes:iPrOH; 1.0 mL/min; 210 nm



Racemic Material



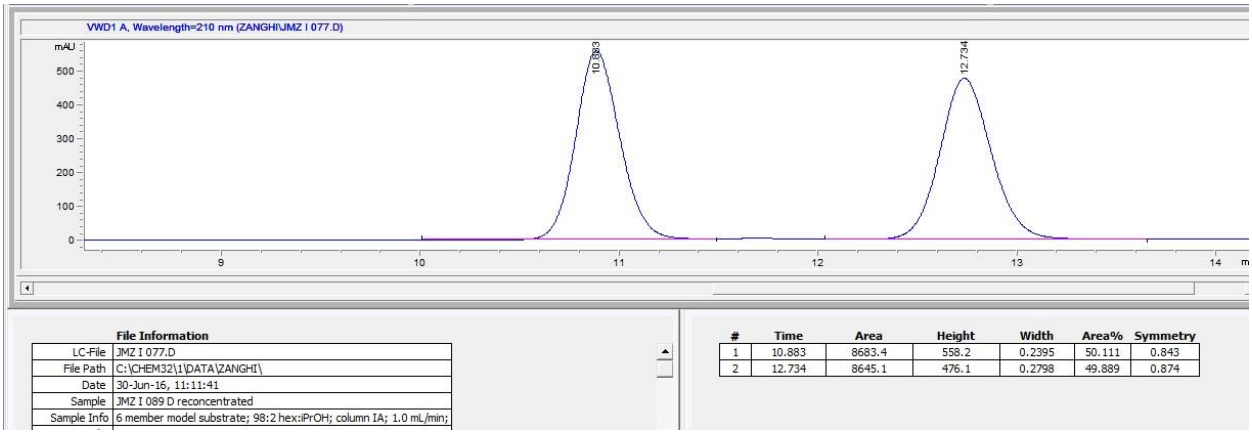
Enantioenriched Material

Minor enantiomer**:** 10.4 min; Major enantiomer: 11.4 min: 94.5:5.5 e.r.

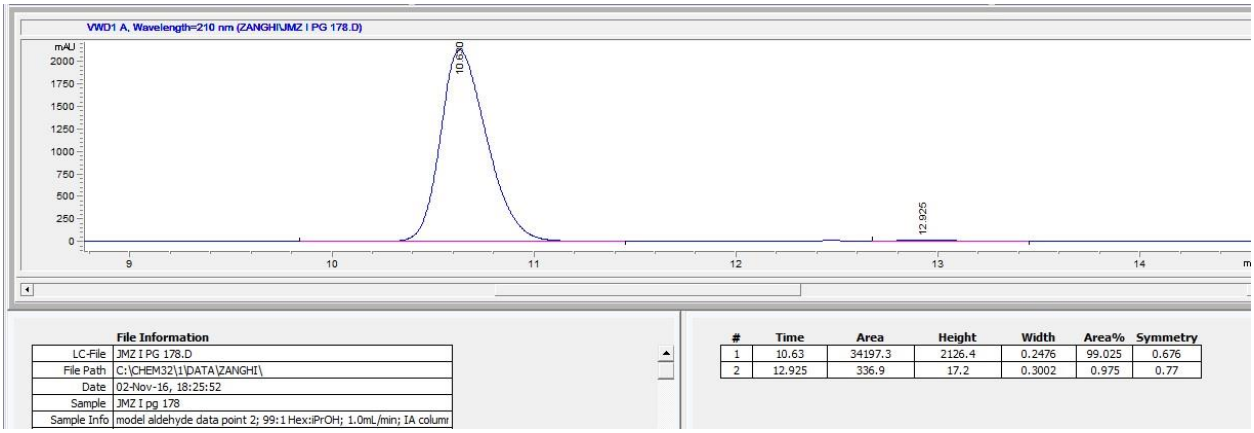
Literature value of $[\alpha]_D^{22}$ + 33.2 (c = 1.00, EtOH), 97.5:2.5 e.r is assigned to the (*R*) enantiomer.[11] Found: $[\alpha]_D^{20}$ + 13.7 (c = 0.49, EtOH). Therefore, the C3 stereocenter was assigned the (*R*) configuration.

HPLC Traces: 2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)-1,2,3,4-tetrahydronaphthalen-1-ol

Diacel CHIRALPAK IA Column; 99:1 hexanes:iPrOH; 1.0 mL/min; 210 nm



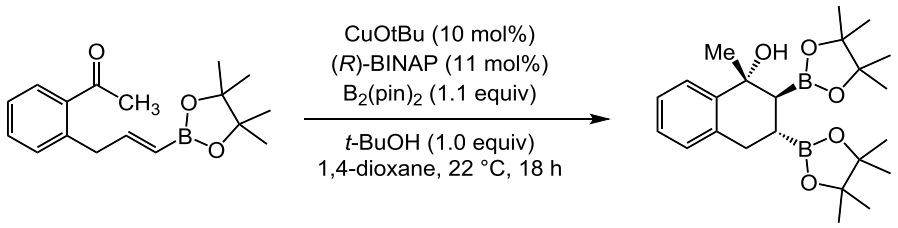
Racemic Material



Enantioenriched Material

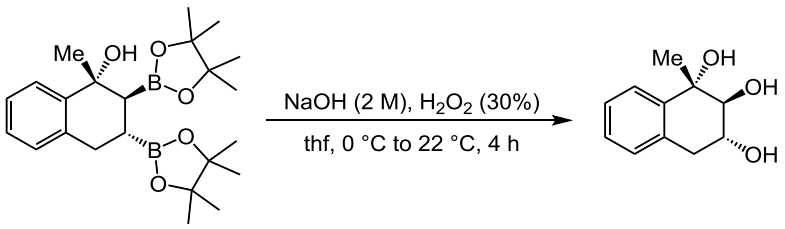
***Anti-,Syn* diastereomer:** (1*S*,2*R*,3*R*) enantiomer**:** 10.8 min; (1*R*,2*S*,3*S*) enantiomer: 12.9 min: 99:1 e.r.

■ **General Procedure (V) for the Enantio- and Diastereoselective Intramolecular Borylation/1,2-Addition to Ketones**

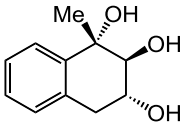


In an N_2-filled glovebox, an 8-mL vial equipped with a magnetic stir bar was charged with Cu*O*t*B*u (1.4 mg, 0.010 mmol, 10 mol%) and (*R*)-BINAP (7.5 mg, 0.012 mmol, 12 mol%), followed by 400 μL 1,4-dioxane. The reaction was capped with a Teflon-lined septum cap and allowed to stir at ambient temperature for 30 minutes, after which time a solution of $B_2(pin)_2$ (27.9 mg, 0.11 mmol, 1.1 equiv) in 200 μL dioxane was added. After stirring for 10 minutes, a solution of ketone substrate (0.10 mmol, 1.0 equiv) in 200 μL dioxane was added. The vial was sealed with electrical tape and removed from the glovebox. Distilled *tert*-butyl alcohol (9.6 μL, 1.0 mmol, 1.0 equiv) was then added by syringe. The reaction was allowed to stir 18 hours at 22 °C. The reaction was quenched with 2 mL of saturated aqueous NH_4Cl and allowed to stir vigorously at 22 °C for 30 minutes. The aqueous layer was extracted three times with diethyl ether, and the combined organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*.

■ **Supplementary Procedure B: NaOH/H_2O_2 Oxidation of Hydroxy(bis)boronate Products**



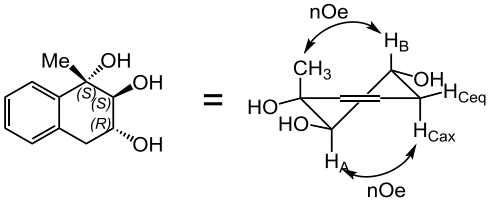
In an 8 mL vial, the crude bis-boronate was dissolved in 500 μL THF and cooled to 0 °C. A 0 °C solution of 2M NaOH (300 μL, 0.6 mmol, 6 equiv) was added dropwise over 30 seconds. Immediately after, a 0 °C solution of 30% (w/w) H_2O_2 (204 μL, 2.0 mmol, 20 equiv) was added dropwise over 30 seconds. The reaction was allowed to stir open to the atmosphere for 1 hour at 0 °C after which point the reaction was allowed to stir for 4 hours at 22 °C. 500 μL of a saturated aqueous solution of NH_4Cl was added, followed by Na_2SO_3, and solid NaCl. 2 mL EtOAc was then added, and the aqueous layer was extracted three times with EtOAc. The combined organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*.



5

1-methyl-1,2,3,4-tetrahydronaphthalene-1,2,3-triol (5). Following General Procedure V and Supplementary Procedure B, the crude reaction mixture was purified *via* silica gel column chromatography to yield 1,2,3-triol **5** as a colorless oil in 95% yield over two steps (18.4 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.52 (d, *J* = 7.5 Hz, 1H), 7.20 (t, *J* = 7.1 Hz, 1H), 7.15 (t, *J* = 7.1 Hz, 1H), 6.98 (d, *J* = 7.2 Hz, 1H), 4.52 (s, 1H), 4.08 (s, 1H), 3.91 (dd, *J* = 15.5, 8.3 Hz, 1H), 3.80 (d, *J* = 10.1 Hz, 1H), 3.67 (s, 1H), 3.12 (dd, *J* = 16.3, 5.5 Hz, 1H), 2.74 (dd, *J* = 15.8, 10.6 Hz, 1H), 1.34 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 141.8, 131.4, 128.4, 127.7, 126.8, 126.1, 80.0, 75.5, 68.4, 36.8, 25.7. **IR** (υ/cm^{-1}): 3361.32 (br), 2926.45 (s), 2360.44 (m), 2342.12 (m), 1443.46 (m), 1369.21, (m), 1102.12 (m). **HRMS** (ESI$^+$): calcd for $C_{11}H_{14}O_3Na^+$ 217.0841, found [M+Na$^+$] 217.0836. **[α]$_D^{22}$** = —51.4 (*c* = 0.66, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Relative stereochemistry was determined through selective 1D ^{1}H NMR experiments.

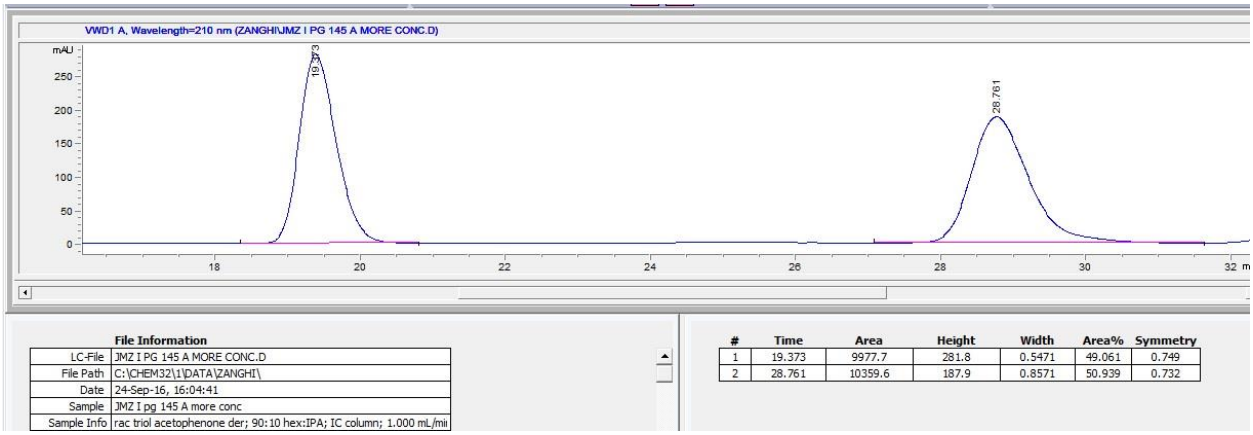


Aryl ring omitted for clarity.

H_A and H_B assignments were made by gCOSY analysis (*vide infra*). The doublet of doublets at 2.74 ppm consists of 15.8 Hz and 10.6 Hz coupling constants, consistent with an *anti* relationship with H_B. The doublet of doublet at 3.12 ppm has coupling constants of 16.5 Hz and 5.5 Hz, consistent with a *gauche* relationship with H_B. The coupling constants confirm the assignments of which proton is axial and which is equatorial.

Absolute stereochemistry was inferred from the stereochemistry obtained for compound **4**.

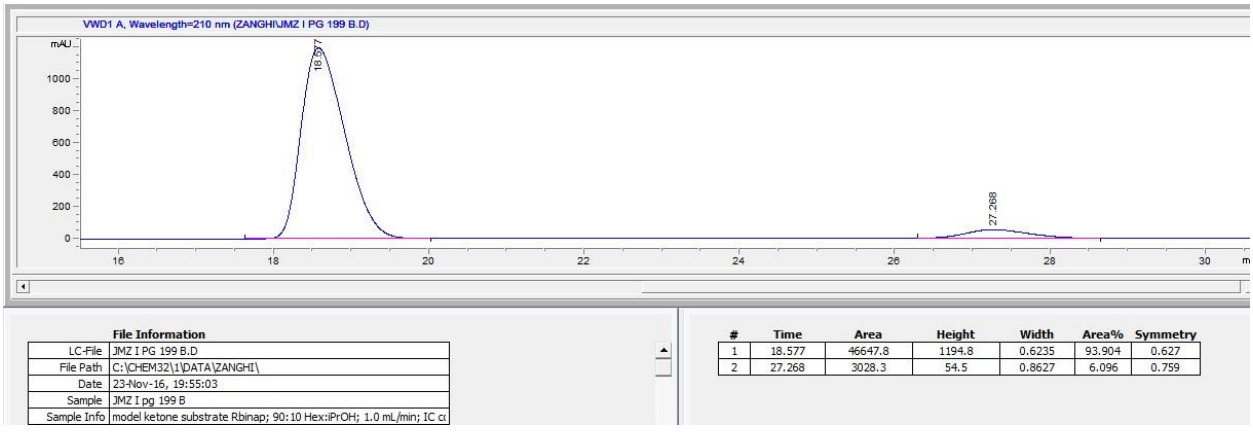
Diacel CHIRALPAK IC Column; 90:10 hexanes:iPrOH; 1.0 mL/min; 210 nm



File Information	
LC-File	JMZ I PG 145 A MORE CONC.D
File Path	C:\CHEM32\1\DATA\ZANGHI\
Date	24-Sep-16, 16:04:41
Sample	JMZ I pg 145 A more conc
Sample Info	rac triol acetophenone der; 90:10 hex:IPA; IC column; 1.000 mL/mi

#	Time	Area	Height	Width	Area%	Symmetry
1	19.373	9977.7	281.8	0.5471	49.061	0.749
2	28.761	10359.6	187.9	0.8571	50.939	0.732

Racemic Material

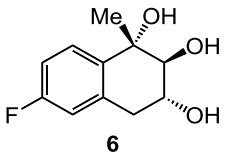


File Information	
LC-File	JMZ I PG 199 B.D
File Path	C:\CHEM32\1\DATA\ZANGHI\
Date	23-Nov-16, 19:55:03
Sample	JMZ I pg 199 B
Sample Info	model ketone substrate Rbinap; 90:10 Hex:iPrOH; 1.0 mL/min; IC c

#	Time	Area	Height	Width	Area%	Symmetry
1	18.577	46647.8	1194.8	0.6235	93.904	0.627
2	27.268	3028.3	54.5	0.8627	6.096	0.759

Enantioenriched Material

***Anti-,Anti* diastereomer:** (1*S*,2*S*,3*R*) enantiomer**:** 18.6 min; (1*R*,2*R*,3*S*) enantiomer: 27.3 min: 94:6 e.r.

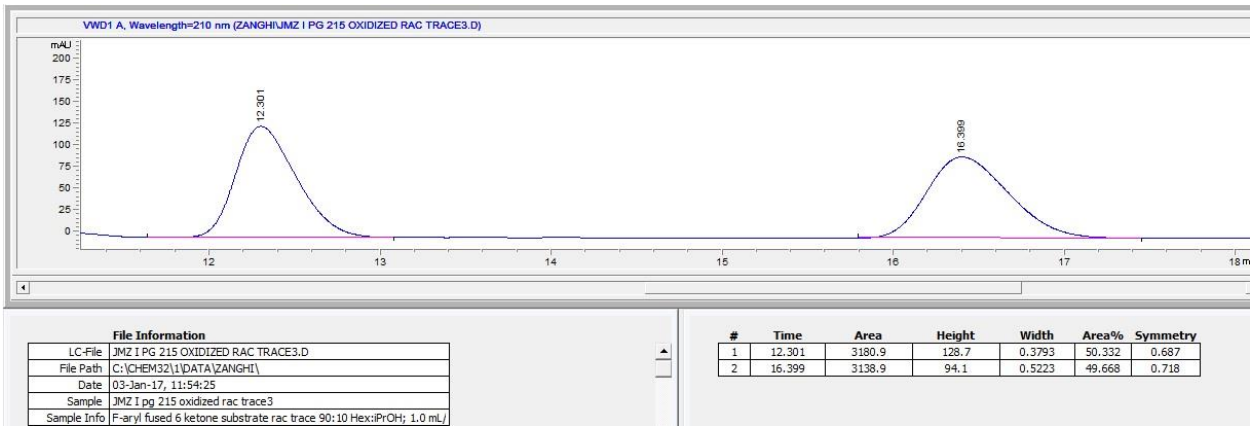


6

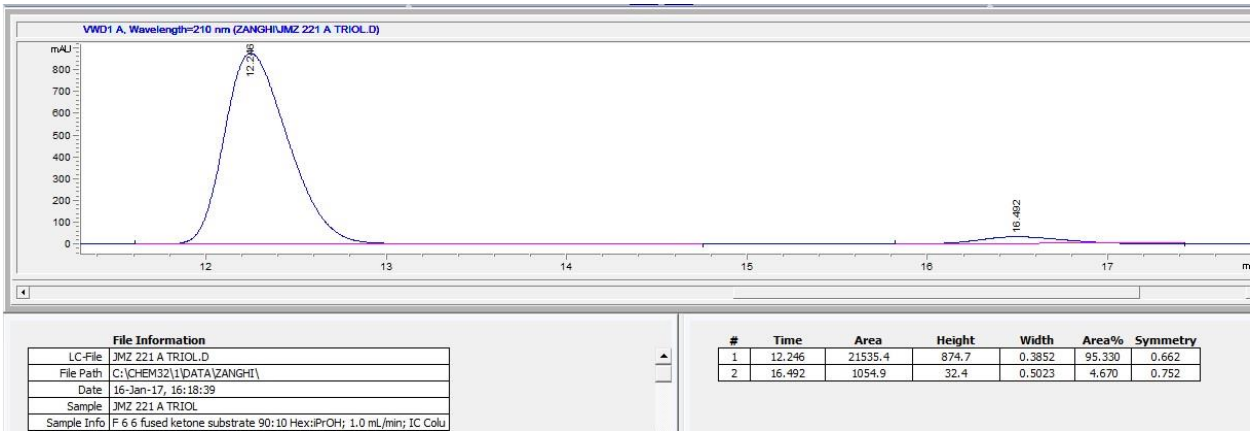
6-fluoro-1-methyl-1,2,3,4-tetrahydronaphthalene-1,2,3-triol (6). Following General Procedure V and Supplementary Procedure B, the crude reaction mixture was purified *via* silica gel column chromatography to yield 1,2,3-triol **6** as a colorless oil in 73% yield over two steps (16.2 mg) and a >20:1 anti:syn diastereomeric ratio. **^{1}H NMR** (600 MHz, CD_3CN) δ 7.53 (dd, *J* = 8.7, 6.0 Hz, 1H), 6.95 (td, J = 8.7, 2.5 Hz, 1H), 6.81 (dd, J = 9.9, 2.4 Hz, 1H), 3.84 (qd, *J* = 9.3, 2.9 Hz, 1H), 3.60 – 3.56 (m, 1H), 3.55 (s, 1H), 3.41 (s, 1H), 3.40 (s, 1H), 3.15 (dd, *J* = 16.8, 6.2 Hz, 1H), 2.72 (dd, *J* = 16.8, 9.5 Hz, 1H), 1.29 (s, 3H). **^{13}C NMR** (151 MHz, CD_3CN) δ 161.7 (d, *J* = 242.8 Hz), 139.2 (d, *J* = 2.8 Hz), 134.8 (d, *J* = 7.8 Hz), 128.6 (d, *J* = 8.5 Hz), 114.0 (d, *J* = 21.0 Hz), 113.3 (d, *J* = 21.5 Hz), 79.0, 73.9, 67.9, 36.4, 36.4, 25.4. **IR** (υ/cm^{-1}): 3358.43 (br), 2981.41 (m), 2933.20 (m), 1615.09 (m), 1497.45 (m), 1240.97 (m). **HRMS** (ESI$^+$): calcd for $C_{11}H_{13}O_3FNa^+$ 235.0746, found [M+Na$^+$] 235.0742. **[α]$_D^{22}$** = — 65.8 (*c* = 0.38, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Relative stereochemistry was inferred from the stereochemistry obtained for compound **5**. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **4**.

Diacel CHIRALPAK IC Column; 90:10 hexanes:iPrOH; 1.0 mL/min; 210 nm

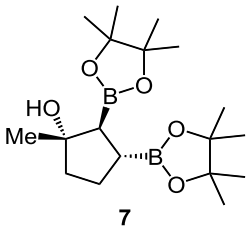


Racemic Material



Enantioenriched Material

***Anti-,Anti* diastereomer:** (1*S*,2*S*,3*R*) enantiomer**:** 12.2 min; (1*R*,2*R*,3*S*) enantiomer: 16.5 min: 95:5 e.r.

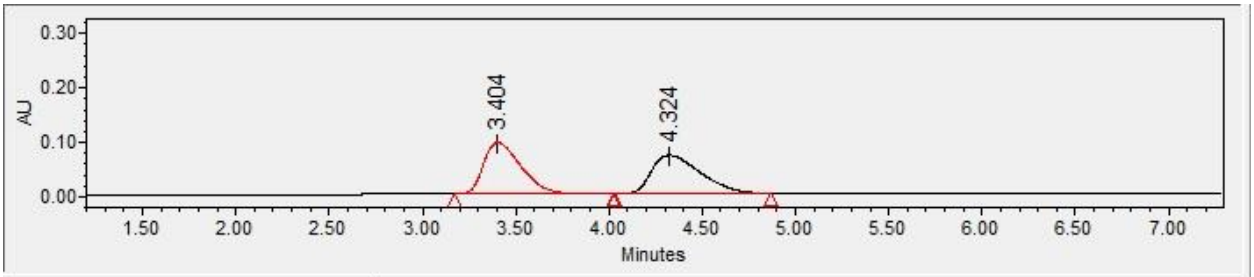


7

1-methyl-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)cyclopentan-1-ol (7). Following General Procedure V, the crude reaction mixture was purified *via* silica gel column chromatography to yield 1-hydroxy-2,3-bisboronate **7** as a colorless oil in 59**%** yield (20.6 mg) and a 5:1 *anti:syn* diastereomeric ratio. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 1.83 – 1.75 (m, 1H), 1.74 – 1.67 (m, 3H), 1.47 – 1.38 (m, 2H), 1.28 (s, 3H), 1.22 (s, 6H), 1.21 (s, 12H), 1.20 (s, 6H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 83.1, 83.1, 82.2, 42.4, 26.1, 25.4, 25.0, 24.7, 24.7. **IR** (υ/cm^{-1}): 3463.53 (br), 2977.55 (s), 2932.33 (m), 2870.52 (m), 1371.44 (m), 1314.25 (s), 1142.62 (m). **HRMS** (ESI^+): calcd for $C_{36}H_{68}O_{10}B_4Na^+$ 727.5082, found [2M+Na^+] 727.5073. **[α]$_D^{22}$** = —4.1 (*c* = 0.71, CH_2Cl_2, *l* = 100 mm).

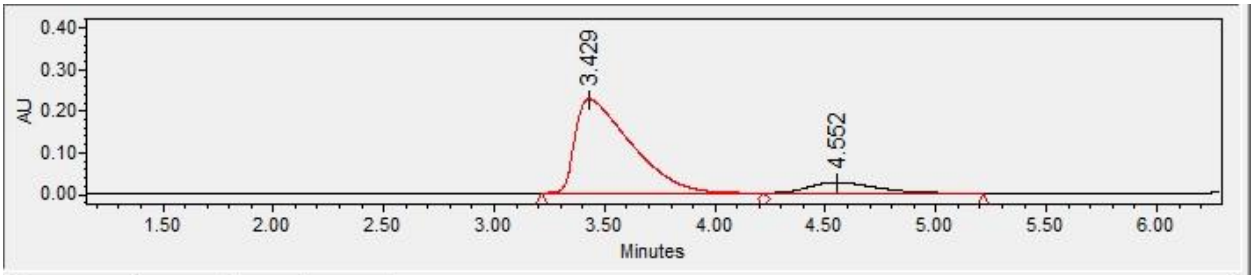
Enantiomeric excess was determined through silylation of the hydroxyl(bis)boronate product with benzylchlorodimethylsilane (*vide infra*), followed by oxidation to provide the mono-protected triol. This compound was analyzed by SFC and compared to the authentic racemic material. Relative stereochemistry was established through oxidation of the crude hydroxy(bis)boronate to the corresponding triol (see Supplementary Procedure B) and comparison to known literature spectra.[12]

Phenomenex Cellulose-1 Column; 98:2 CO_2:iPrOH; 2.0 mL/min; 22 °C; 210 nm



	Retention Time (min)	Area (μV*sec)	% Area	Height (μV)
1	3.404	1323603	50.45	94470
2	4.324	1300162	49.55	70940

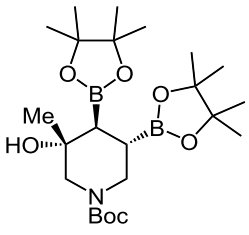
Racemic Material



	Retention Time (min)	Area (μV*sec)	% Area	Height (μV)
1	3.429	3948044	88.03	225772
2	4.552	537000	11.97	25680

Enantioenriched Material

***Anti-,Anti* diastereomer:** (1*S*,2*S*,3*R*) enantiomer**:** 3.5 min; (1*R*,2*R*,3*S*) enantiomer: 4.6 min: 88:12 e.r.



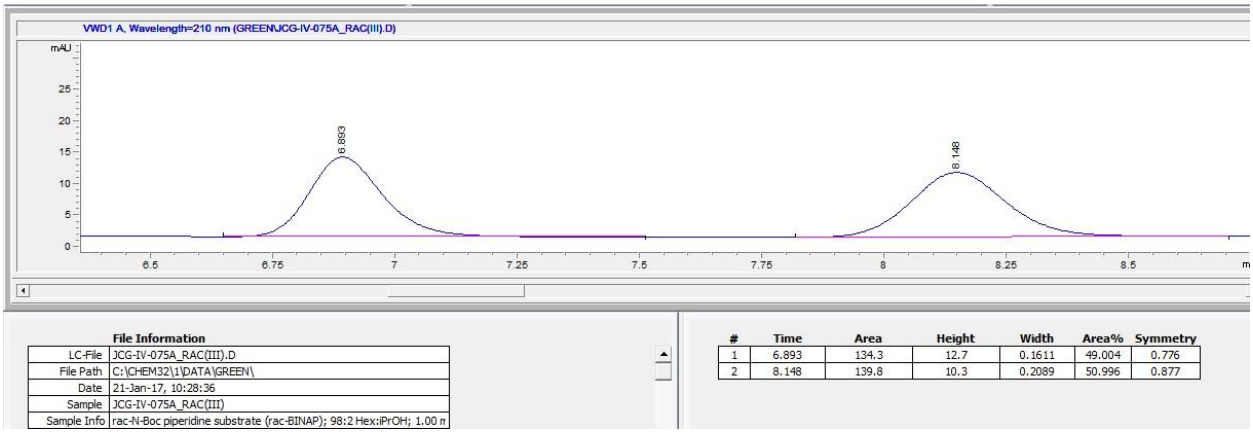
8

***tert*-butyl-3-hydroxy-3-methyl-4,5-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)piperidine-1-carboxylate (8)**. Following General Procedure V, the crude reaction mixture was purified *via* silica gel column chromatography to yield 1-hydroxy-2,3-bisboronate **8** as a colorless oil in 58% yield (27.1 mg) and a >20:1 *anti*:*syn* diastereomeric ratio. At room temperature, the product exists as a 1.3:1 mixture of chair conformations, which were resolved through variable temperature ^{1}H NMR experiments (*vide infra*). Peaks corresponding to the minor conformation

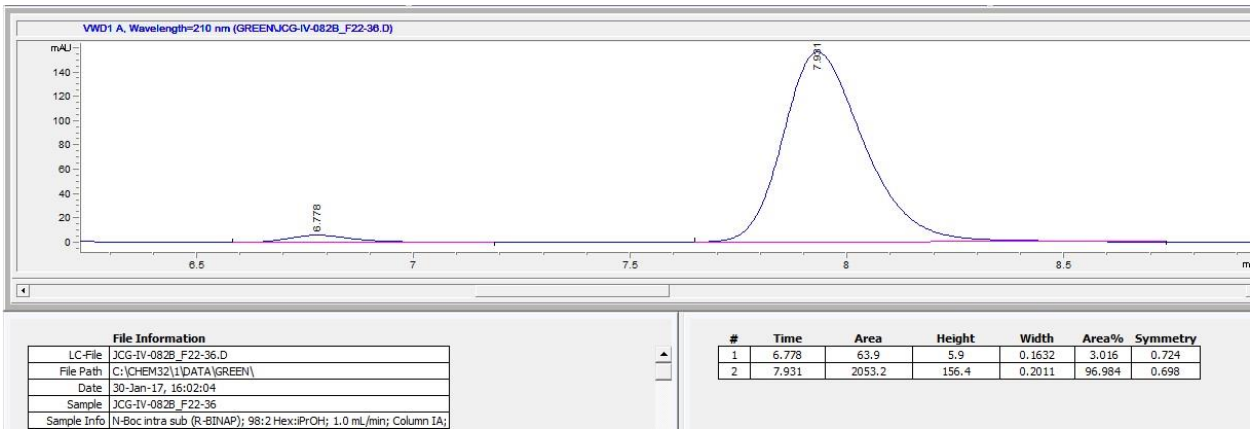
are starred. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 4.01 (dd, *J* = 62.8, 18.1 Hz, 2H), *3.86 (s, *J* = 9.7 Hz, 2H), *3.37 (d, *J* = 8.0 Hz, 2H), 3.32 (dd, *J* = 14.2, 9.3 Hz, 1H), 3.24 (dd, *J* = 14.1, 6.7 Hz, 1H), 2.10 (s, 3H), *2.09 (s, 3H), 1.45 (s, 9H), *1.38 (s, 9H), 1.22 (s, 24H), *1.22 (s, 12H), *1.21 (s, 12H), 0.90 – 0.75 (m, 2H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 205.6, 205.2, 156.3, 155.3, 83.2, 83.14, 83.0, 83.0, 80.0, 79.8, 65.9, 57.2, 56.8, 51.3, 50.9, 28.4, 28.3, 27.0, 26.7, 24.9, 24.9, 24.8, 15.3. **IR** (υ/cm^{-1}): 3552.24 (br), 2977.55 (m), 2930.31 (m), 2360.44 (m), 2342.12 (m), 1736.58 (s), 1697.05 (m), 1369.21 (m), 1146.47 (m). **HRMS** (ESI$^+$): calcd for $C_{23}H_{43}O_7B_2NNa^+$ 490.3123, found [M+Na$^+$] 490.3118. **[α]$_D^{22}$** = —3.7 (*c* = 0.73, CH_2Cl_2, *l* = 100 mm).

Enantiomeric excess was determined by HPLC analysis compared to the authentic racemic material. Relative stereochemistry was inferred from the stereochemistry obtained for compound **7**. Absolute stereochemistry was inferred from the stereochemistry obtained for compound **4**.

Diacel CHIRALPAK IA Column; 98:2 hexanes:iPrOH; 1.0 mL/min; 210 nm

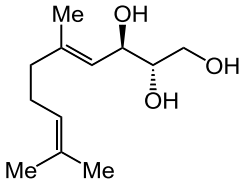


Racemic Material



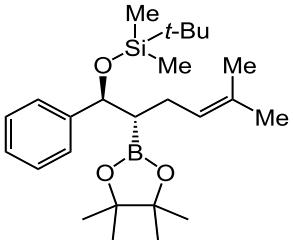
Enantioenriched Material

***Anti-,Anti* diastereomer:** (3*S*,4*R*,5*R*) enantiomer**:** 6.8 min; (3*R*,4*S*,5*S*) enantiomer: 8.1 min: 97:3 e.r.



9

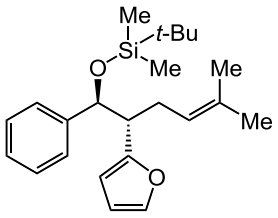
***E*-5,9-dimethyldeca-4,8-diene-1,2,3-triol (9).** A vial containing **2o** (17.3 mg, 0.0398 mmol) was charged with thf (159 μL) and allowed to cool to 0 °C (ice/water bath). The reaction was charged with 3M NaOH (80 μL, 0.24 mmol) and then 30% H_2O_2 (80 μL, 0.80 mmol) dropwise. The reaction was allowed to slowly warm up to ambient temperature over 2 hours, followed by 4 hours of additional stirring at that temperature. The reaction was allowed to cool to 0 °C and quenched by dropwise addition of 1M $Na_2S_2O_3$. The reaction was diluted with water and then extracted 6X with EtOAc. The combined organic extracts were dried over Na_2SO_4, filtered, and then dried *in vacuo*. The crude reaction mixture was purified *via* silica gel chromatography (1:1 EtOAc:hexanes to pure EtOAc) to yield the triol in 93% yield (7.9 mg) as a colorless oil. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 5.22 (dq, *J* = 9.0, 1.3 Hz, 1H), 5.08 (tq, *J* = 5.5, 1.4 Hz, 1H), 4.42 – 4.36 (m, 1H), 3.76 – 3.68 (m, 1H), 3.60 – 3.53 (m, 2H), 3.13 (s, 1H), 2.33 (s, 2H), 2.12 (q, *J* = 7.4 Hz, 2H), 2.09 – 2.03 (m, 2H), 1.73 (d, *J* = 1.4 Hz, 3H), 1.70 (d, *J* = 1.4 Hz, 3H),, 1.62 (d, *J* = 1.3 Hz, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 142.1, 132.0, 123.7, 123.1, 75.0, 69.5, 65.9, 39.7, 26.3, 25.7, 24.9, 17.7, 16.9. **IR** (ν/cm^{-1}): 3745 (s), 2968 (m), 2888 (m), 1314 (w), 1225 (m). **HRMS** (ESI$^+$): calcd for $C_{12}H_{22}O_3Na$ 237.1467, found: [M+Na$^+$] 237.1462. **[α]$_D^{22}$** = —92.1 (*c* = 3.95, CH_2Cl_2, *l* = 100 mm).



12

tert-butyldimethyl((-5-methyl-1-phenyl-2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)hex-4-en-1-yl)oxy)silane (12). Following a modified literature procedure[13], **10** (20.0 mg, 0.0398 mmol) was charged with a thf solution (362 μL) of $Pd(OAc)_2$ (0.4 mg, 0.00199 mmol) and RuPhos (0.9 mg, 0.00119 mmol) that was allowed to stir at ambient temperature for 10 minutes under N_2. This was followed by vinyl bromide **11** (5.3 μL, 0.052 mmol) under N_2, and a solution of KOH (6.7 mg, 0.12 mmol) in H_2O (35.8 μL) that had been sparged with N_2 for 2.5 hours. The reaction was sealed and allowed to stir at 70 °C for 12 hours. The reaction was allowed to cool to

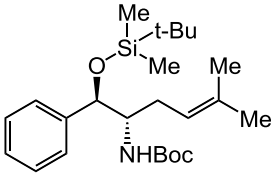
ambient temperature, then quenched by addition of methylene chloride and water. The layers were separated and the aqueous layer was extracted 3X with methylene chloride. The combined organic layers were dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The crude reaction was purified *via* silica gel chromatography (25:1 pentane:Et_2O, Seebach Stain visualization) to afford the product in 51% yield (8.8 mg) as a single diastereomer. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.34 – 7.26 (m, 4H), 7.25 – 7.17 (m, 1H), 5.05 (ddq, *J* = 7.6, 6.1, 1.4 Hz, 1H), 4.71 (d, *J* = 8.2 Hz, 1H), 1.99 (ddd, *J* = 14.1, 10.8, 8.2 Hz, 1H), 1.78 – 1.70 (m, 1H), 1.63 (d, *J* = 1.5 Hz, 3H), 1.50 (s, 4H), 1.25 (s, 6H), 1.25 (s, 6H), 0.87 (s, 9H), 0.02 (s, 3H), -0.34 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 145.4, 131.4, 127.7, 126.9, 126.8, 123.9, 83.0, 26.9, 25.9, 25.7, 25.3, 25.0, 18.1, 17.8, -4.3, -4.7. **IR** (ν/cm^{-1}): 2935 (m), 2921 (s), 2838 (m), 1328 (m), 1427 (w), 1338 (m), 1376 (m). **HRMS** (ESI$^+$): calcd for $C_{25}H_{43}O_3BSiNa^+$ 453.2972, found: [M+Na$^+$] 453.2968. **[α]$_D^{22}$** = – 22.8 (*c* = 4.12, CH_2Cl_2, *l* = 100 mm).



13

tert-butyl(((1S,2S)-2-(furan-2-yl)-5-methyl-1-phenylhex-4-en-1-yl)oxy)dimethylsilane (13). TBS-protected alcohol **13** was prepared following a modified literature procedure.[14] A flame--dried 8-mL vial was charged with furan (6.2 μL, 0.0859 mmol) and anhydrous thf (0.290 mL). The reaction was allowed to cool to -78 ˚C (dry ice/acetone) and then charged with *n*-butyllithium (54.7 μL, 0.0859 mmol, 1.57 M solution in hexanes). The cooling bath was removed and the reaction was allowed to stir at ambient temperature for 1 hour. The mixture was allowed to cool back down to -78 ˚C (dry ice/acetone) and then charged with **12** (3.7:1 d.r.) as a 0.4 M solution in thf (30.8 mg, 0.0715 mmol) and allowed to stir at that temperature for 1.5 hour. NBS (15.3 mg, 0.0859 mmol) was then added to the reaction as a 0.3 M solution in thf. After allowing the reaction to stir for 1.5 hours, 1 mL of a saturated aqueous solution of $Na_2S_2O_3$ was added to the reaction and allowed to stir at ambient temperature for 30 minutes. The layers were separated and extracted three times with diethyl ether. The combined organic extracts were dried over MgSO4, filtered, and concentrated *in vacuo*. The crude reaction mixture was purified by silica gel chromatography (pure hexanes to 50:1 hexanes:Et_2O, $KMnO_4$ stain visualization) to give the product **13** as a colorless oil in 52% yield (13.9 mg) and 3.8:1 *anti*:*syn* diastereomeric ratio. ***Anti* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.34 – 7.32 (m, 1H), 7.28 – 7.25 (m, 2H), 7.22 – 7.17 (m, 1H), 7.17 – 7.13 (m, 2H), 6.29 (dd, *J* = 3.1, 1.8 Hz, 1H), 5.99 (d, *J* = 3.1 Hz, 1H), 4.95 (ddd, *J* = 7.0, 5.7, 1.3 Hz, 1H), 4.83 (d, *J* = 6.6 Hz, 1H), 2.98 (ddd, *J* = 10.9, 6.6, 4.7 Hz, 1H), 2.21 – 2.07 (m, 2H), 1.59 (s, 3H), 1.45 (s, 3H), 0.81 (s, 9H), -0.08 (s, 3H), -0.24 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 155.8, 143.2, 140.5, 132.5, 127.7, 126.8, 122.1, 110.1, 107.2, 48.8, 27.9,

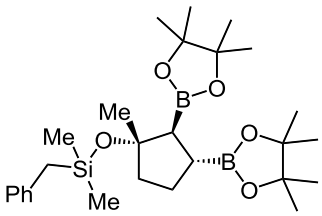
25.7, 18.1, 17.6, -4.9, -5.4. ***Syn* diastereomer**: **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.25 – 7.22 (m, 6H), 6.20 (dd, *J* = 3.1, 1.8 Hz, 1H), 5.82 (d, *J* = 3.1 Hz, 1H), 4.98 (dd, *J* = 11.5, 4.2 Hz, 1H), 4.88 (d, *J* = 6.2 Hz, 1H), 2.92 – 2.87 (m, 1H), 2.61 – 2.54 (m, 1H), 2.41 – 2.33 (m, 1H), 1.60 (s, 3H), 1.51 (s, 3H), 0.90 (s, 9H), -0.08 (s, 3H), -0.25 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 155.6, 143.8, 140.6, 132.4, 127.6, 127.1, 126.8, 126.3, 110.0, 107.0, 65.9, 49.3, 26.7, 25.8, 25.7, 18.2, 15.3, -4.8, -5.4. **IR** (ν/cm^{-1}): 2956.34 (s), 2927.41 (m), 2856.06 (m), 1250.61 (m), 1090.55 (m). **HRMS** (ESI$^+$): calcd for $C_{23}H_{34}O_2SiNa^+$ 393.2231, found: [M+Na$^+$] 393.2226. **[α]$_D^{22}$** = + 7.0 (*c* = 0.70, CH_2Cl_2, *l* = 100 mm).



14

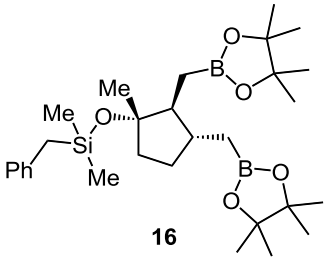
tert-butyl ((1R,2S)-1-((tert-butyldimethylsilyl)oxy)-5-methyl-1-phenylhex-4-en-2-yl)carbamate (14). Carbamate **14** was prepared from compound **12** according to literature procedure.[3] A flame-dried 8-mL vial equipped with a magnetic stir bar was flushed with N_2 and charged with **12** (21.6 mg, 0.0502 mmol) and 414 μL of anhydrous thf. A 0.837 M solution of *O*-methylhydroxylamine (180 μL, 0.151 mmol) was added to a separate N_2-flushed, flame-dried 8-mL vial and then diluted with 328 μL of anhydrous thf. Both vials were cooled to -78 °C in a dry ice/acetone bath. A 1.69 M solution of n-butyllithium in hexanes (89 μL, 0.151 mmol) was added dropwise to the *O*-methylhydroxylamine solution and this was allowed to stir at -78 °C for 30 minutes. After this time, the *in situ* generated solution of lithium *O*-methylhydroxylamide was cannula transferred to the cooled solution of **12**. The resulting solution was allowed to warm to room temperature and was then heated to 60 °C with stirring for 20 h. After this time, the solution was allowed to cool to 22 °C and di-tert-butyl dicarbonate (36.8 μL, 0.161 mmol) was added via syringe. The solution was allowed to stir for 2 hours at 22 °C. The reaction was quenched with 3 mL of deionized water, and the aqueous layer was extracted four times with ethyl acetate. The combined organic layers were then dried over Na_2SO_4, filtered, and concentrated *in vacuo*. The crude residue was purified by silica gel column chromatography (10:1 pentane:diethyl ether), yielding the title carbamate **14**. The title compound was isolated as a colorless oil in 30% yield (6.3 mg). **^{1}H NMR** (3:1 mixture of rotamers, asterisks denote minor rotamer peaks, 600 MHz, $CDCl_3$) δ 7.31 – 7.27 (m, 3H), 7.24 – 7.20 (m, 2H), 5.13 (tt, *J* = 7.1, 1.4 Hz, 1H), 4.74 (d, *J* = 3.2 Hz, 1H), *4.69 (bs, 1H), 4.57 (d, *J* = 9.5 Hz, 1H), *4.42 (d, *J* = 9.8 Hz, 1H), 3.68 (d, *J* = 8.2 Hz, 1H), *3.55 (bs, 1H), 2.31-2.27 (m, 1H), 2.14 – 1.97 (m, 1H), 1.70 (s, 3H), 1.59 (s, 3H), 1.35 (bs, 9H), 0.91 (s, 9H), 0.05 (s, 3H), -0.17 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 155.5, 142.1, 133.9, 127.8, 127.2, 126.5, 120.5, 57.1, 30.3, 28.4, 28.1, 27.4, 25.9, 25.8, 18.2, 18.1, 14.1, -4.5, -5.1. **IR** (ν/cm^{-1}): 2929 (s), 2857 (m), 1716 (s), 1496 (m), 1456 (m), 1364 (m), 1253 (m). **HRMS** (ESI$^+$): calcd

for $C_{48}H_{82}N_2O_6Si_2Na^+$ 861.5610, found: [2M+Na$^+$] 861.5601. **[α]$_D^{22}$** = + 13.9 (*c* = 0.09, CH_2Cl_2, *l* = 100 mm).



15

Benzyldimethyl(((1S,2S,3R)-1-methyl-2,3-bis(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)cyclopentyl)oxy)silane (15). A crude reaction mixture of 1-hydroxy-2,3-bisboronate **7** (0.2 mmol scale) was charged with imidazole (54.5 mg, 0.8 mmol) and a magnetic stir bar and dried under vacuum for 20 minutes. Anhydrous dmf (1.3 mL) was then added via syringe under N_2, followed by benzylchlorodimethylsilane (109 μL, 0.6 mmol). The reaction was allowed to stir at ambient temperature for 18 hours. The reaction was quenched by addition of 1 mL of a saturated aqueous solution of NH_4Cl. The mixture was extracted 3X with diethyl ether and the combined organic extracts were washed with a saturated aqueous solution of $NaHCO_3$, followed by brine. The washed organic extracts were dried over $MgSO_4$, filtered, and concentrated *in vacuo*. The crude reaction mixture was purified *via* silica gel chromatography (20:1 hexanes:Et_2O, Seebach Stain visualization) to yield the silyl-proteced 1-hydroxy-2,3-bisboronate **15** as a colorless oil in 43% yield (43.0 mg, over two steps) and in 4.8:1 d.r. **Anti-, Anti diastereomer:** **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.19 (dd, *J* = 10.5, 4.7 Hz, 2H), 7.08 (d, *J* = 7.3 Hz, 2H), 7.05 (t, *J* = 7.2 Hz, 1H), 2.16 (s, 2H), 1.76 – 1.65 (m, 2H), 1.61 – 1.55 (m, 1H), 1.52 (d, *J* = 12.6 Hz, 1H), 1.39 – 1.32 (m, 2H), 1.27 (s, 3H), 1.25 (s, 6H), 1.24 (s, 6H), 1.22 (s, 6H), 1.22 (s, 6H), 0.07 (s, 3H), 0.06 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 140.2, 128.5, 128.0, 123.8, 85.1, 82.8, 82.8, 44.1, 28.8, 27.2, 25.8, 25.0, 24.8, 24.8, 0.4, 0.4. **IR** (ν/cm^{-1}): 2976.59 (s), 2932.23 (m), 2360.44 (m), 2341.16 (m), 1600.63 (s), 1371.14 (m), 1316.18 (m), 1144.55 (m). **HRMS** (ESI$^+$): calcd for $C_{27}H_{46}O_5B_2SiNa^+$ 523.3198, found: [M+Na$^+$] 523.3190. **[α]$_D^{22}$** = + 3.6 (*c* = 0.46, CH_2Cl_2, *l* = 100 mm).



16

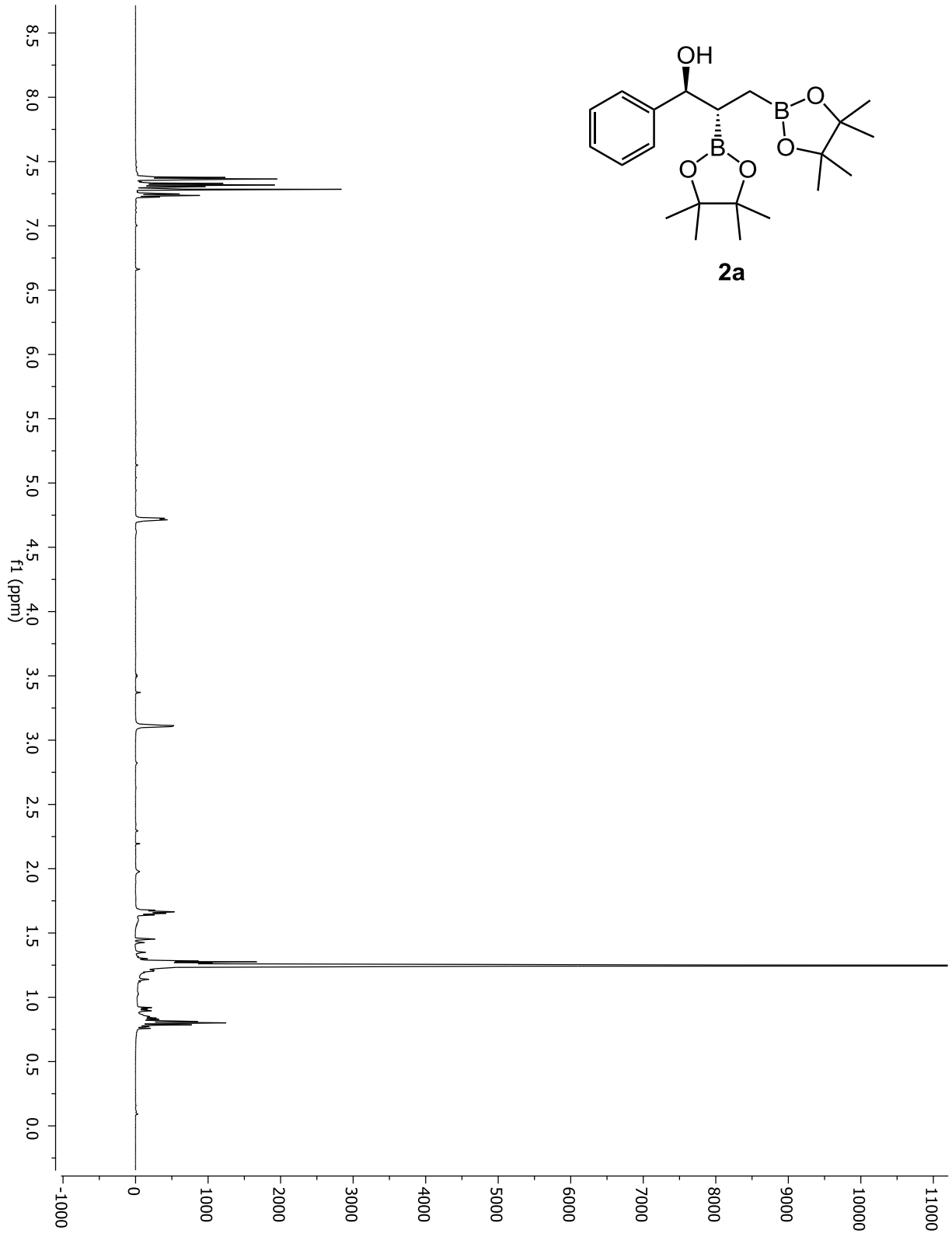
benzyldimethyl(((1S,2S,3R)-1-methyl-2,3-bis((4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl)cyclopentyl)oxy)silane (16). Bis-homologated 1-hydroxy-2,3-bisboronate **16** was prepared according to a modified literature procedure.[15] Protected hydroxyboronate **15** (35.6

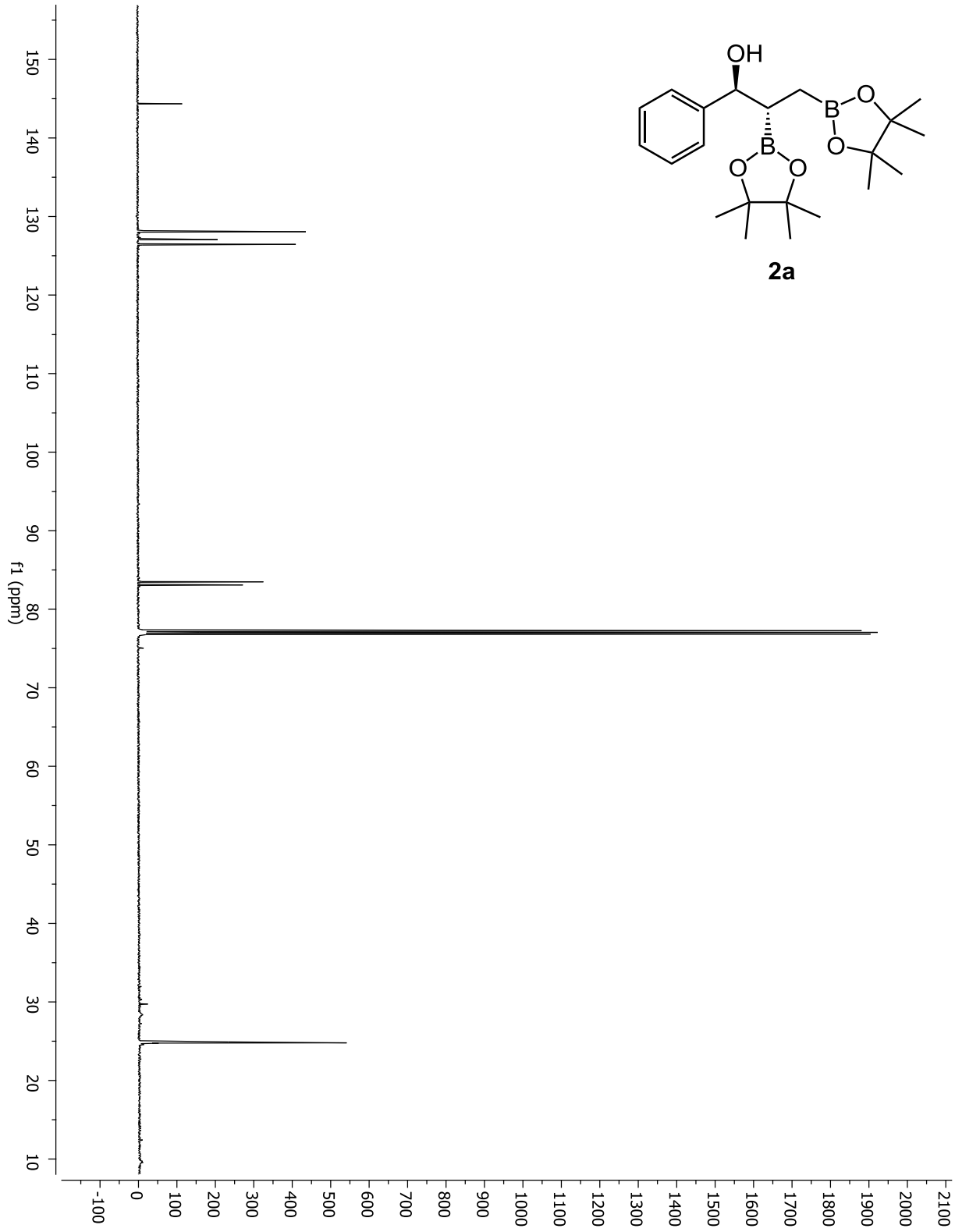
mg, 0.0711 mmol) was added to an oven-dried 8 mL vial containing a stir bar. The vial was purged with nitrogen for 3 minutes. A solution of dibromomethane in thf was made (0.178 mmol, 0.25M) and an aliquot (0.711 mL) was added to the vial via syringe. The vial was cooled to -78 °C (dry ice/acetone bath). A solution of nBuLi (0.100 mL, 0.157 mmol, 1.57M) in hexanes was added dropwise via syringe. The reaction was allowed to stir at -78 °C for 20 minutes and then allowed to warm to room temperature and stirred for an additional two hours. The reaction was quenched with a saturated solution of ammonium chloride (1.5 mL), extracted with diethyl ether (3x), dried over MgSO4 and concentrated. The crude material was purified via silica gel chromatography (20:1 to 10:1 hexanes:Et_2O, Seebach's stain visualization) to yield the desired bis-homologated product **16** in 78% yield (29.3 mg) as a viscous, colorless oil. **^{1}H NMR** (600 MHz, $CDCl_3$) δ 7.19 (t, *J* = 7.7 Hz, 2H), 7.05 (d, *J* = 7.1 Hz, 3H), 2.13 (d, *J* = 2.7 Hz, 2H), 1.79 – 1.72 (m, 2H), 1.71 – 1.67 (m, 2H), 1.57 – 1.49 (m, 2H), 1.25 (s, 12H), 1.23 (s, 6H), 1.22 (s, 6H), 1.10 (dd, *J* = 15.6, 3.7 Hz, 1H), 1.06 (s, 3H), 0.88 – 0.83 (m, 1H), 0.69 (dd, *J* = 15.4, 11.0 Hz, 1H), 0.57 (dd, *J* = 15.4, 8.6 Hz, 1H), 0.06 (s, 3H), 0.05 (s, 3H). **^{13}C NMR** (151 MHz, $CDCl_3$) δ 140.1, 128.5, 128.0, 123.8, 83.6, 82.9, 82.8, 54.8, 40.3, 39.9, 29.8, 28.8, 25.1, 25.0, 24.9, 24.7, 24.2, 0.6, 0.5. **IR** (ν/cm^{-1}): 2976.34 (m), 2929.34 (m), 1371.14 (m), 1316.18 (m), 1145.51 (m). **HRMS** (ESI$^+$): calcd for $C_{29}H_{52}O_5B_2SiNa^+$ 551.3511, found: [M+Na$^+$] 551.3518. **[α]$_D^{22}$** = – 3.0 (*c* = 0.44, CH_2Cl_2, *l* = 100 mm).

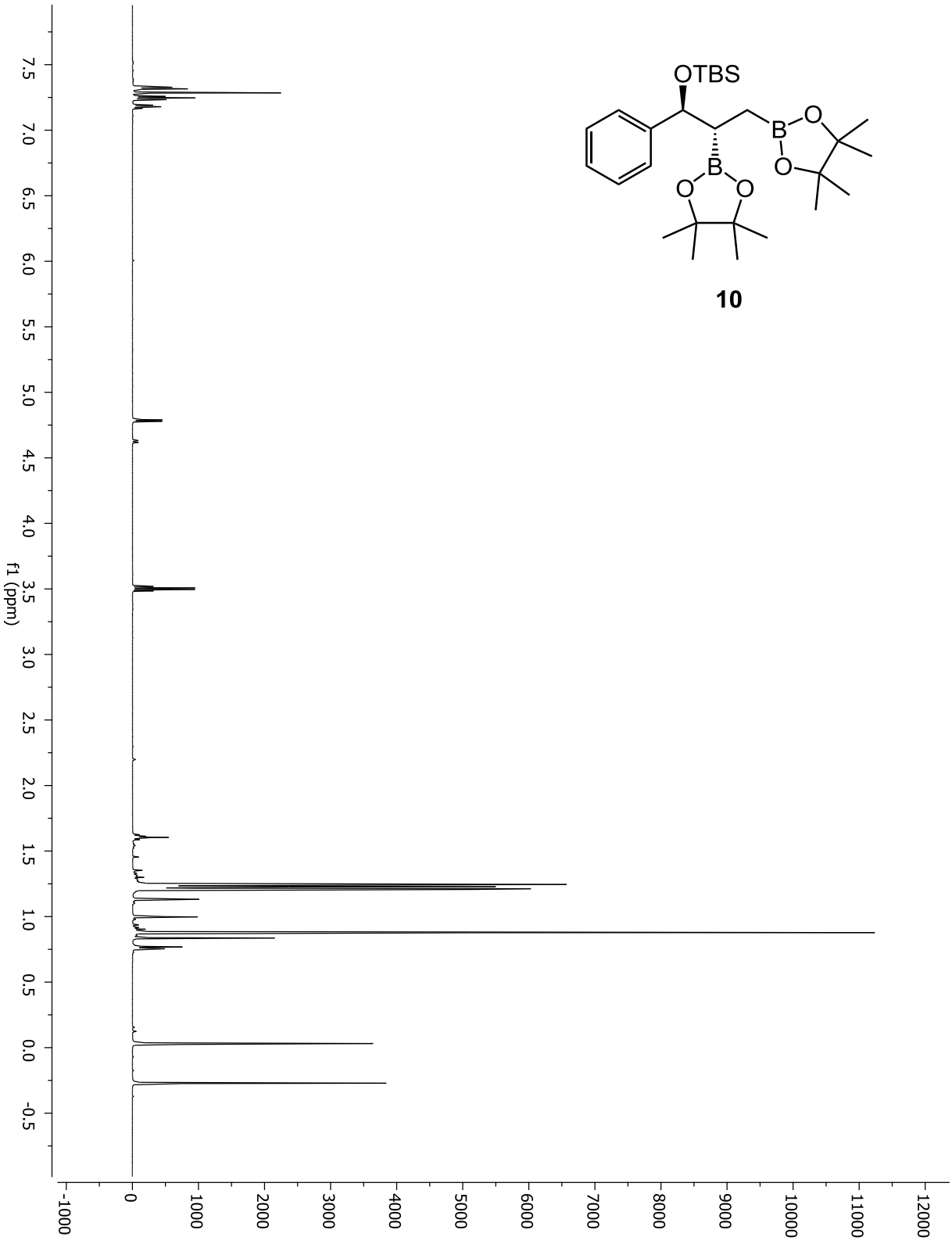
References

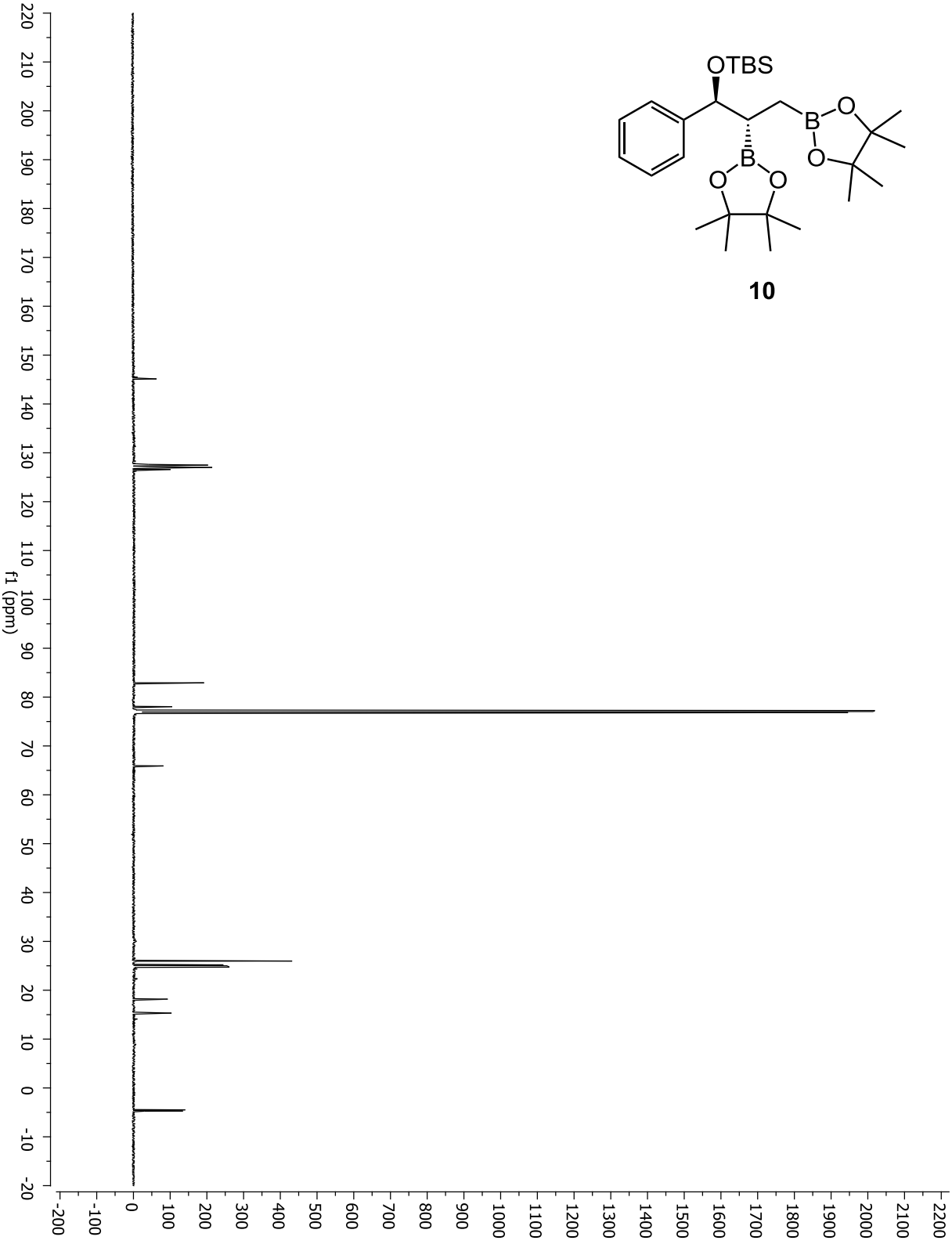
1) Qin, Y.; Lv, J.; Luo, S.; Cheng, J.-P. *Org. Lett.* **2014**, *16*, 5032—5035.
2) Finney, N. S.; Moore, J. D. *Org. Lett.* **2002**, *4*, 3001–3003.
3) S. N. Mlynarski, A. S. Karns, J. P. Morken, *J. Am. Chem. Soc*. **2012**, *134*, 16449-16451.
4) F. Girand, *Eur. J. Med. Chem.* **2012**, *56*, 225-236.
5) Jang, H.; Zhugralin, A.R.; Lee, Y.; Hoveyda, A.H. *J. Am. Chem. Soc*. **2011**, *133*, 7859–7871.
6) Saijo, H.; Ohashi, M.; Ogoshi, S. *J. Am. Chem. Soc.* **2014**, *136*, 15158–15161.
7) Rémy, H.; François, C.; Bertrand, C. *J. Org. Chem*. **2013**, *78*, 6786—6792.
8) Selander, N.; Willy, B.; Szab, K.J. *Angew. Chem., Int. Ed*. **2010**, *49*, 4051—4053.
9) Lee, Y. T.; Fisher, J. F. *Bioorg. Chem.* **2000**, *28*, 163-175.
10) Lee, Y.; Jang, H.; Hoveyda, A.H. *J. Am. Chem. Soc.* **2009**, *13*, 18234–18235.
11) Cardillo, G.; Orena, M.; Romero, M.; Sandri, S. *Tetrahedron* **1989**, *45*, 1501–1508.
12) Niidu, A.; Paju, A.; Eek, M.; Müürisepp, A.-M.; Pehk, T.; Lopp, M. *Tetrahedron: Asymmetry* **2006**, *17*, 2678-2683.

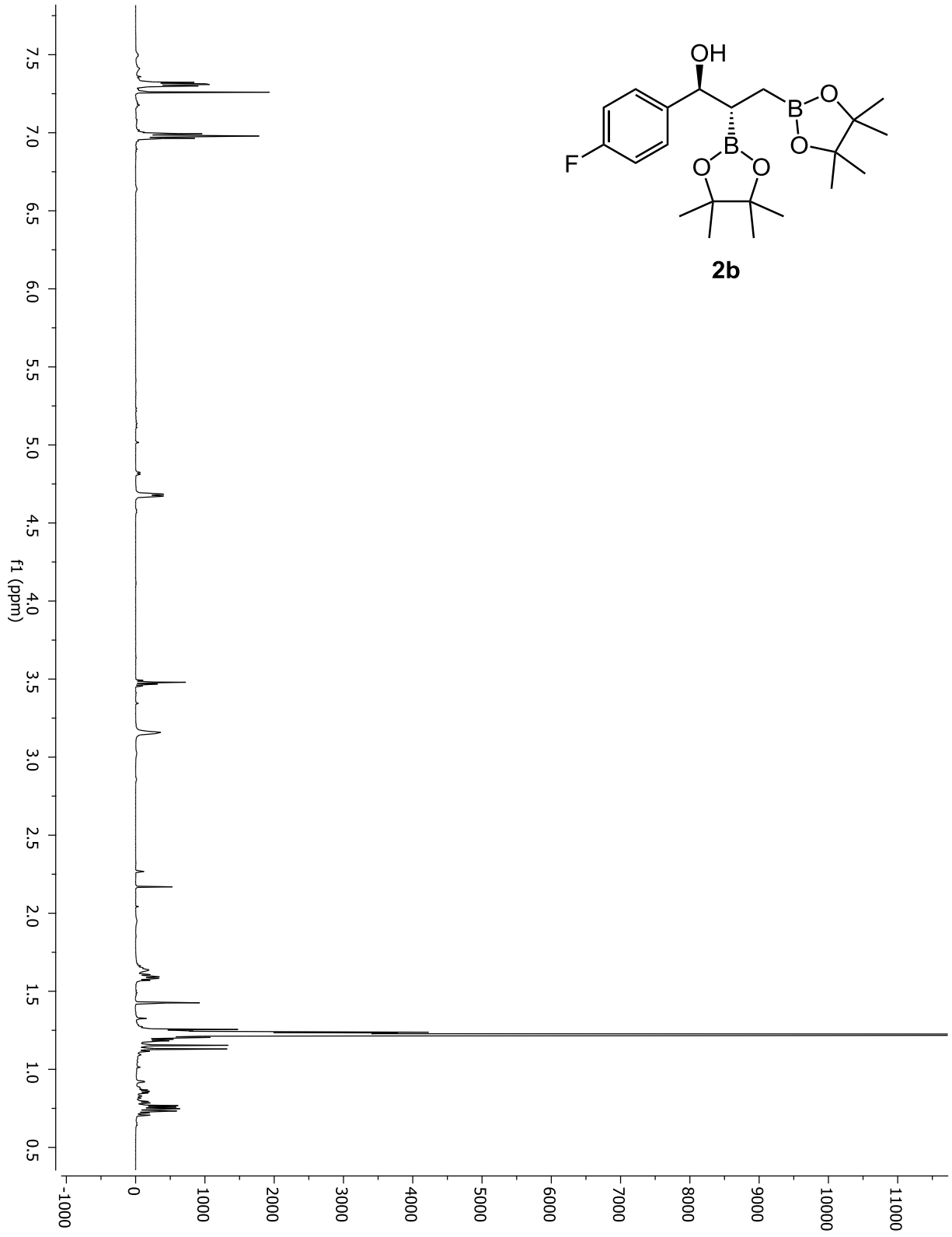
13) Lallana, E.; Freire, F.; Seco, J. M.; Quinoa, E.; Riguera, R. *Org. Lett.* **2006**, *8*, 4449–4452.
14) Bonet, A.; Odachowski, M.; Leonori, D.; Essafi, S.; Aggarwal, V. K. *Nat. Chem.* **2014**, *6*, 584-589.
15) Sonawane, R. P.; Jheengut, V.; Rabalakos, C.; Larouche-Gauthier, R.; Scott, H. K.; Aggarwal, V. K. *Angew. Chem., Int. Ed.* **2011**, *50*, 3760-3763.

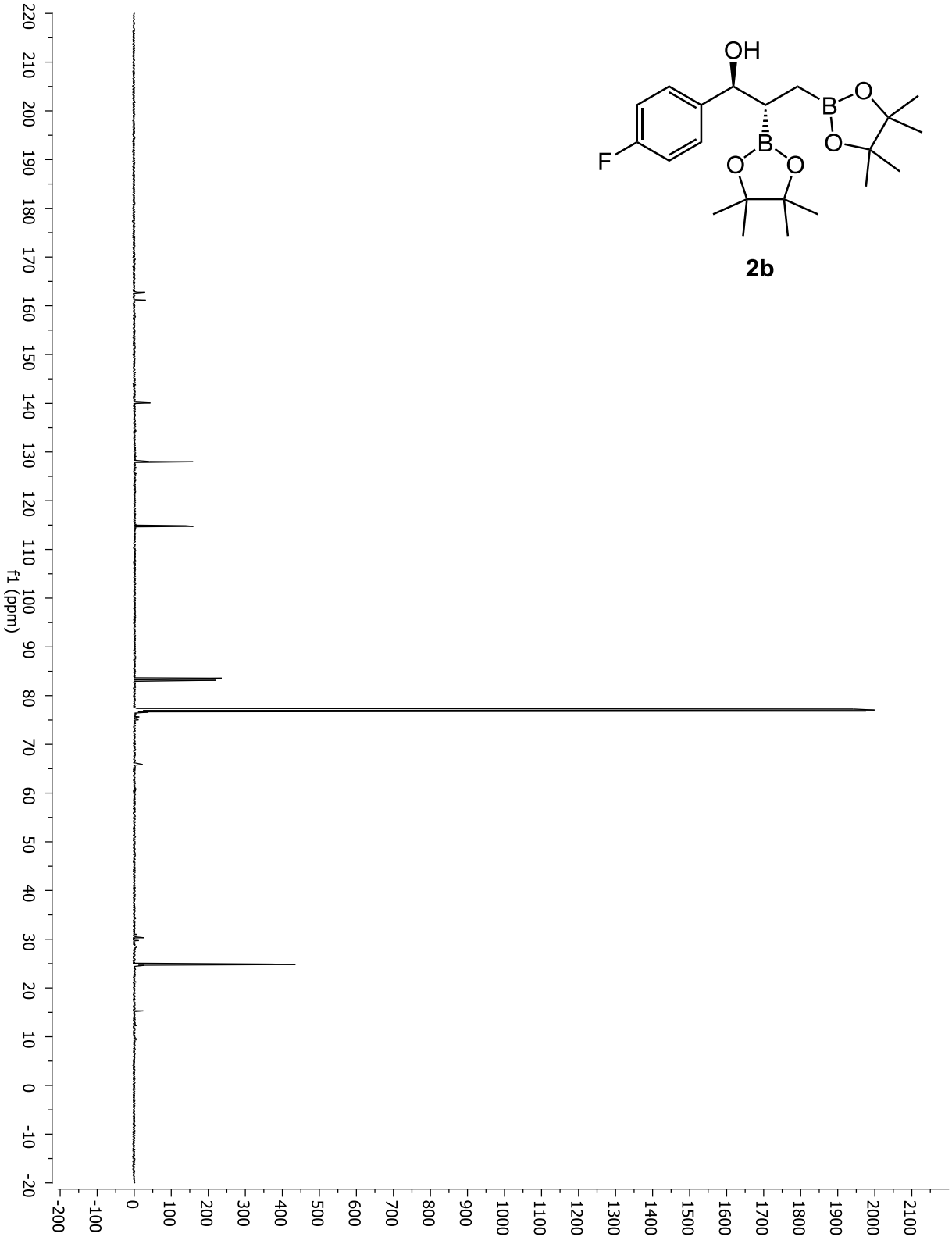

OH
B
O
O
B
O
O
2a
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000


OH
B
O
O
B
O
O
2a
f1 (ppm)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
2100

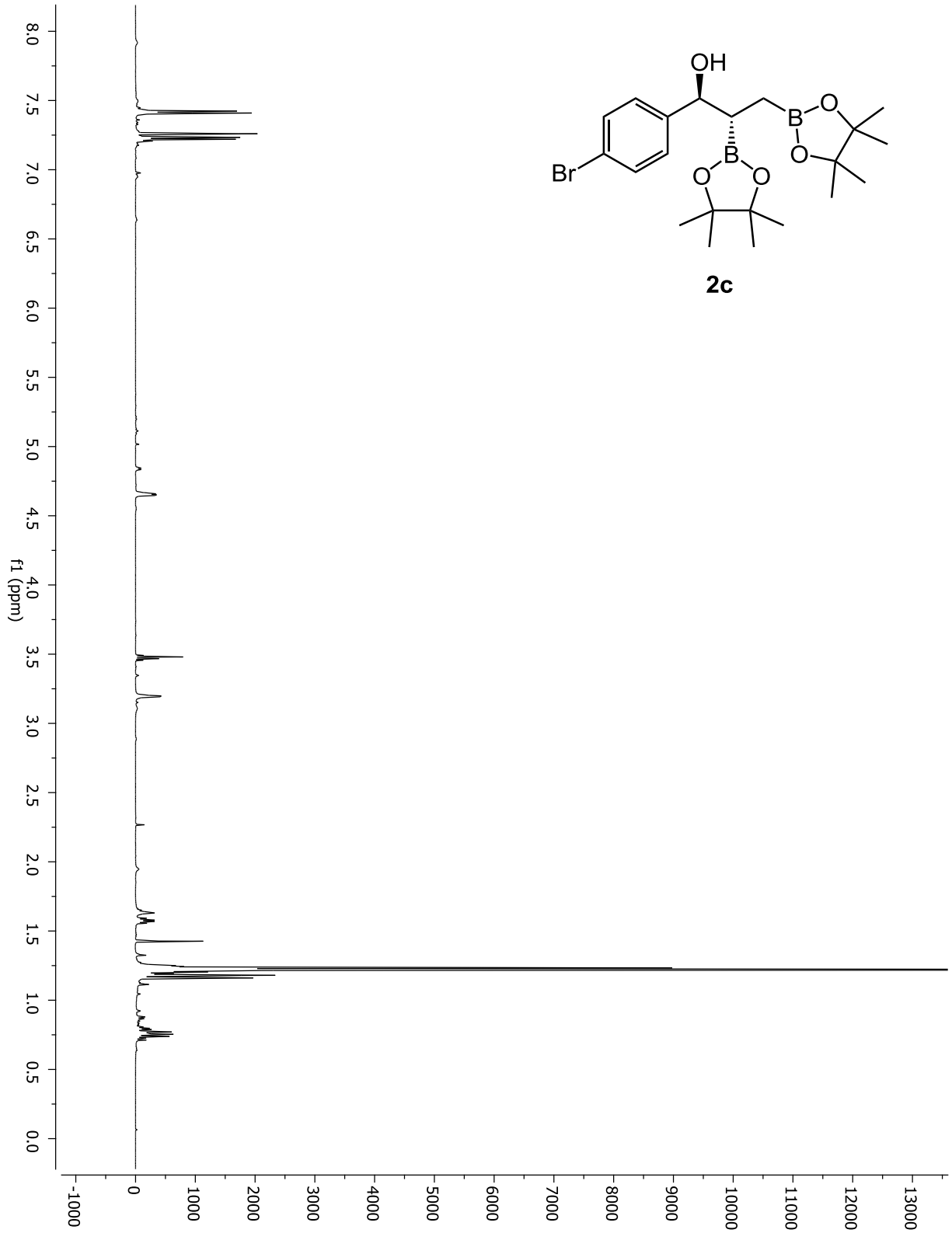

OTBS
B
O
O
B
O
O
B
O
O
10
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000

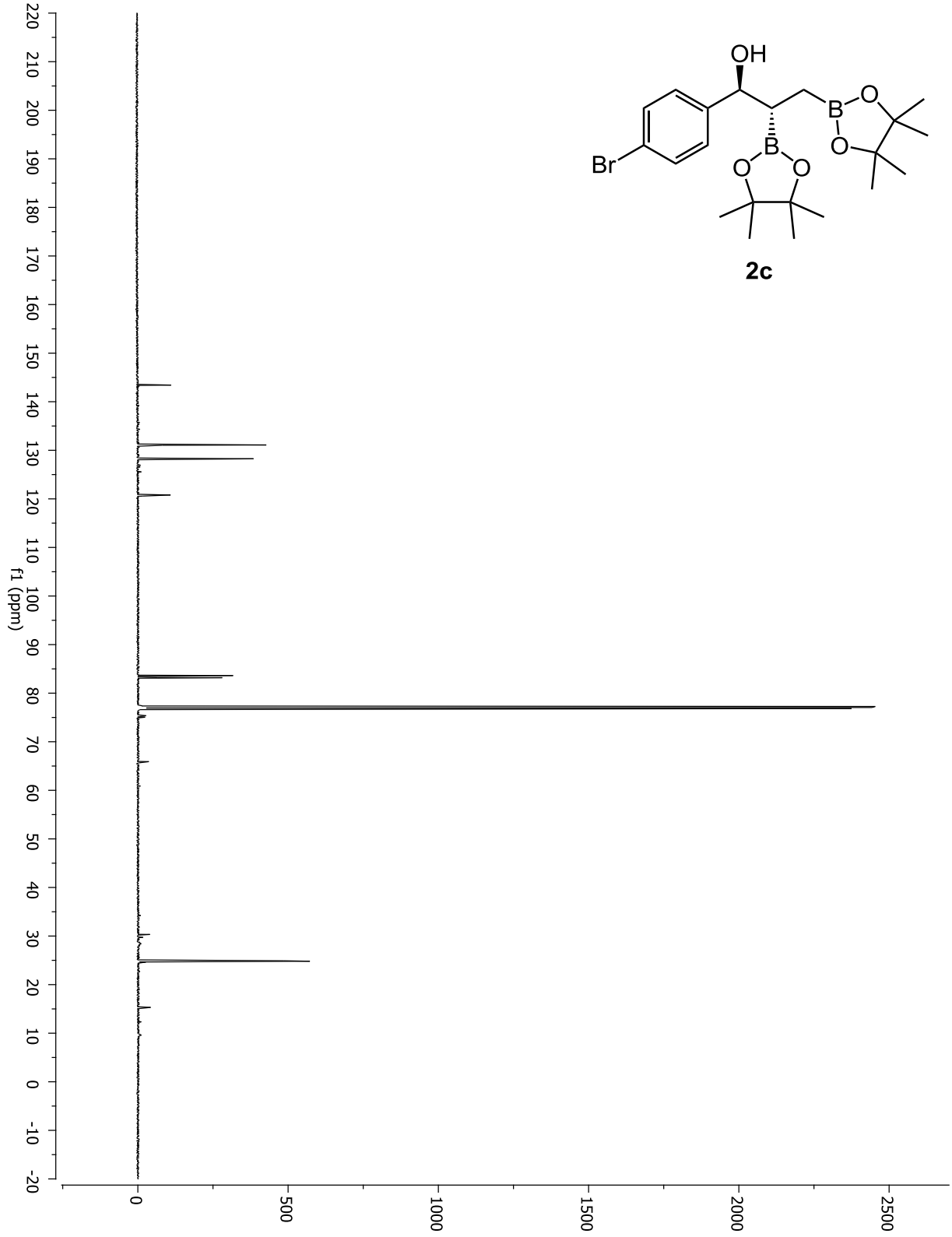

OTBS
B
O
O
B
O
O
10
f1 (ppm)

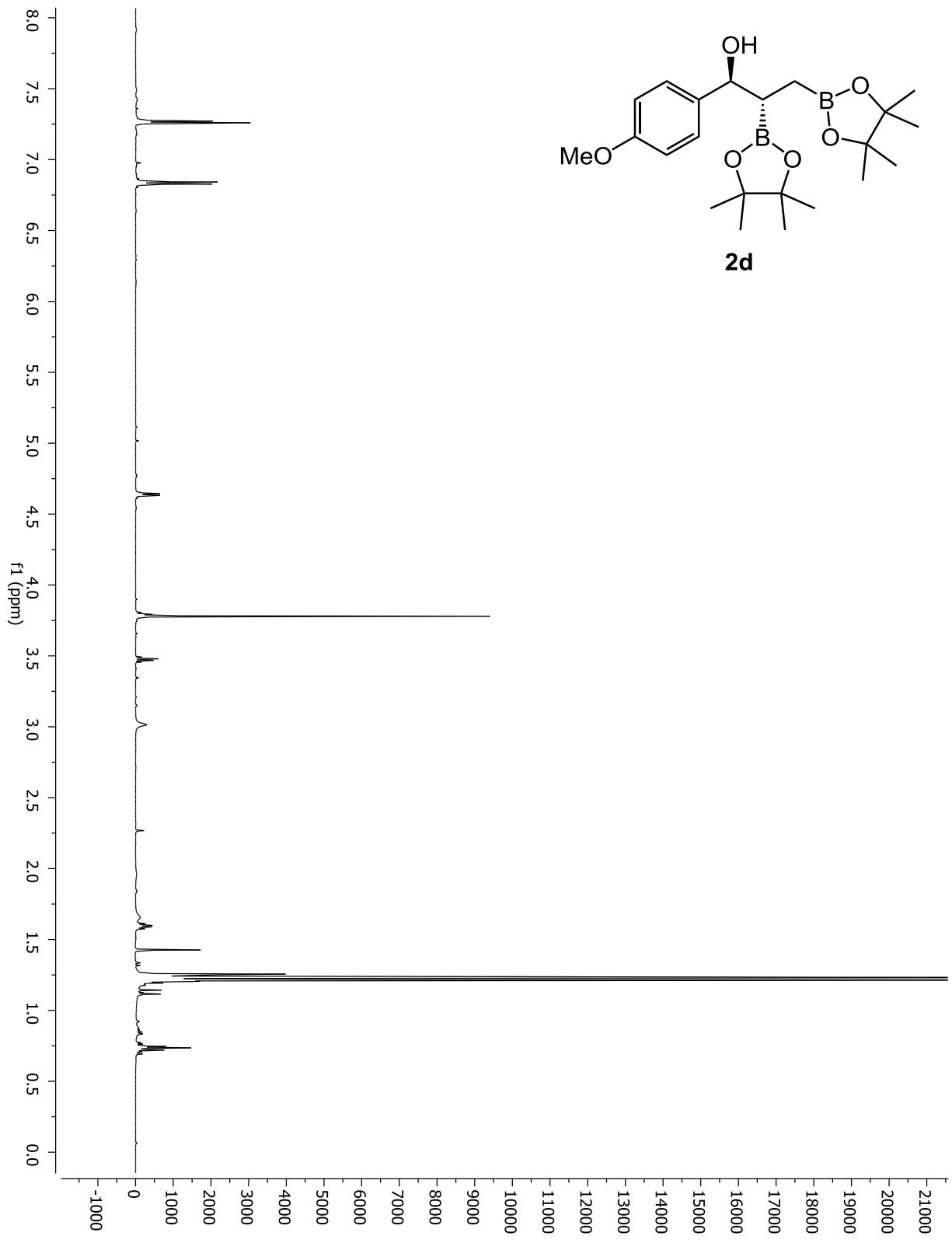

OH
F
B
O
O
B
O
O
B
O
O
2b
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000

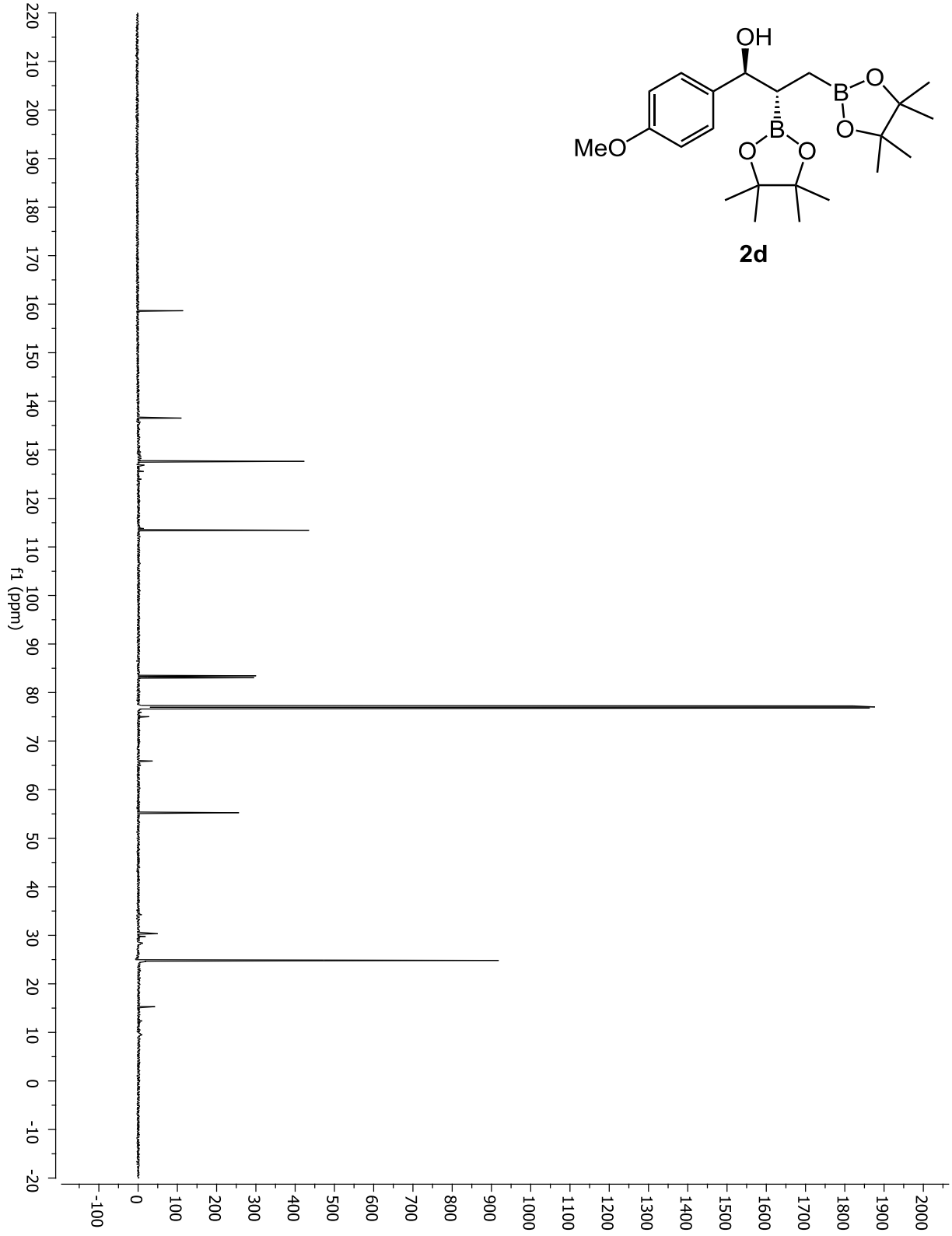

OH
F
B
O
O
B
O
O
B
O
O
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-200 -100 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100

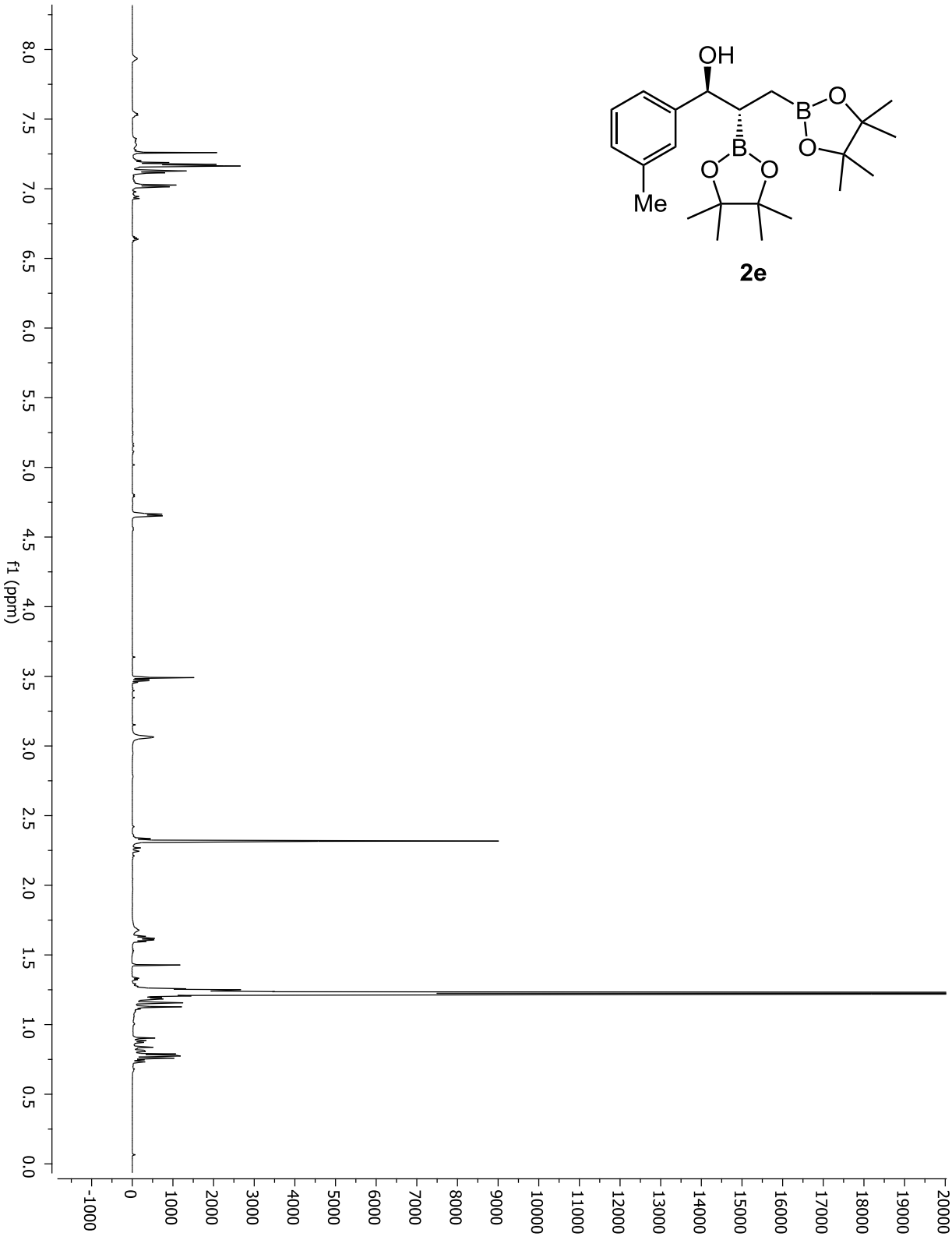
2b

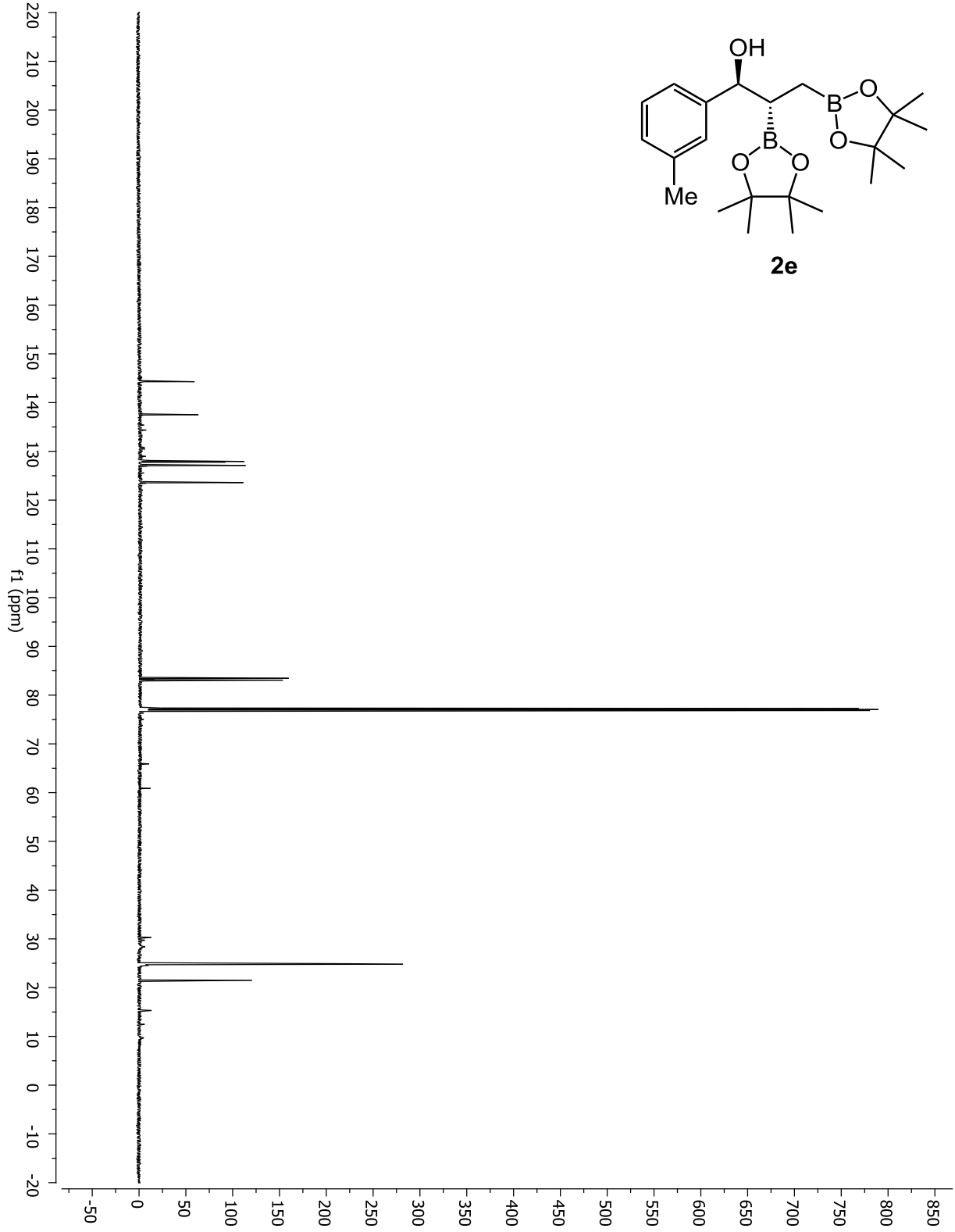

OH
Br
B
O
O
B
O
O
B
O
O
2c
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000

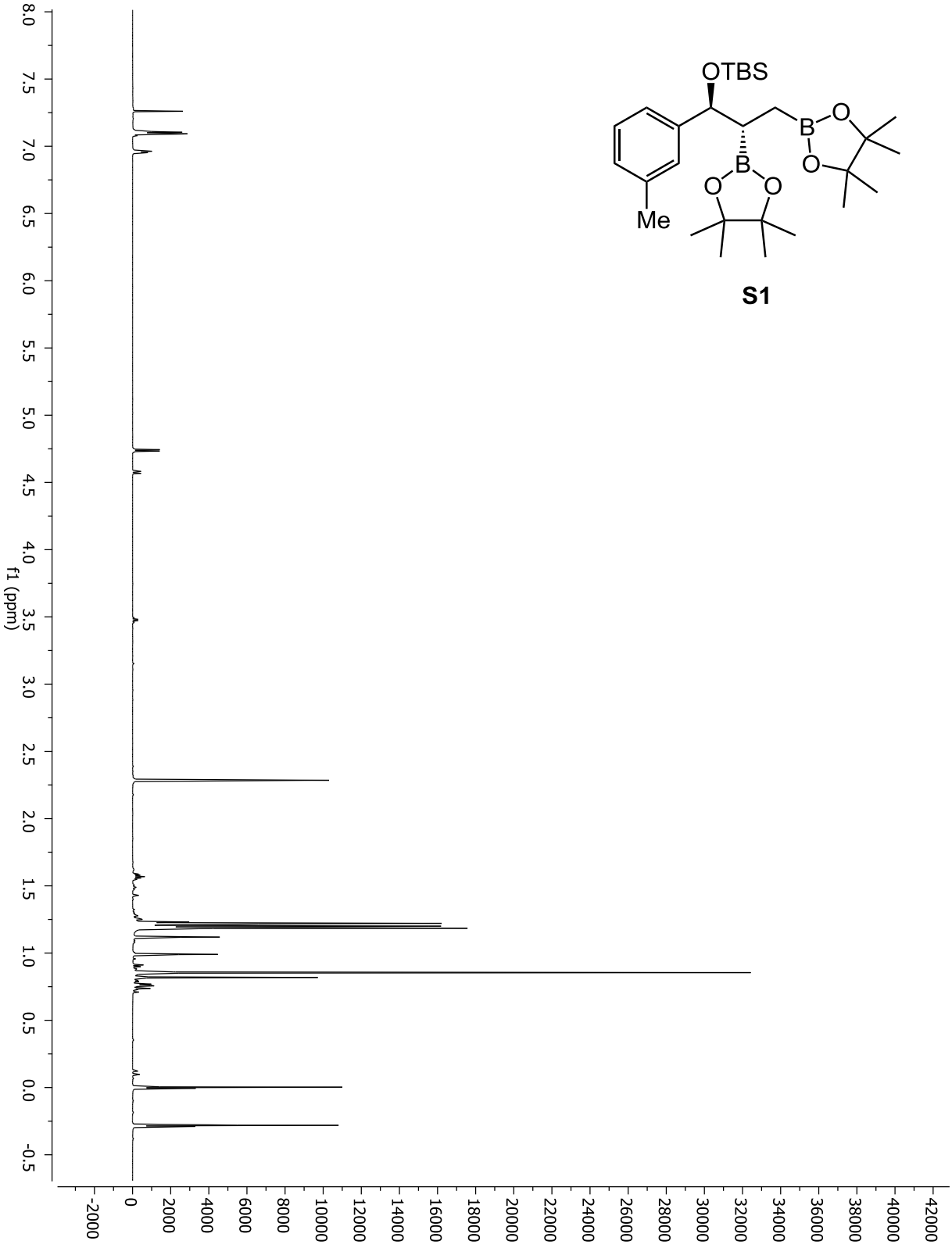

OH
Br
B
O
O
B
O
O
2c
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
0
500
1000
1500
2000
2500


OH
MeO
B
O
O
B
O
O
B
O
O
2d
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000
21000

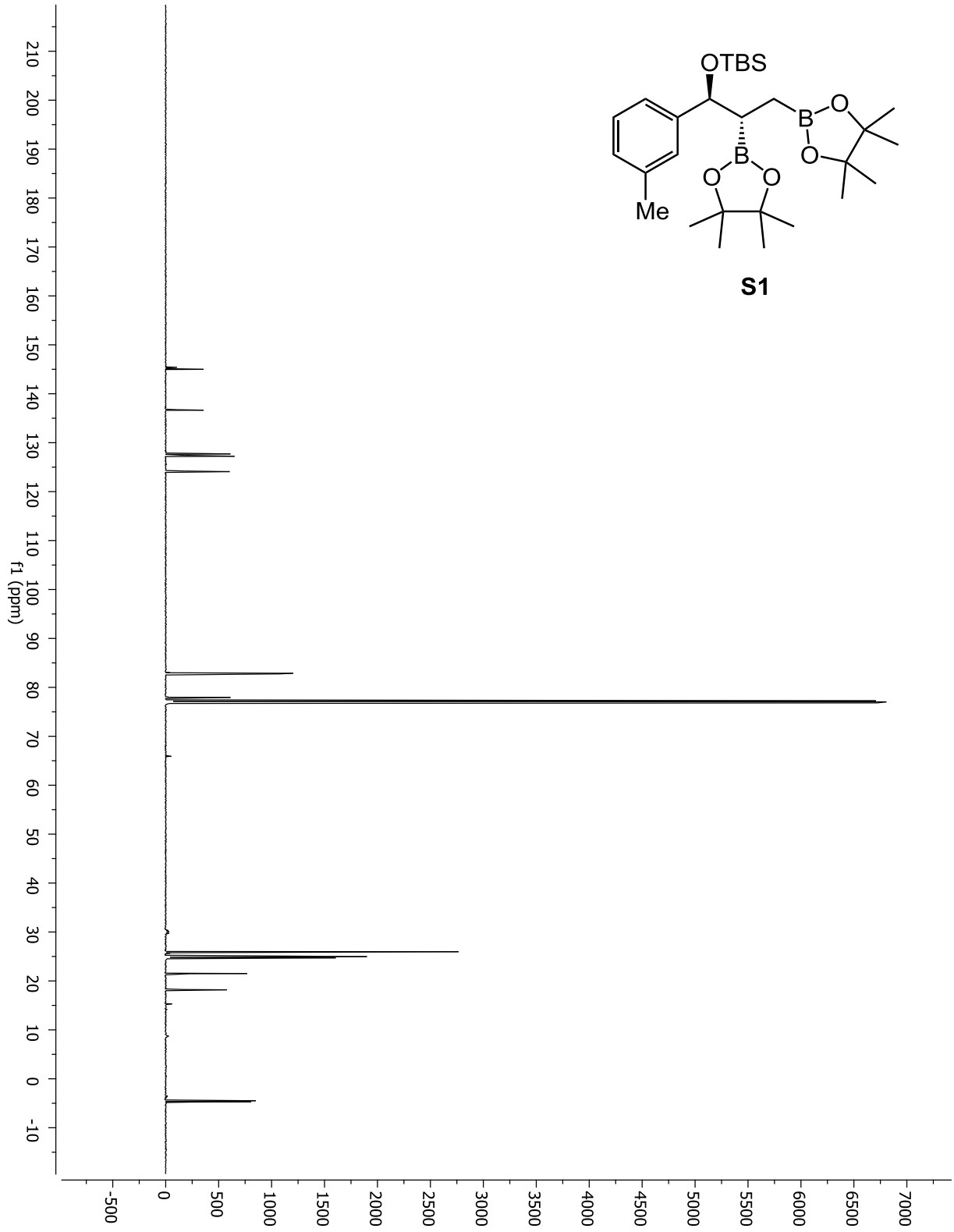

OH
MeO
B
O
O
B
O
O
B
O
O
2d
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-100 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000

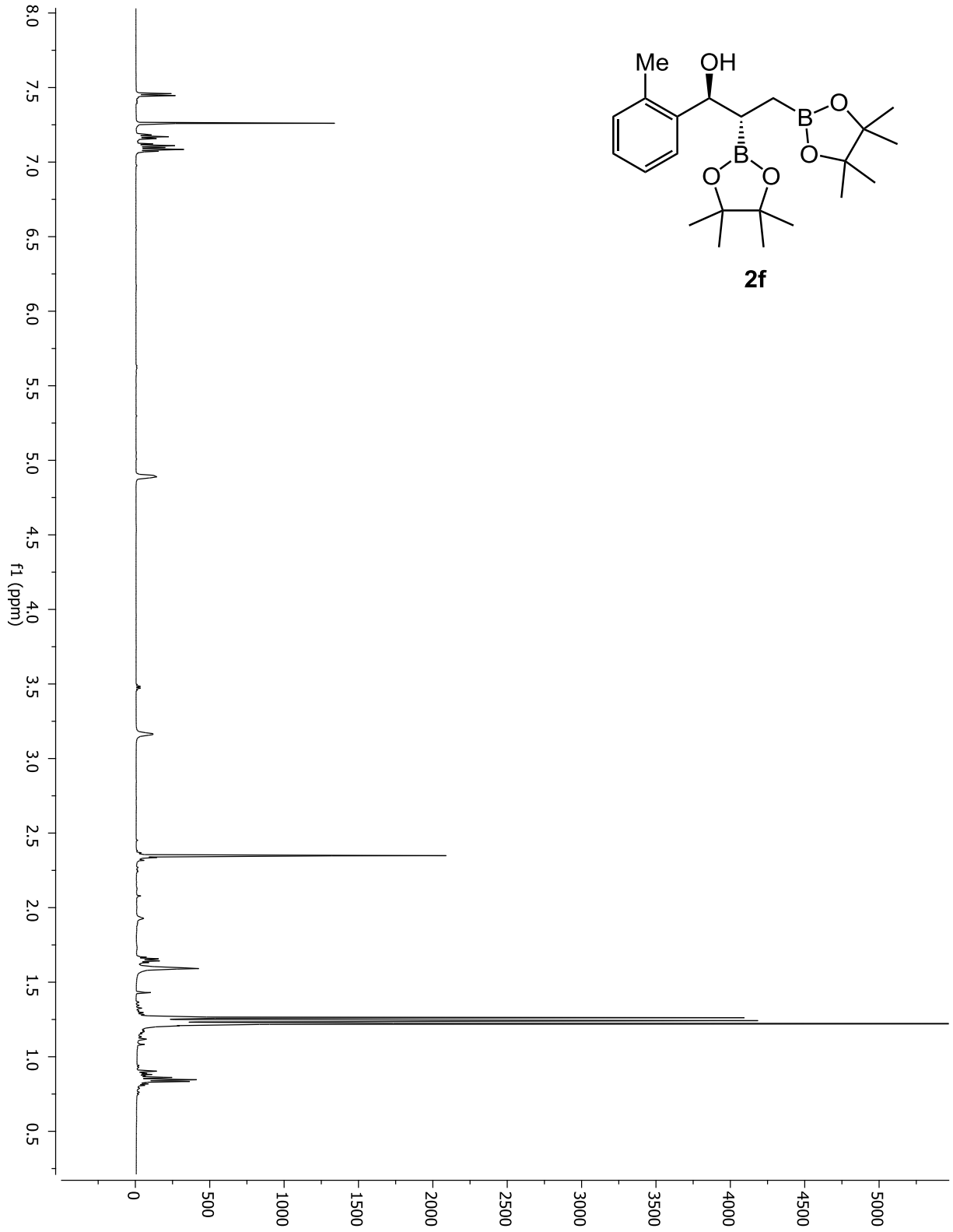

OH
B
O
O
B
O
O
Me
2e
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000

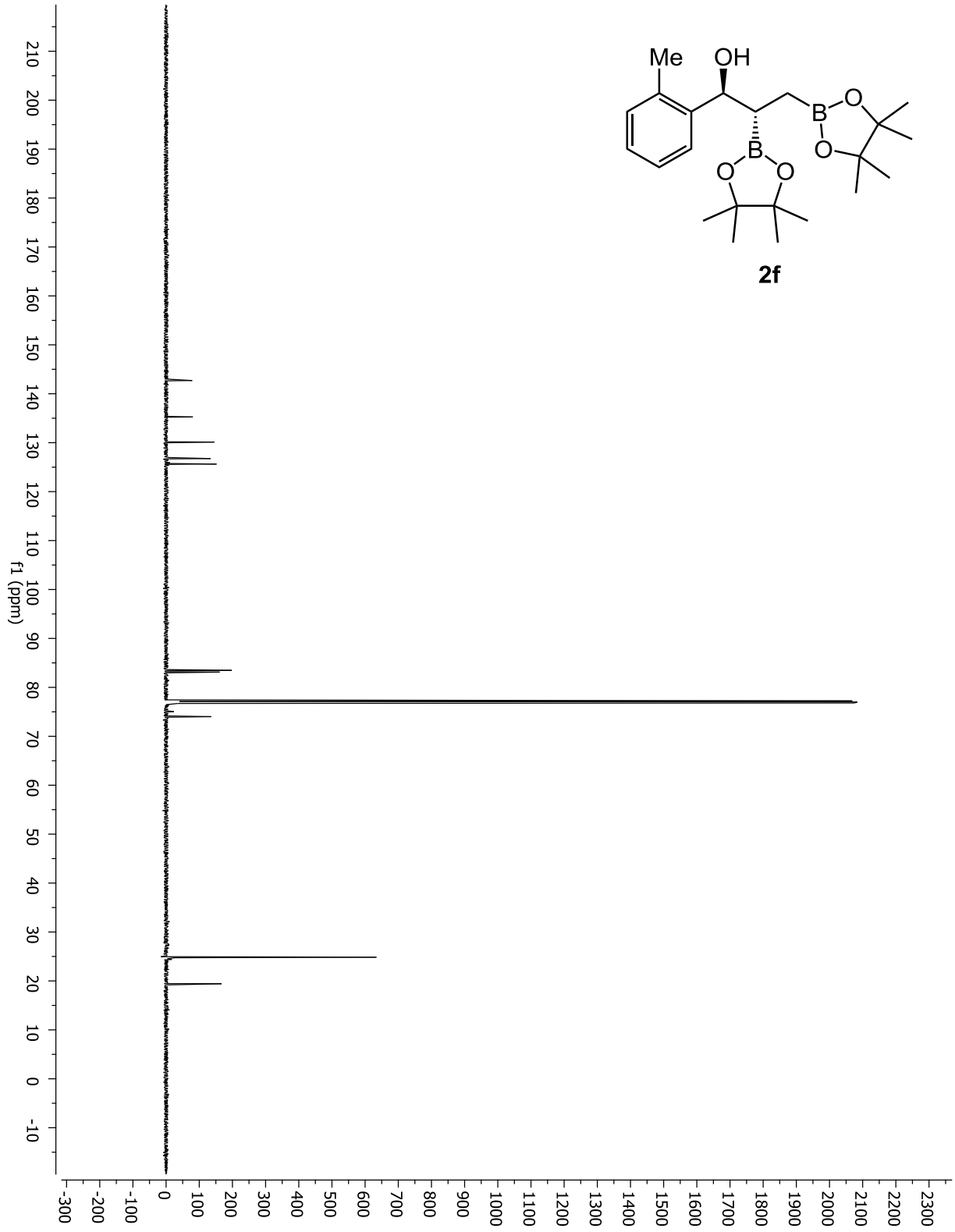

OH
B
O
O
B
O
O
Me
2e
f1 (ppm)

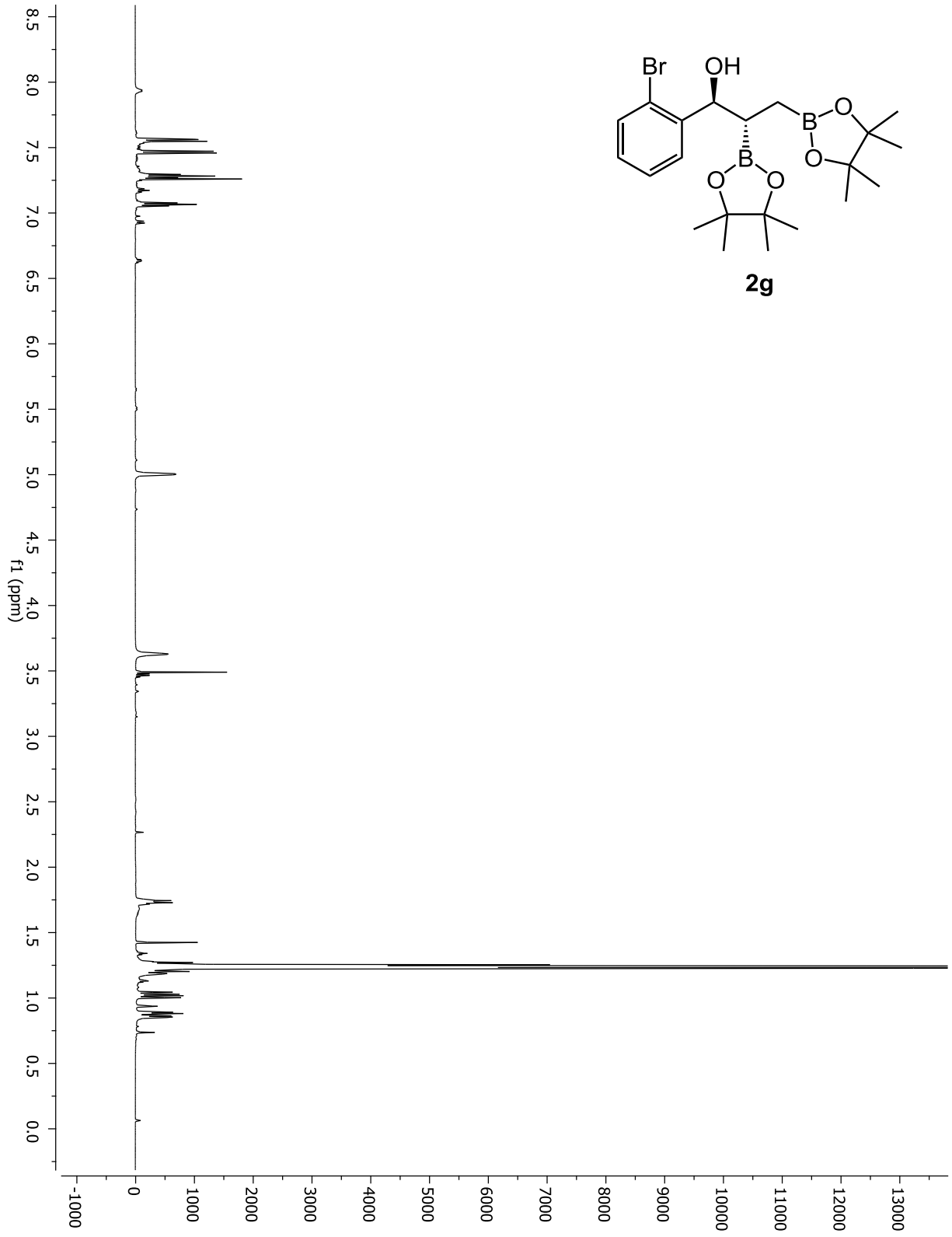

OTBS
B
O
O
B
O
O
Me
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000
36000
38000
40000
42000

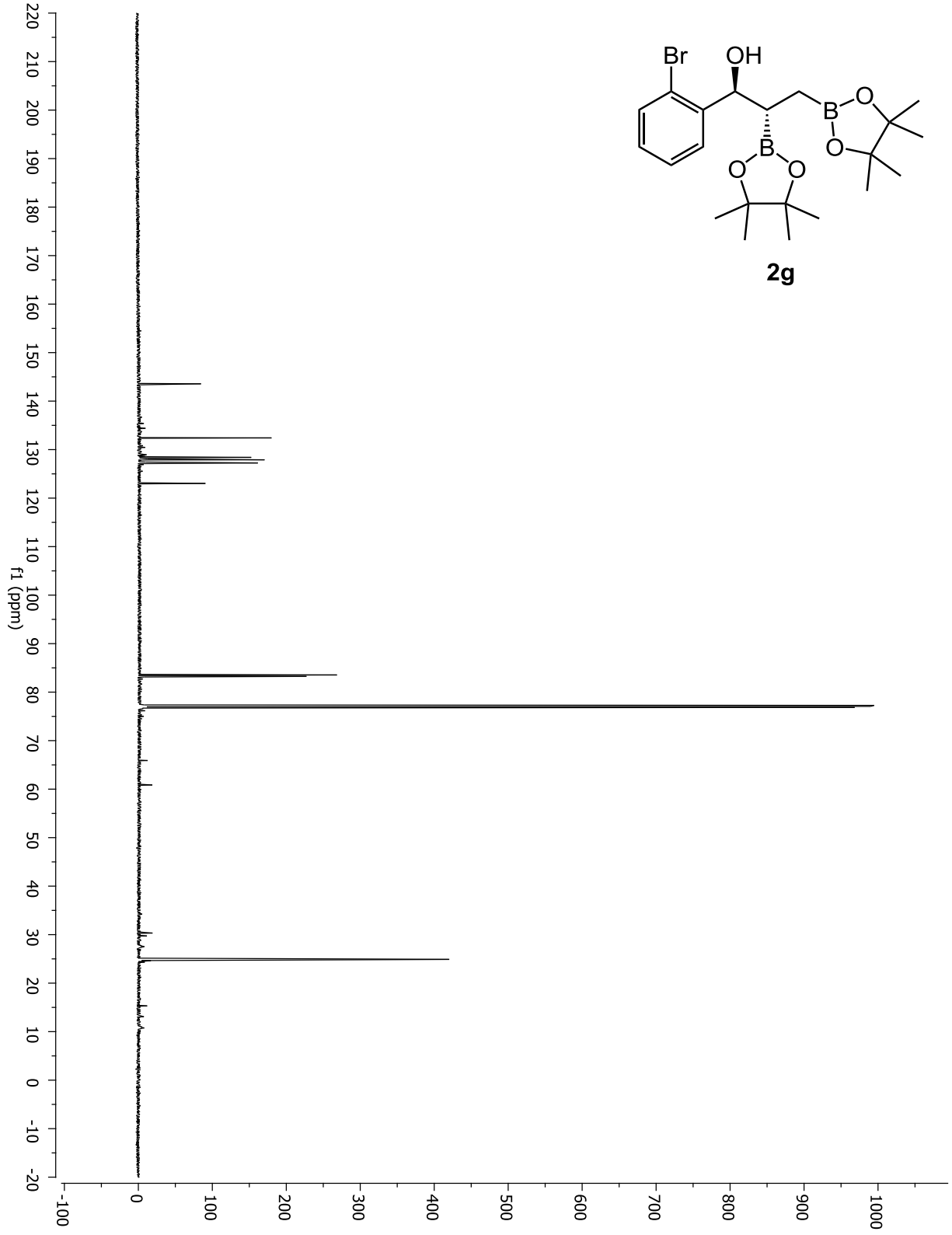
S1

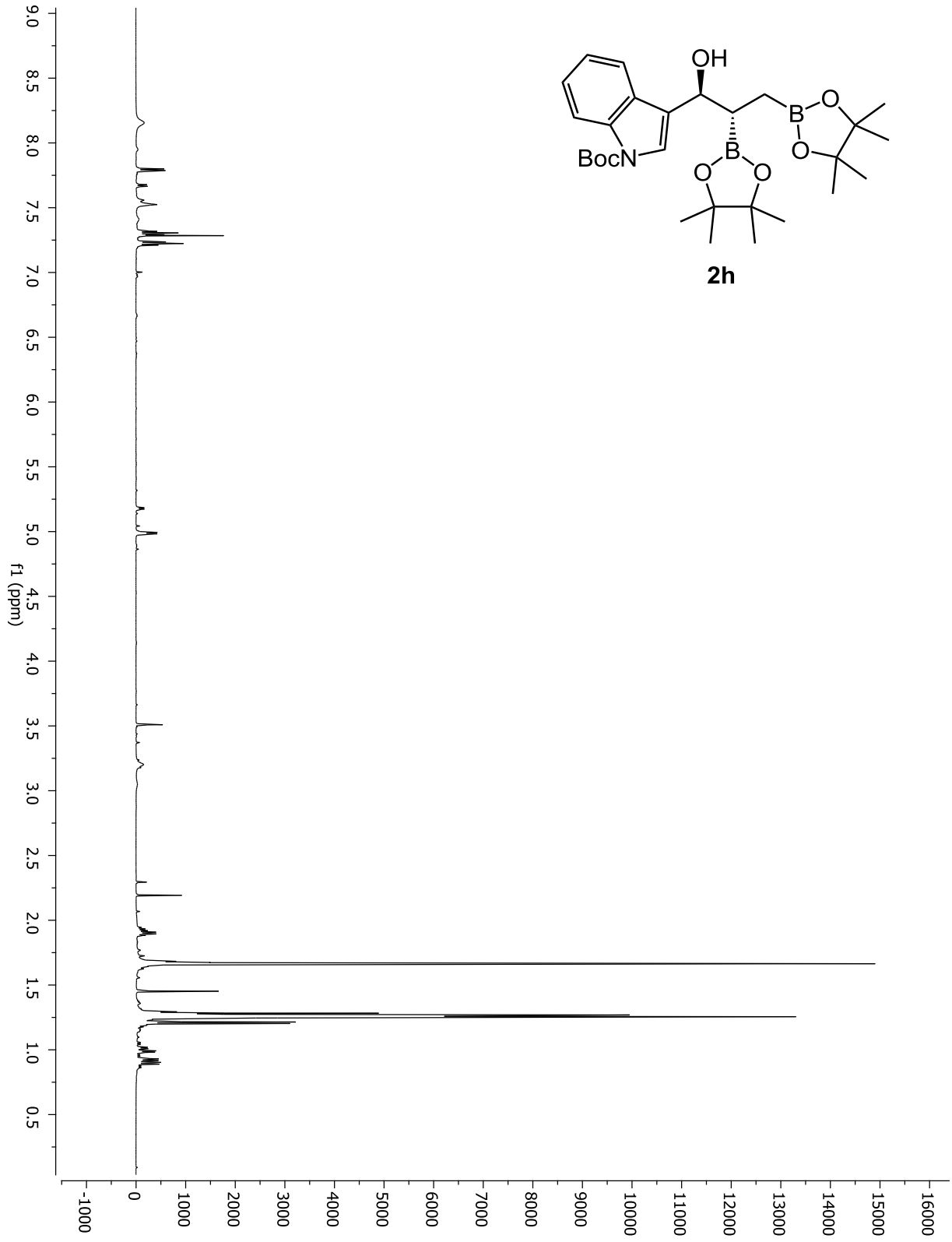

OTBS
B
O
O
B
O
O
Me
S1
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10
-500 0 500 1000 1500 2000 2500 3000 3500 4000 4500 5000 5500 6000 6500 7000

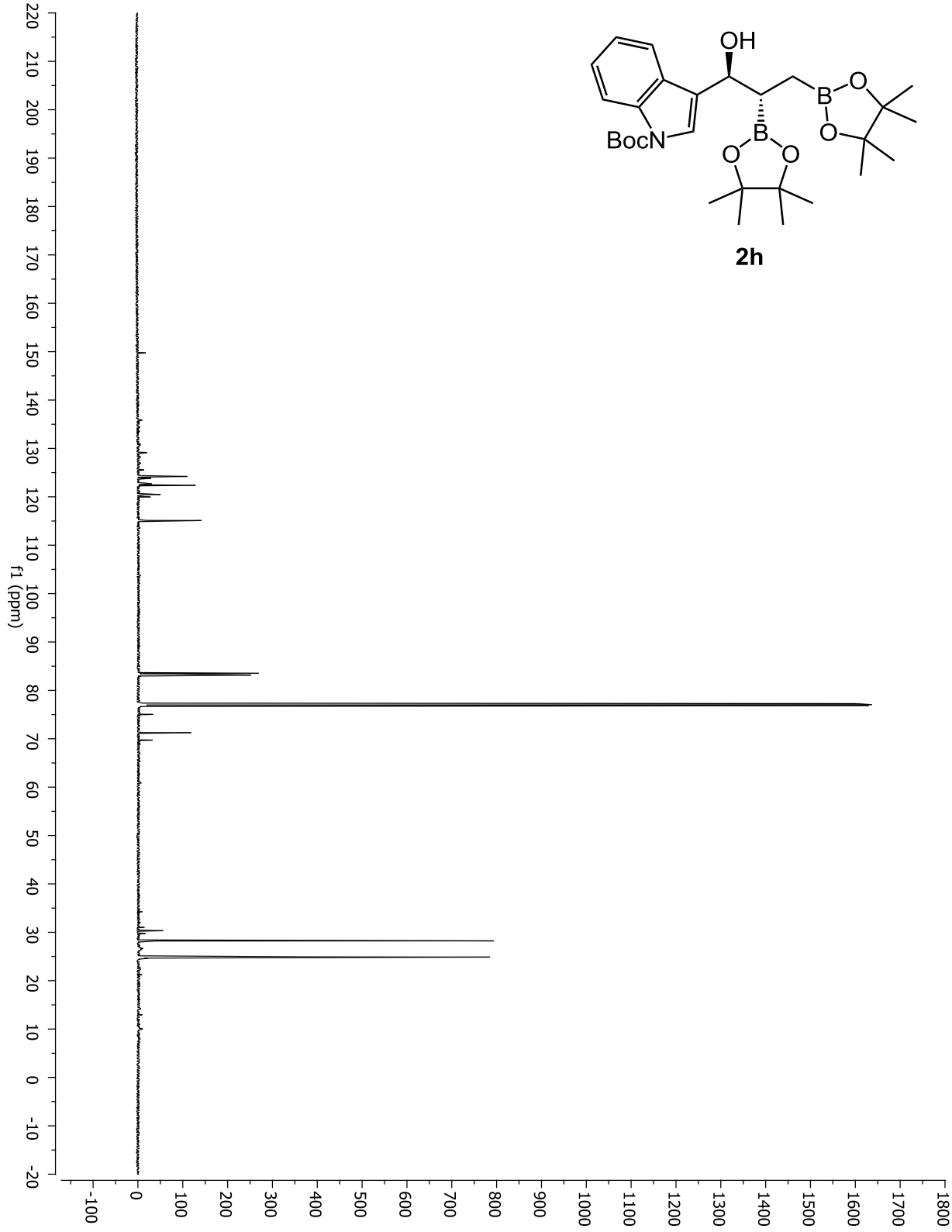

Me
OH
B
O
O
B
O
O
2f
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

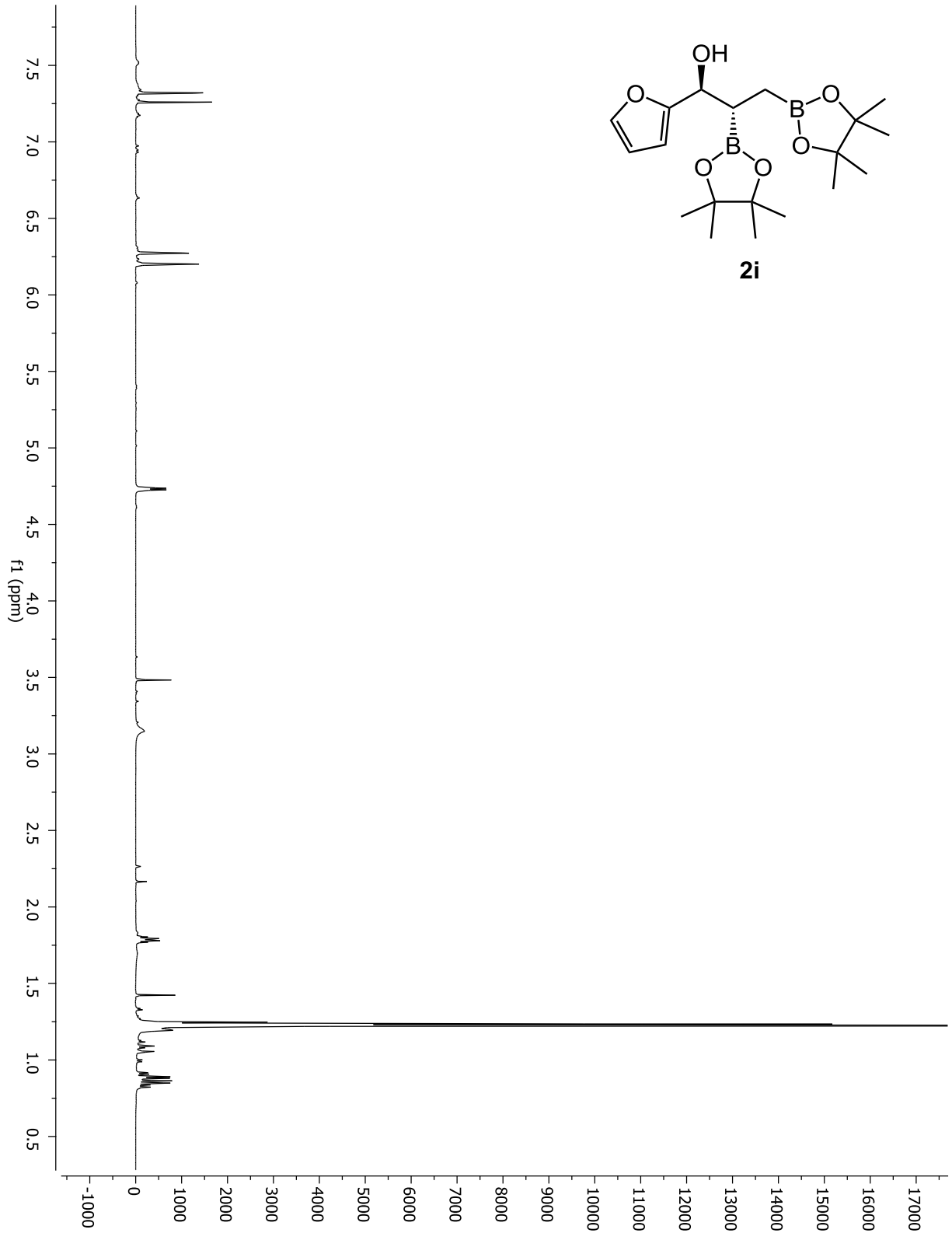

Me
OH
B
O
O
B
O
O
2f
f1 (ppm)

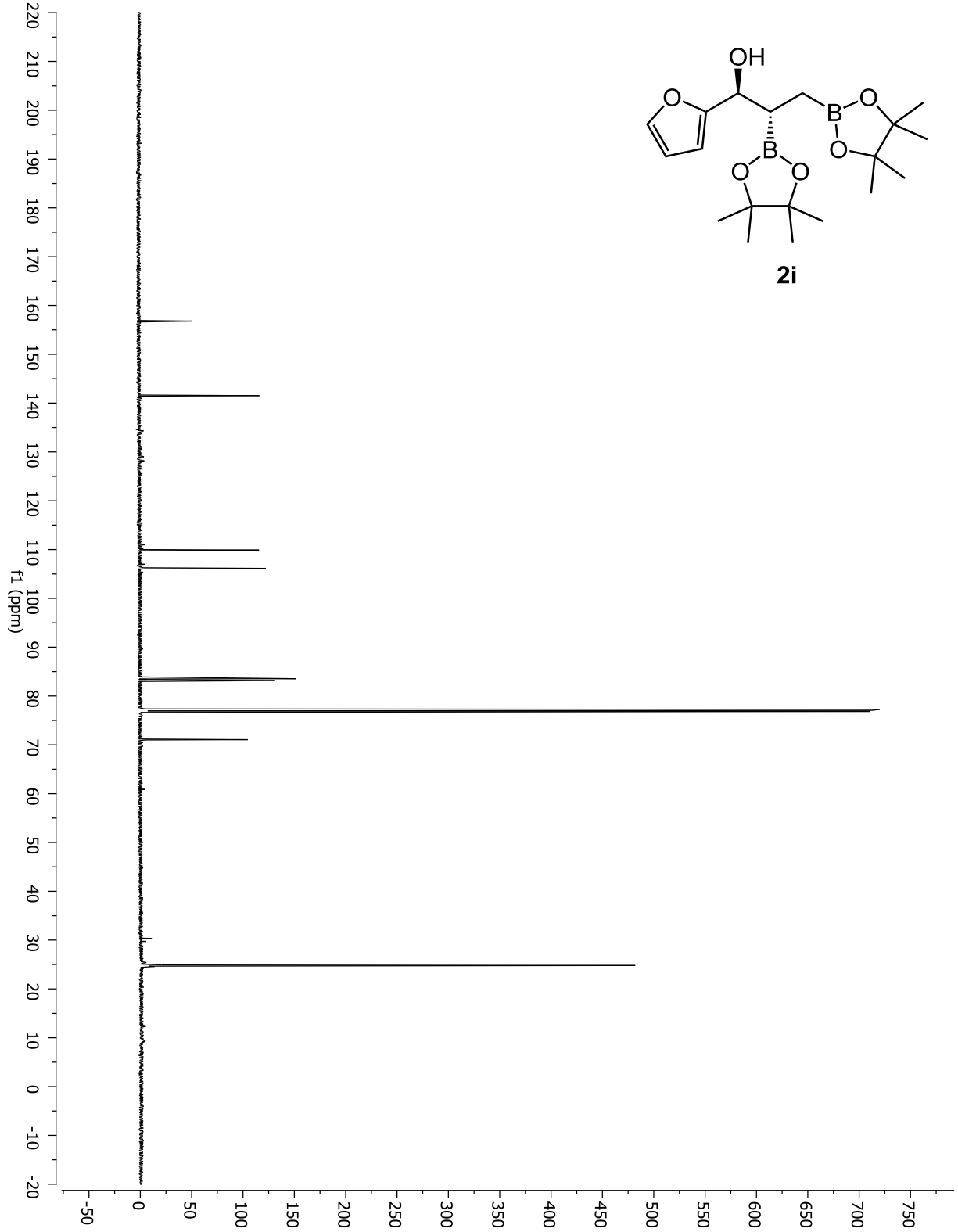

Br
OH
B
O
O
B
O
O
2g
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000


Br
OH
B
O
O
B
O
O
B
O
O
2g
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-100
0
100
200
300
400
500
600
700
800
900
1000

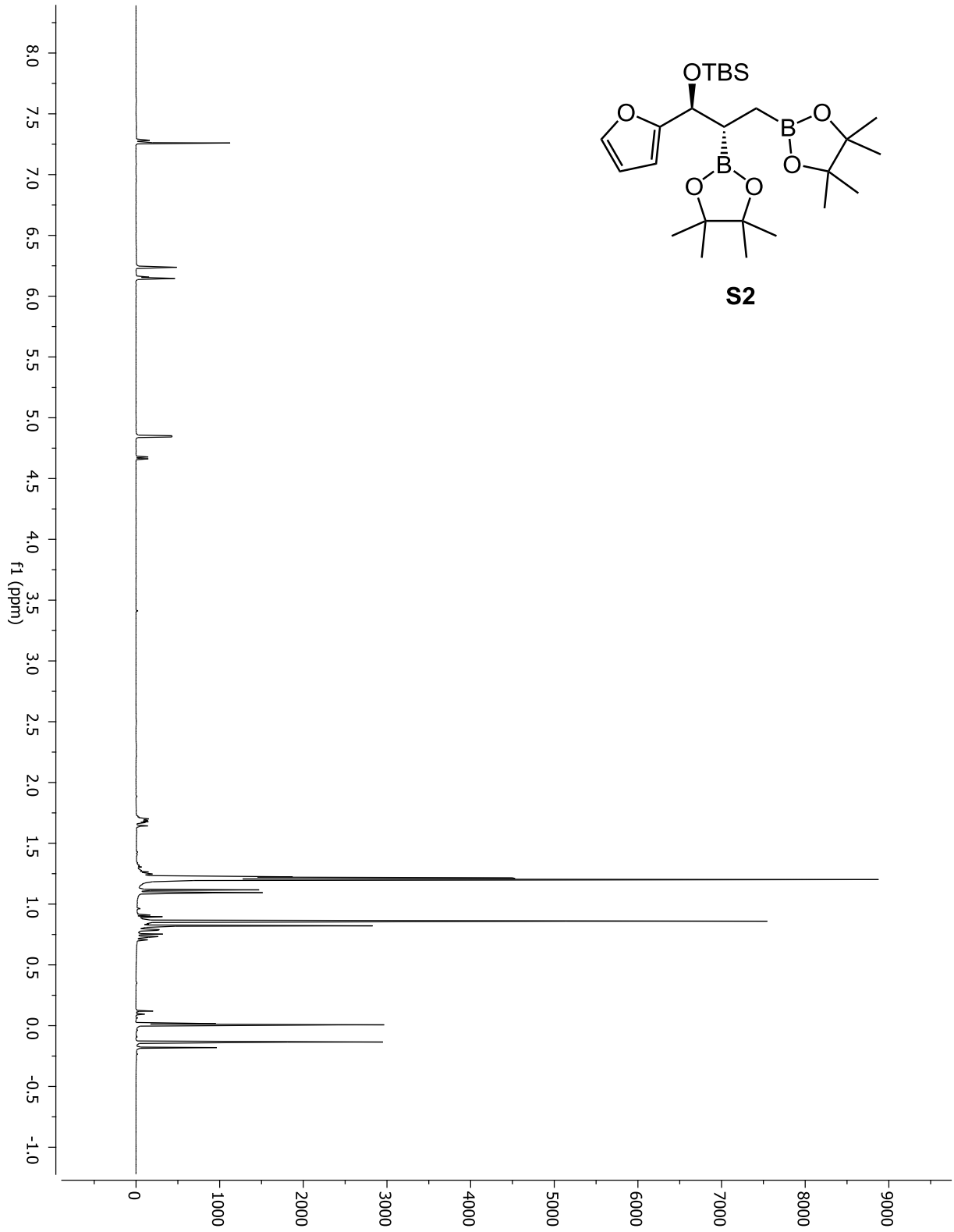

OH
BocN
B
O
O
B
O
O
B
O
O
2h
f1 (ppm)
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000

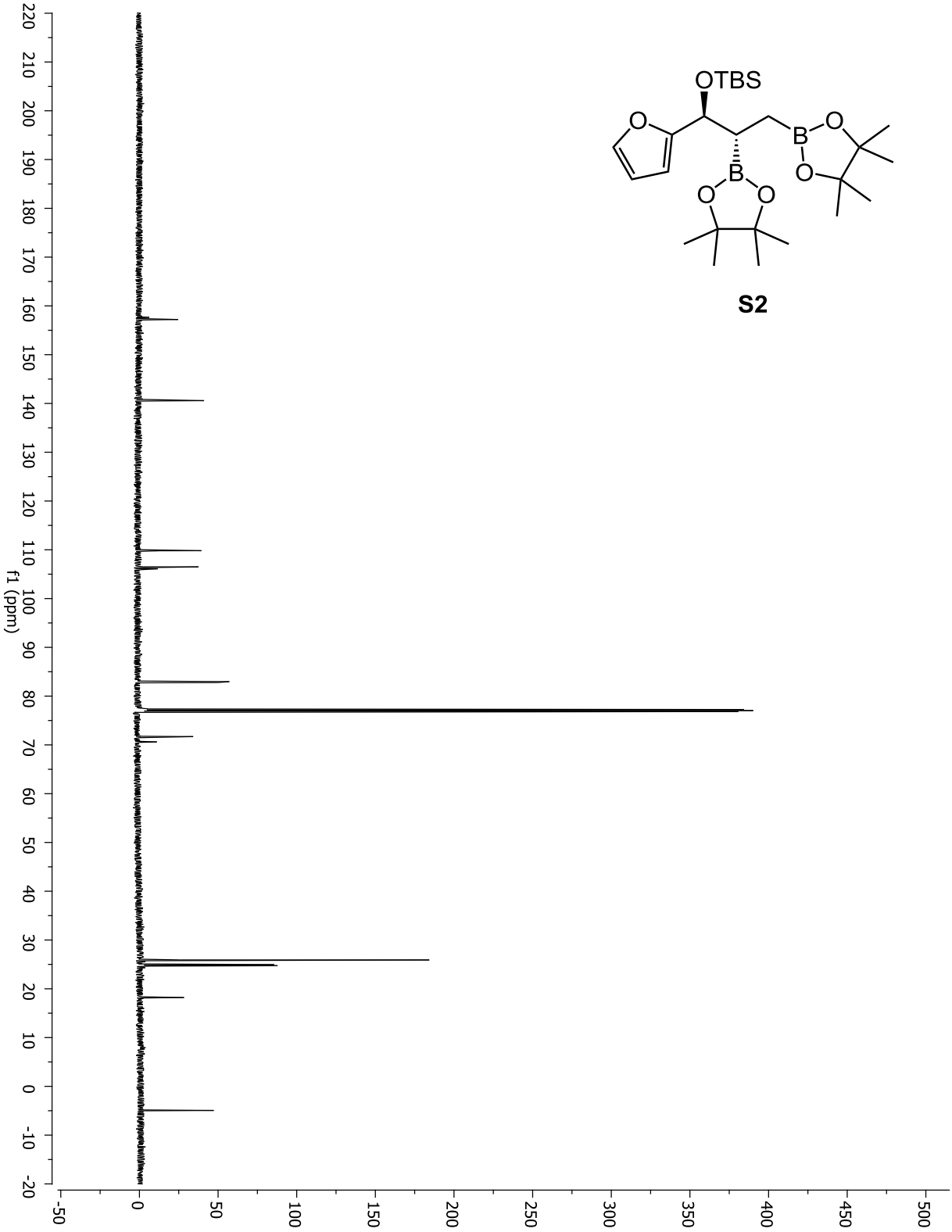

OH
BocN
B
O
O
B
O
O
2h
f1 (ppm)

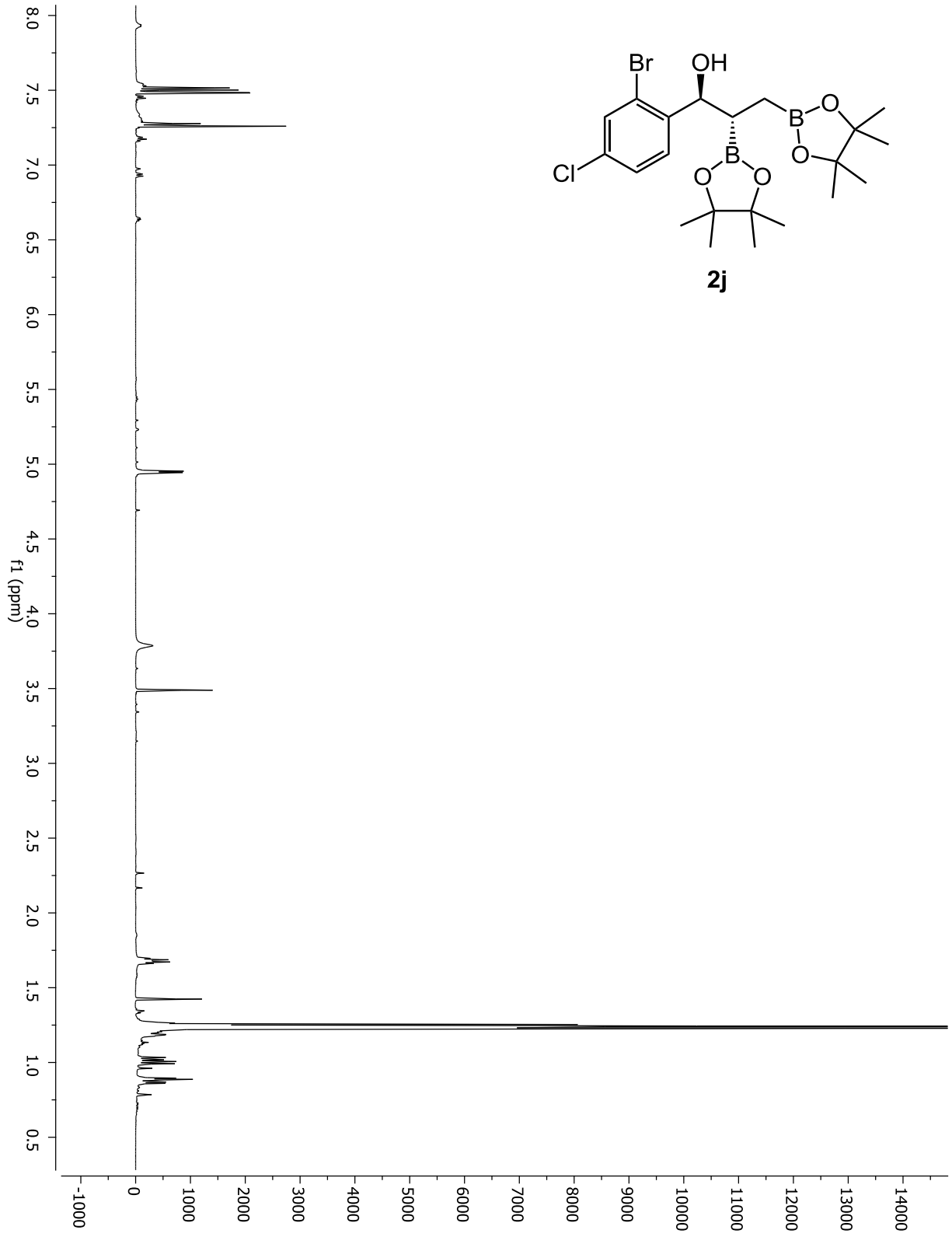

OH
O
B
O
O
B
O
O
2i
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000

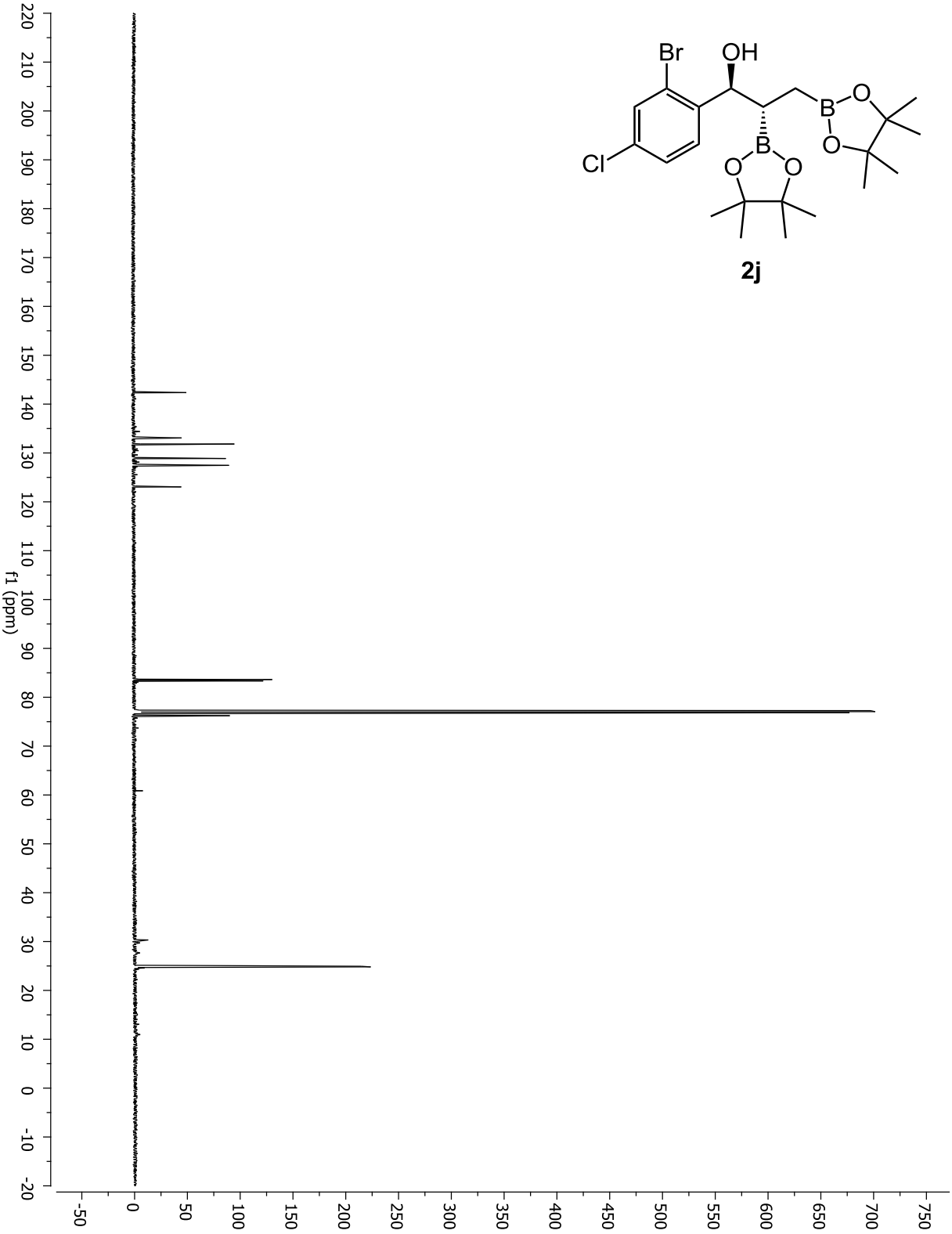

OH
O
B
O
O
B
O
O
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750

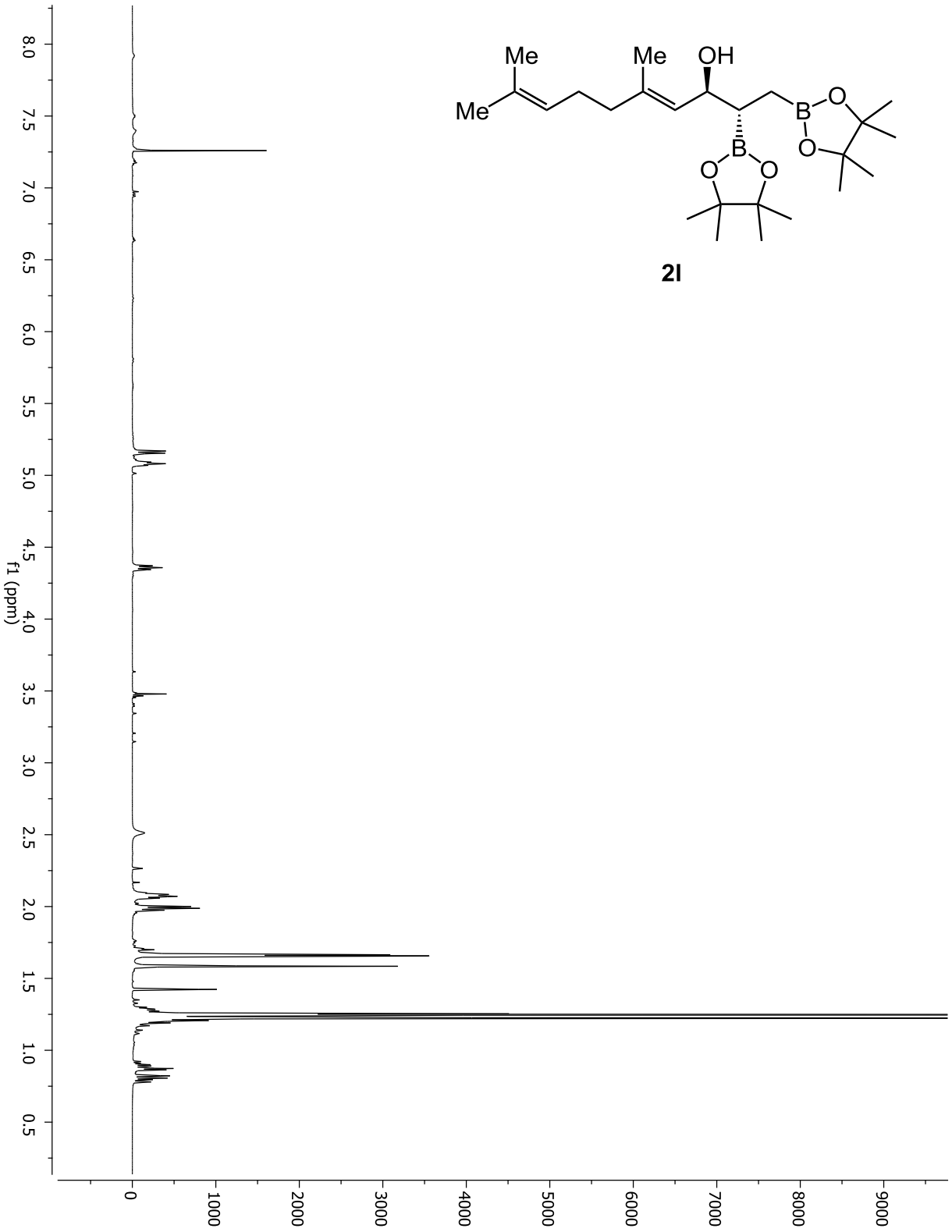
2i

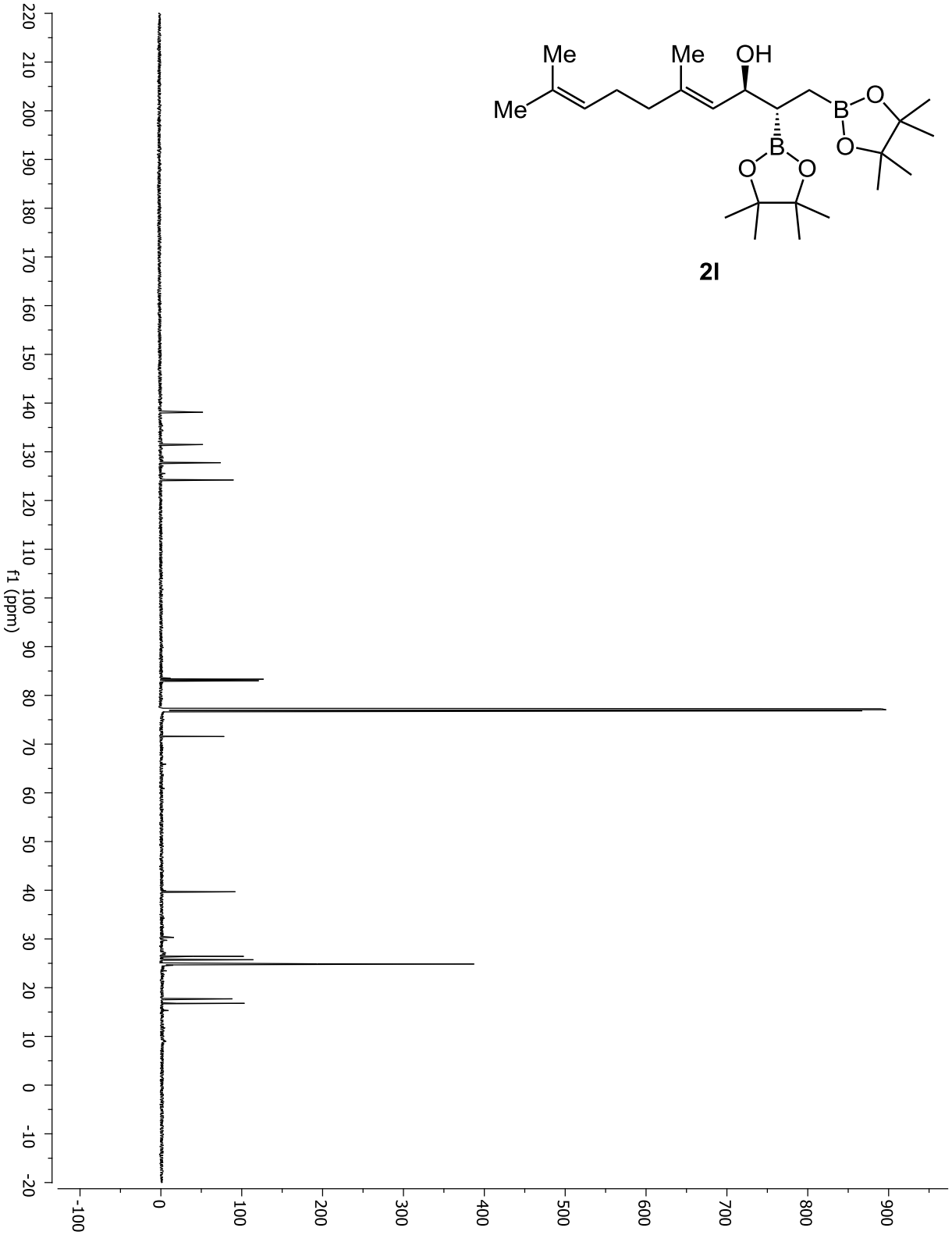

OTBS
O
B
O
O
B
O
O
B
O
O
S2
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
f1 (ppm)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

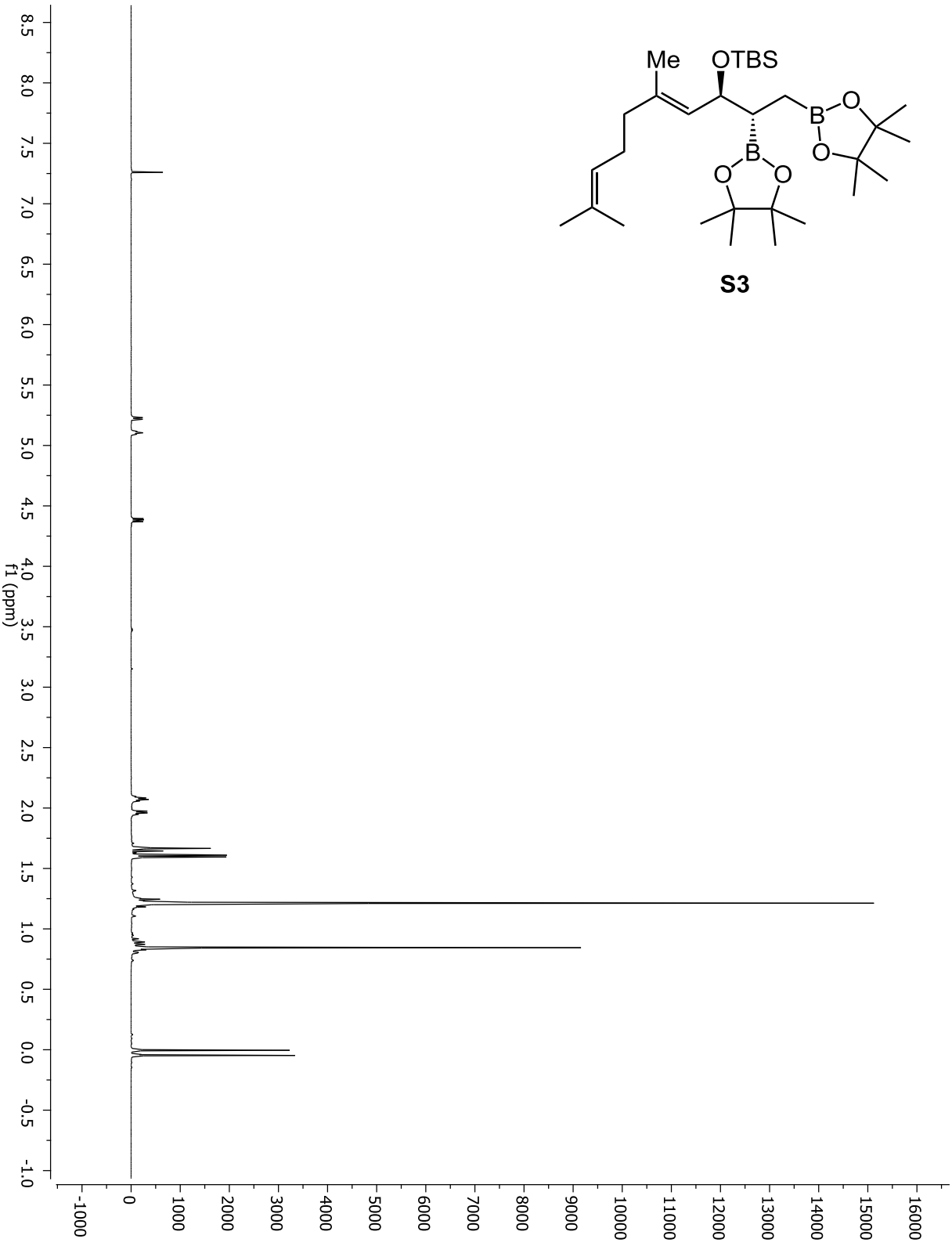

OTBS
O
B
O
O
B
O
O
S2
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-50 0 50 100 150 200 250 300 350 400 450 500


Br
OH
Cl
B
O
O
B
O
O
B
O
O
2j
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000

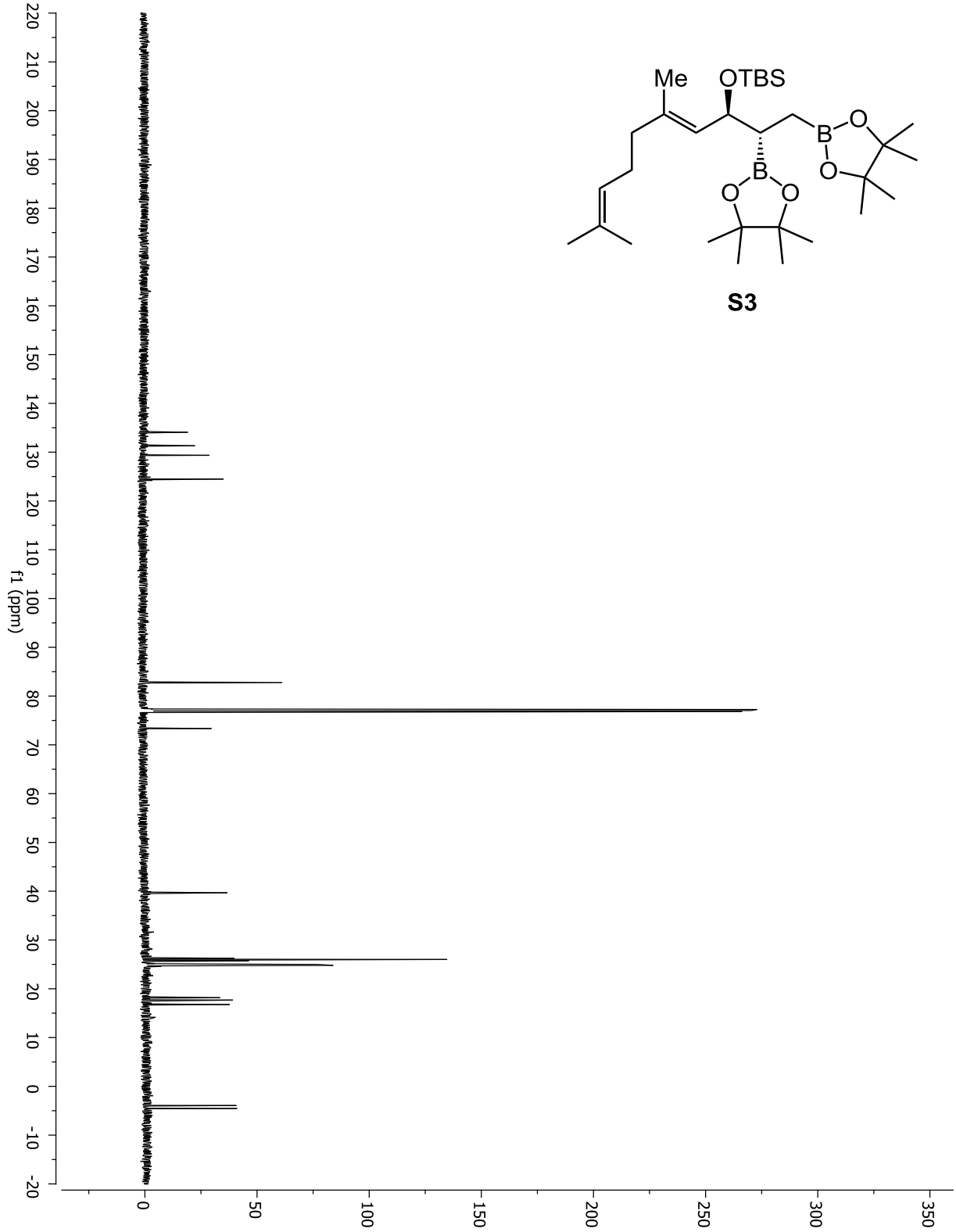

Br
OH
Cl
B
O
O
B
O
O
B
O
O
2j
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-50 0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750

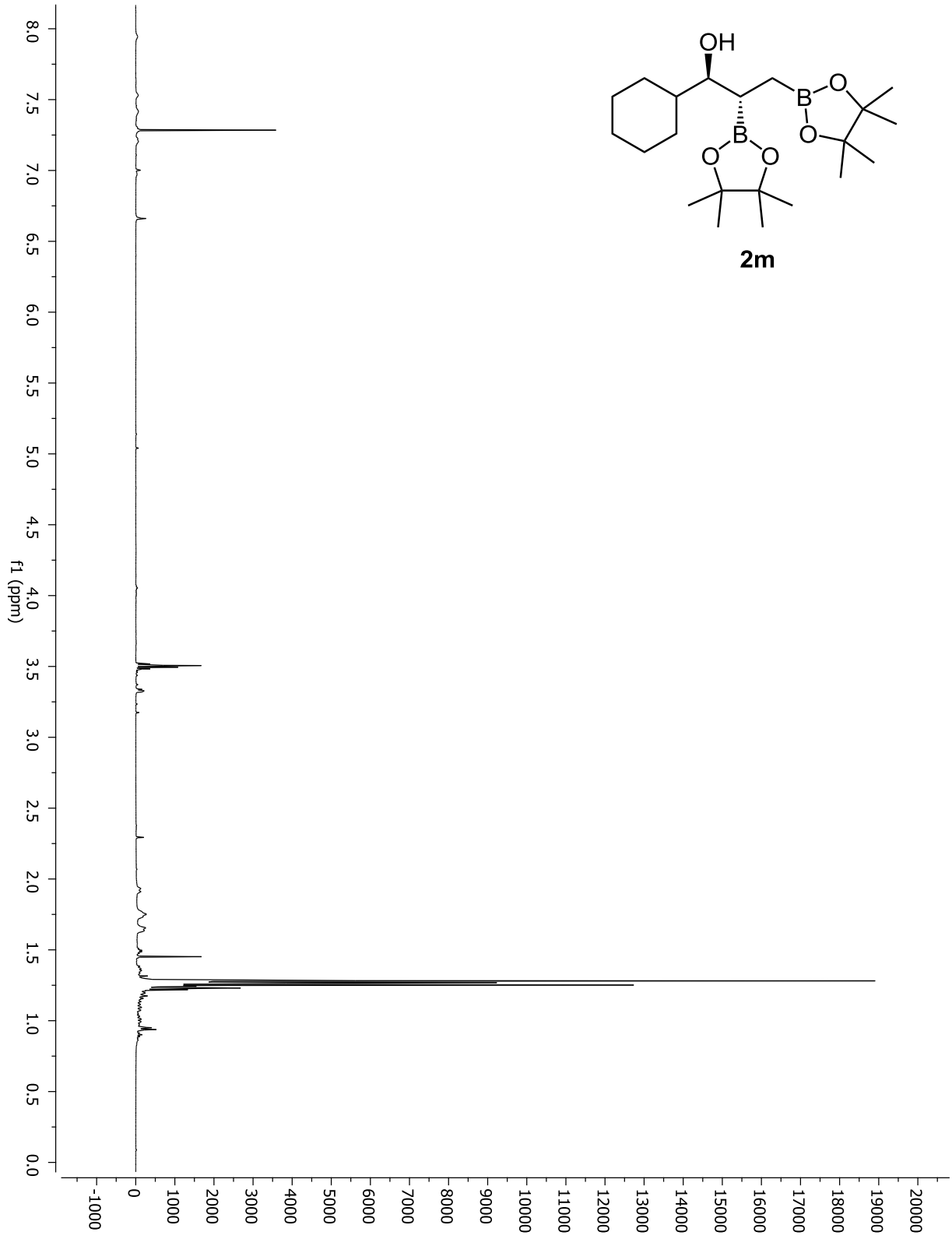

Me
Me
OH
Me
B
O
O
B
O
O
2l
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
1000
2000
3000
4000
5000
6000
7000
8000
9000

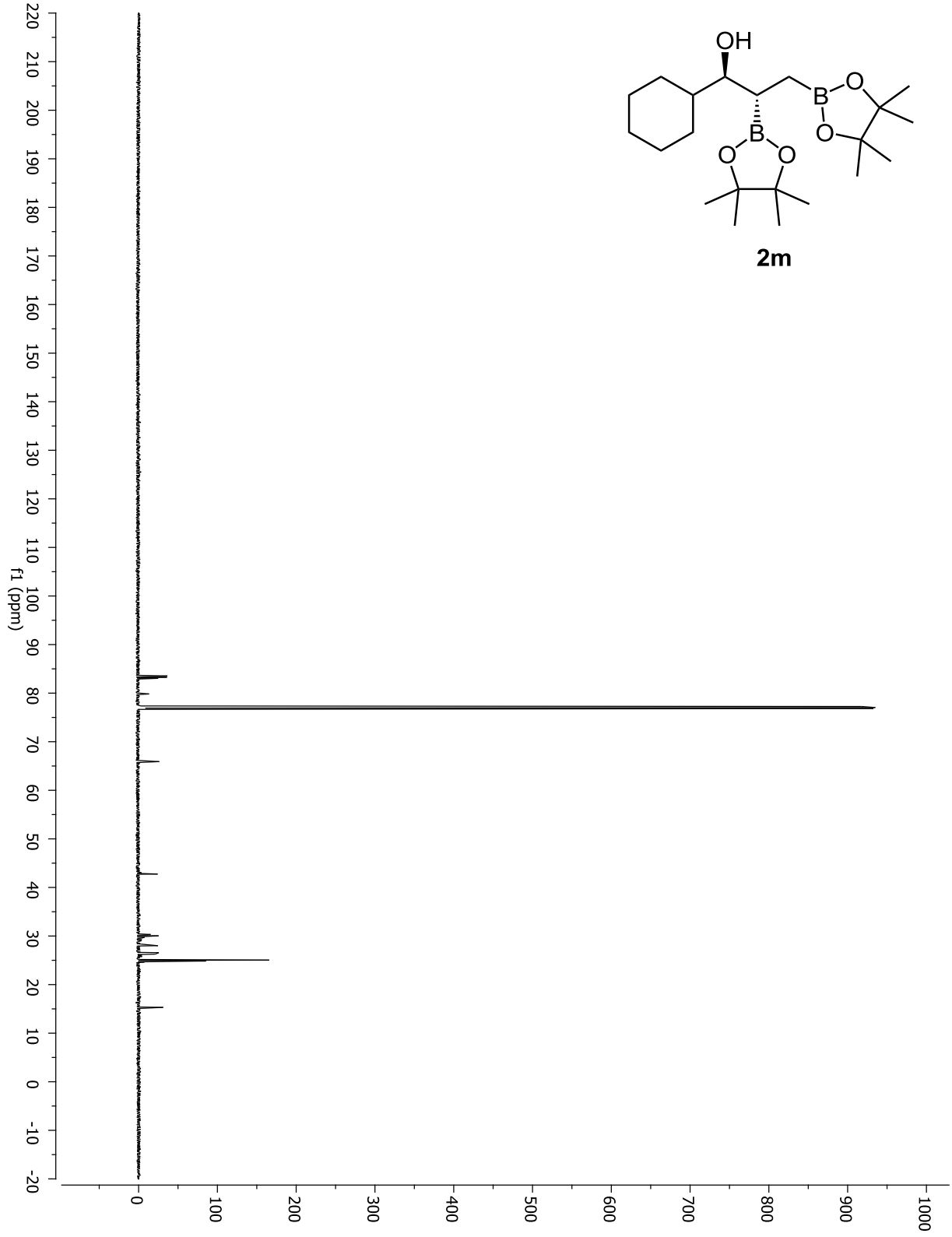

Me
Me
OH
Me
B
O
O
B
O
O
2l
f1 (ppm)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-100
0
100
200
300
400
500
600
700
800
900

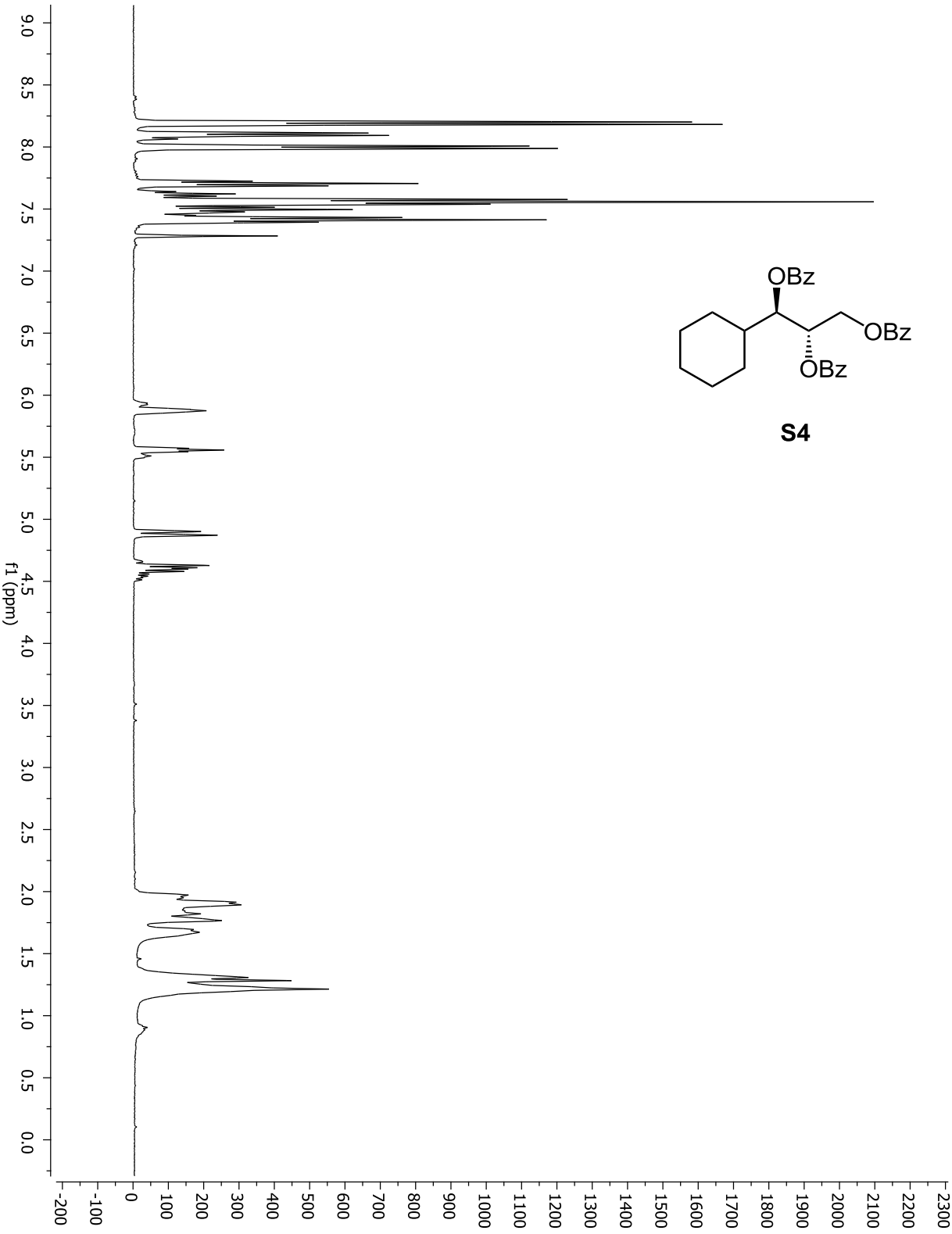

Me
OTBS
B
O
O
B
O
O
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000

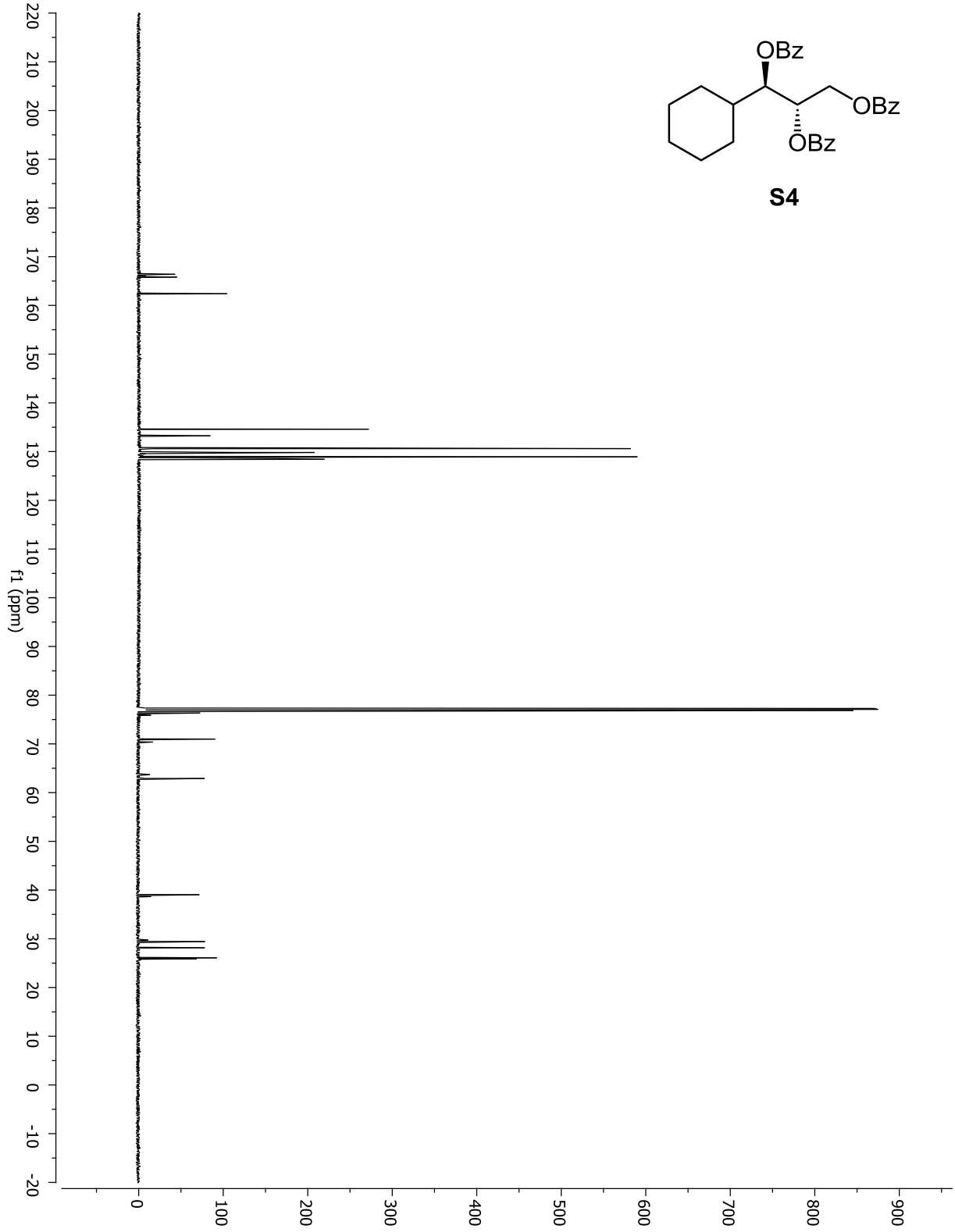
S3

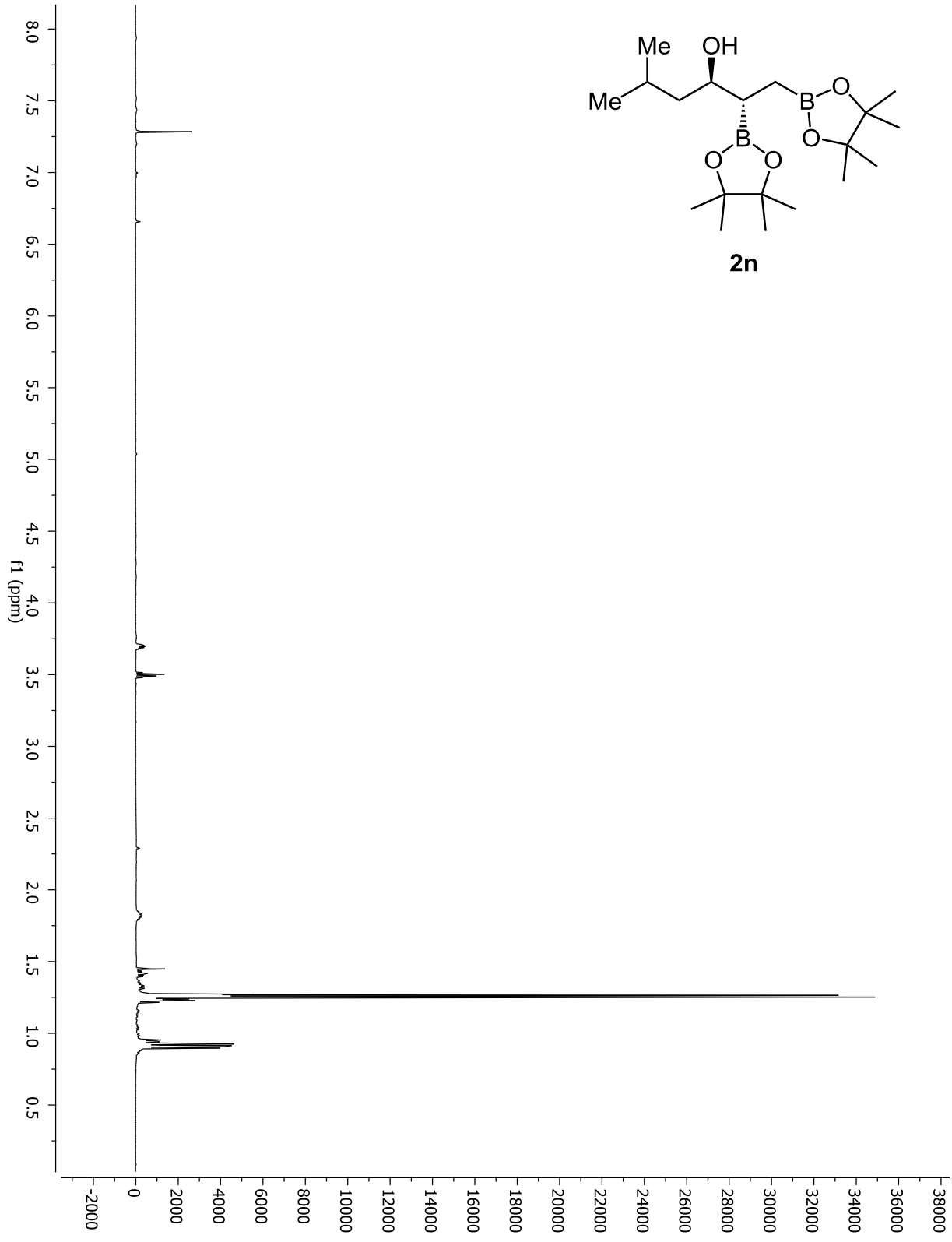

Me
OTBS
B
O
O
B
O
O
B
O
O
S3
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
0 50 100 150 200 250 300 350

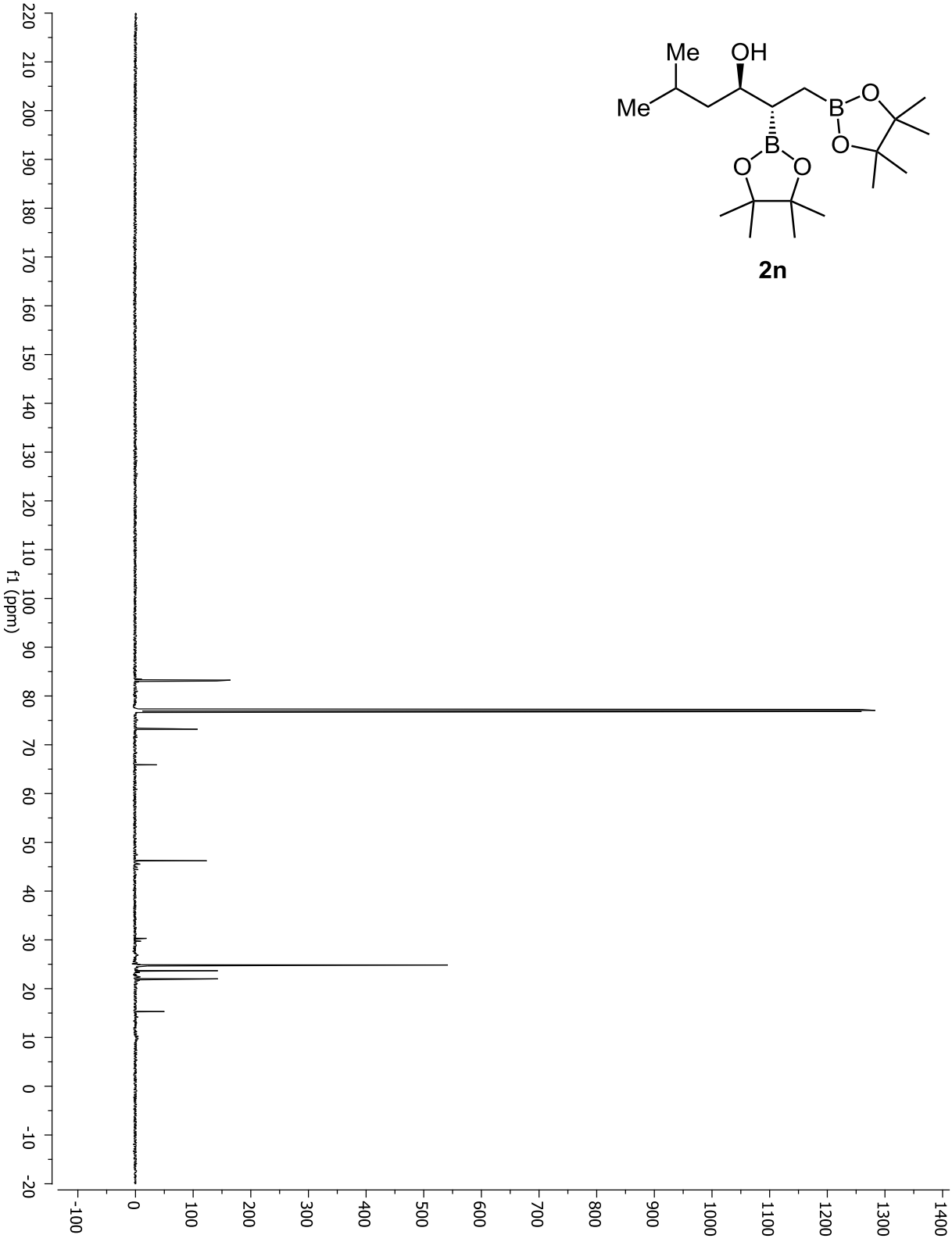

OH
B
O
O
B
O
O
2m
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000

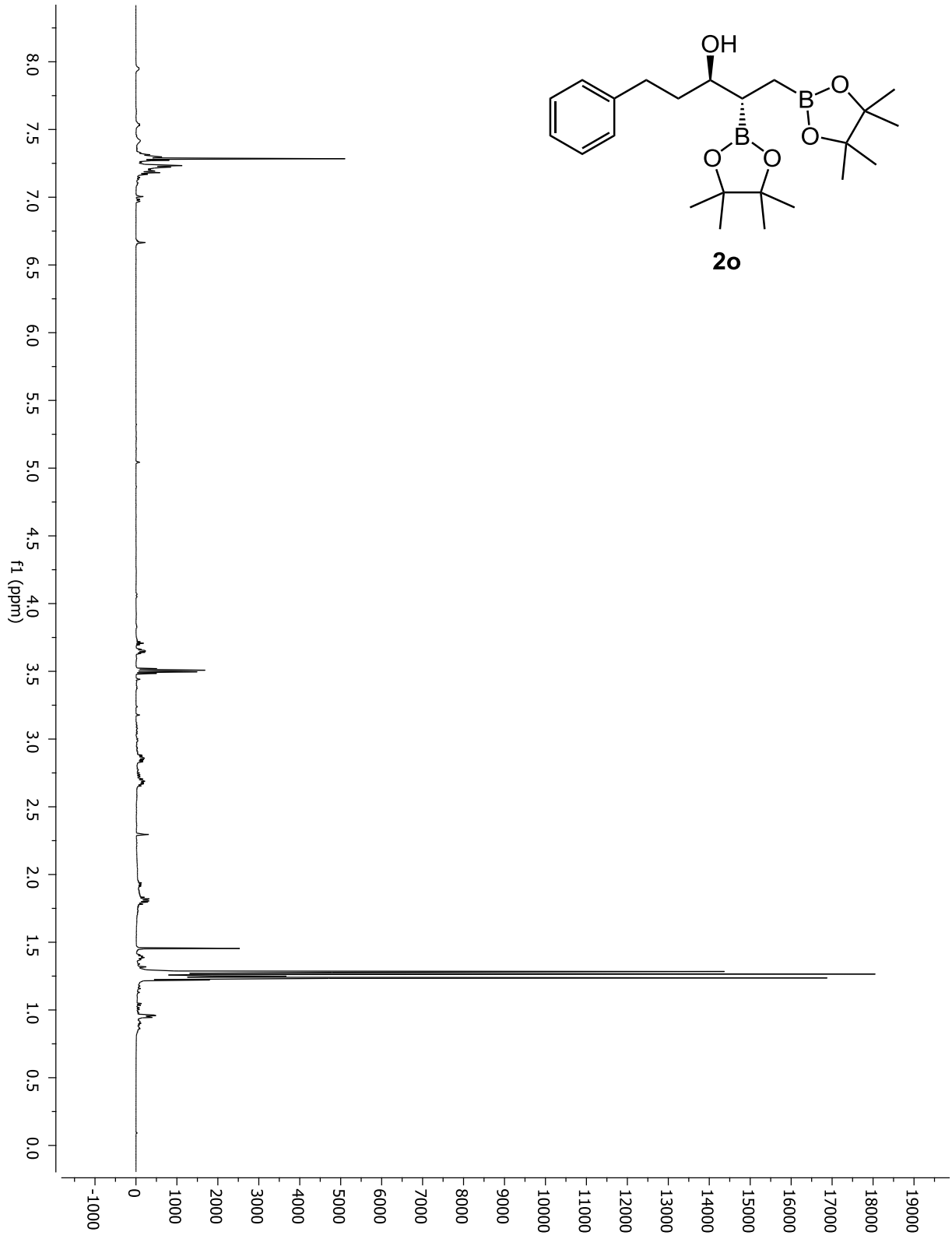

OH
B
O
O
B
O
O
2m
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
0 100 200 300 400 500 600 700 800 900 1000

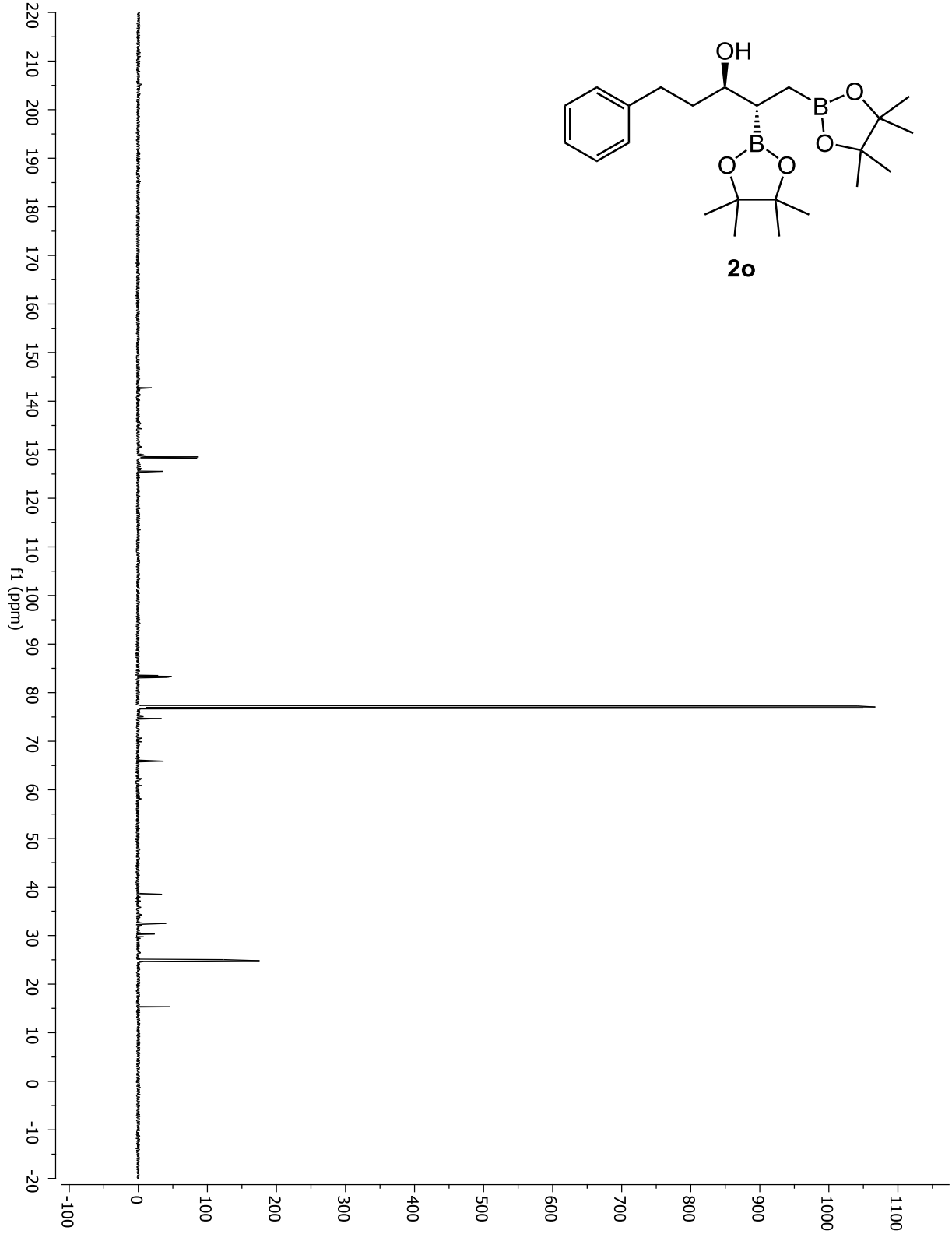

OBz
OBz
OBz
S4
f1 (ppm)

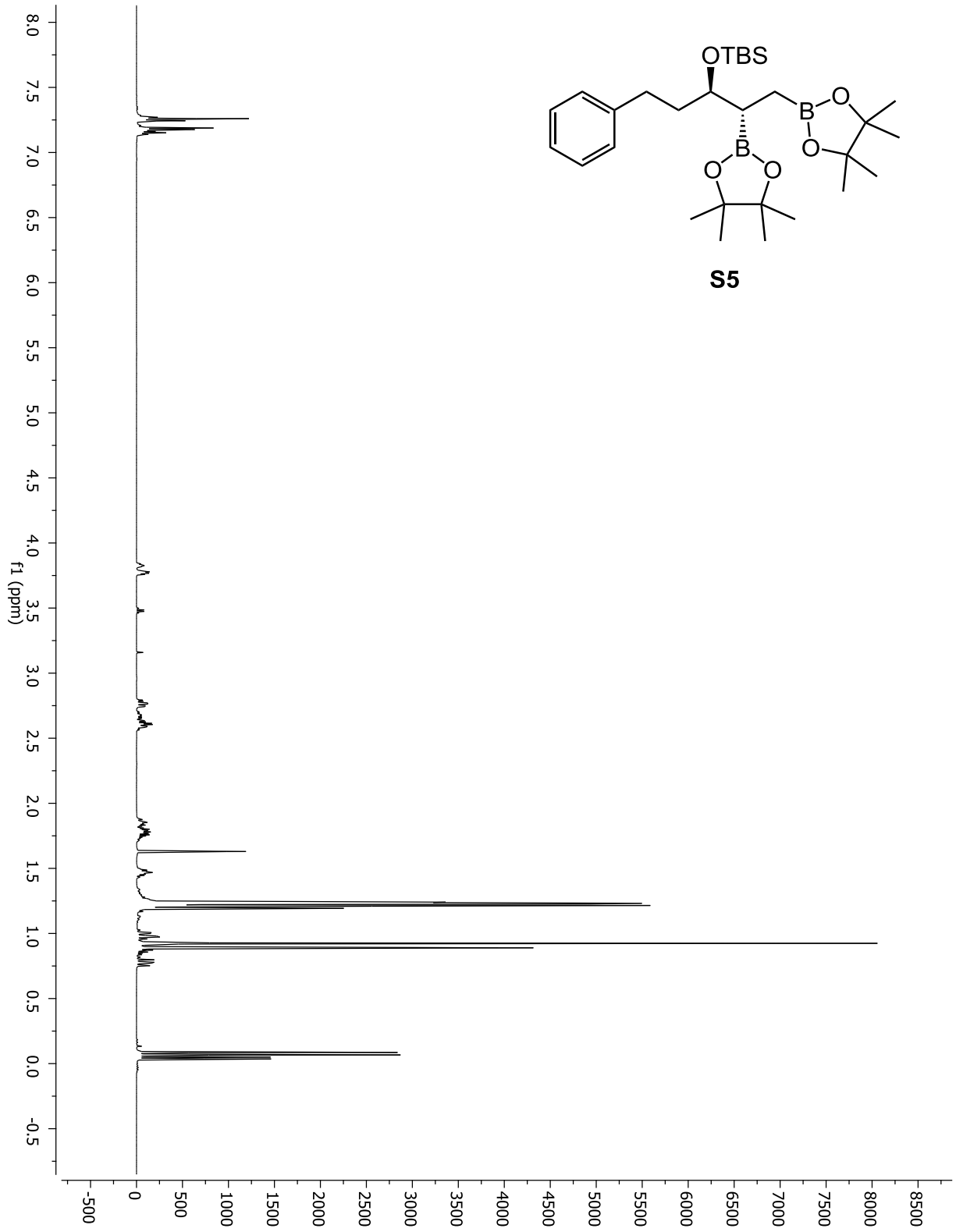

OBz
OBz
OBz
S4
f1 (ppm)

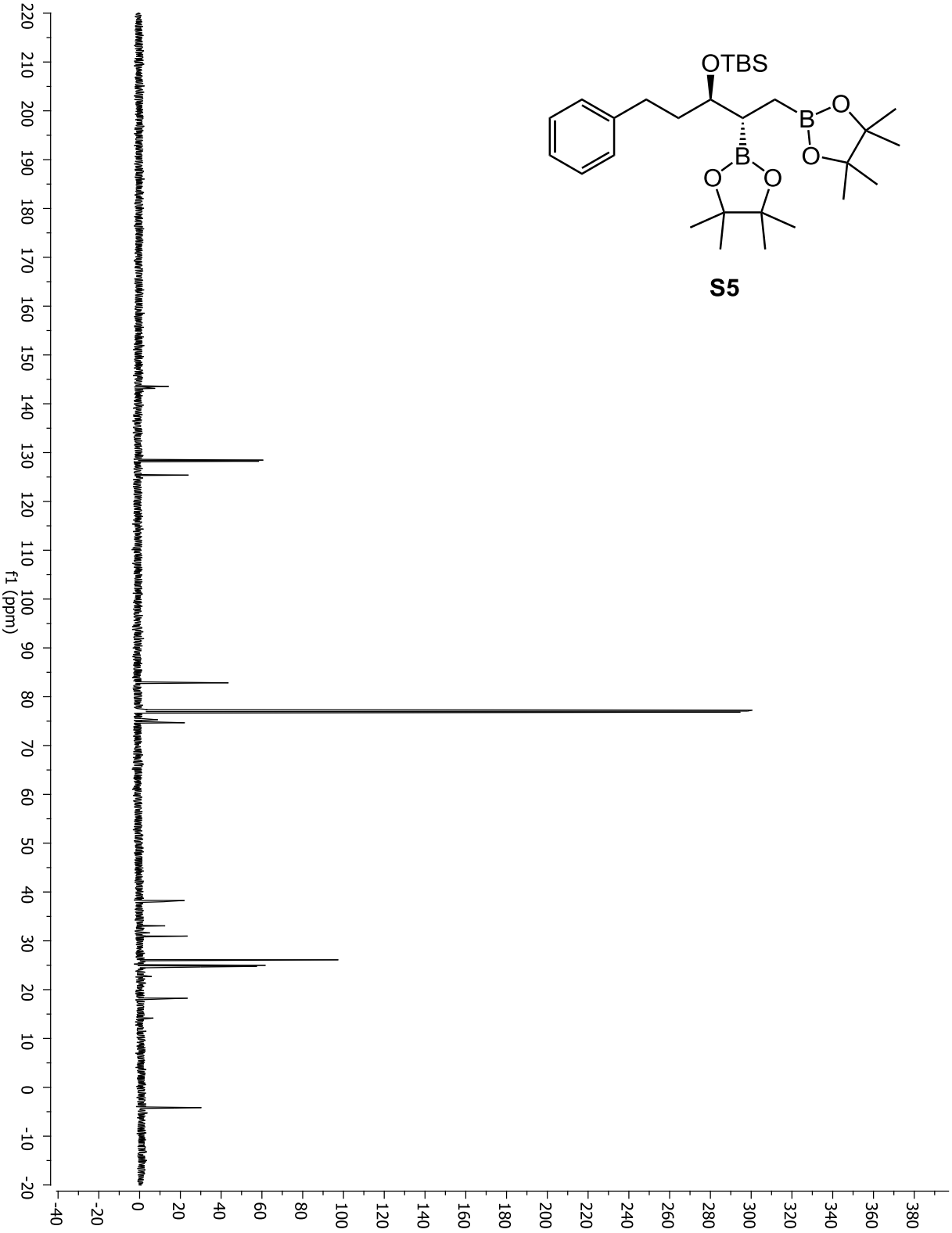

Me
OH
Me
B
O
O
B
O
O
2n
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000
36000
38000


Me
OH
Me
B
O
O
B
O
O
2n
f1 (ppm)

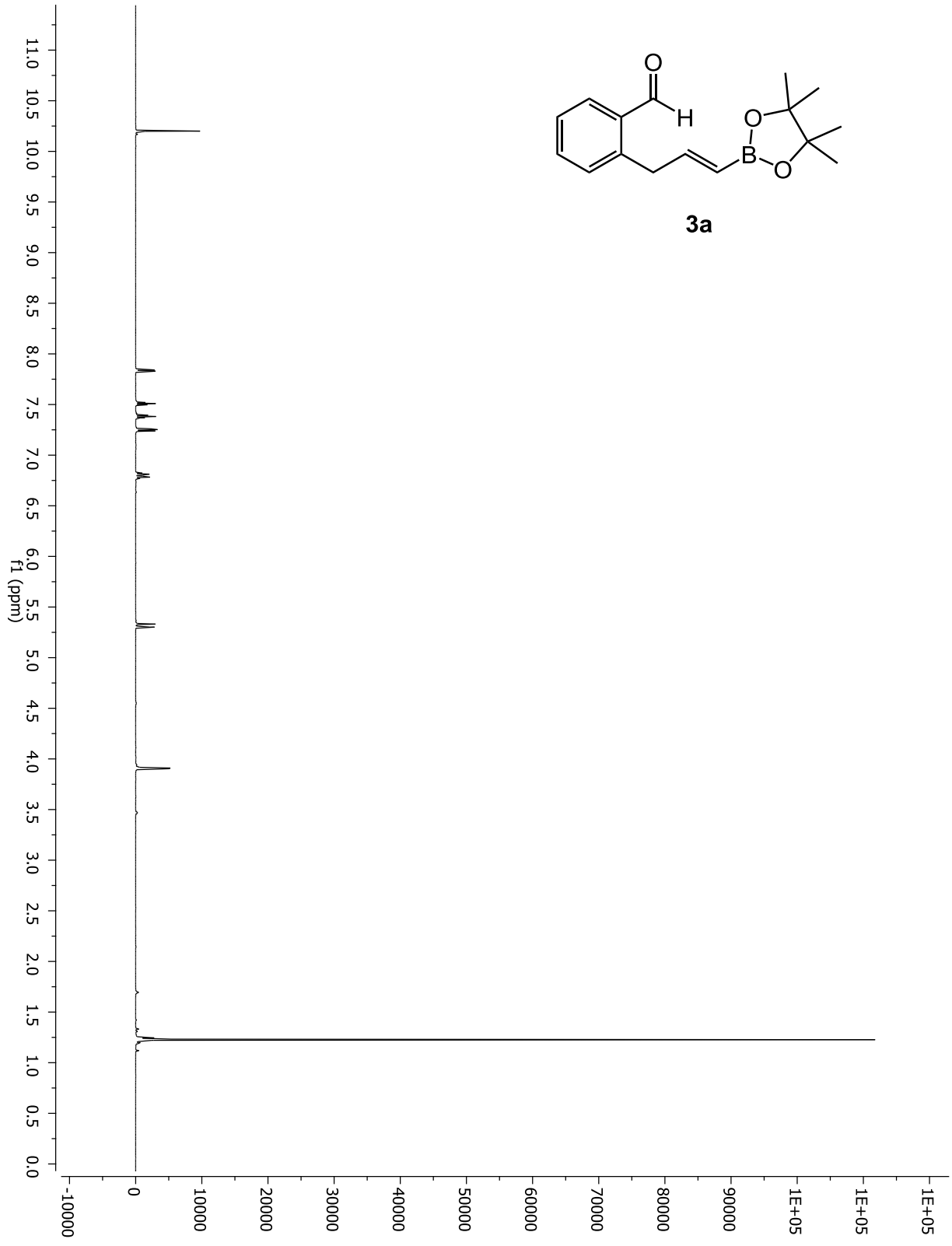

OH
B
O
O
B
O
O
2o
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000

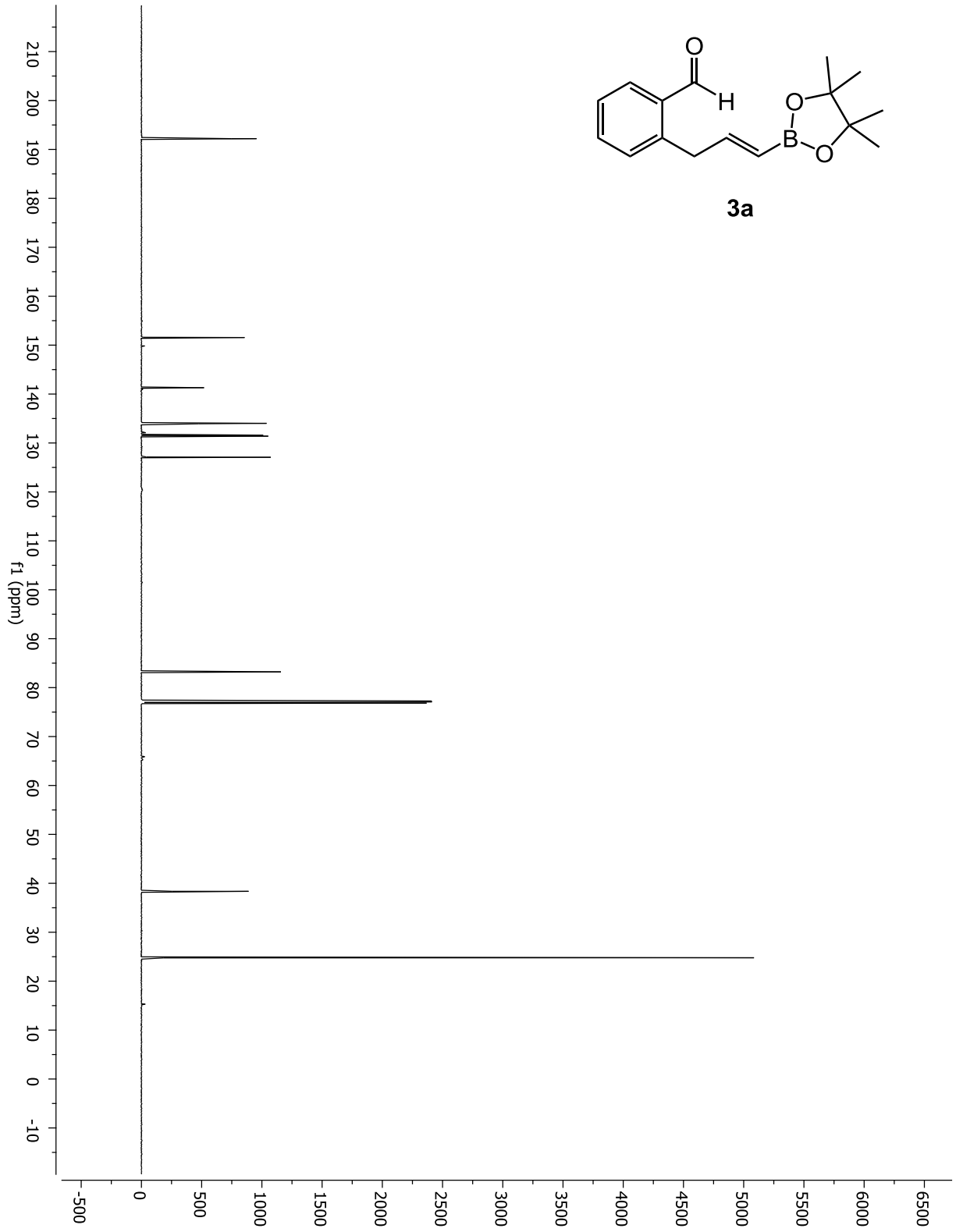

OH
B
O
O
B
O
O
2o
f1 (ppm)

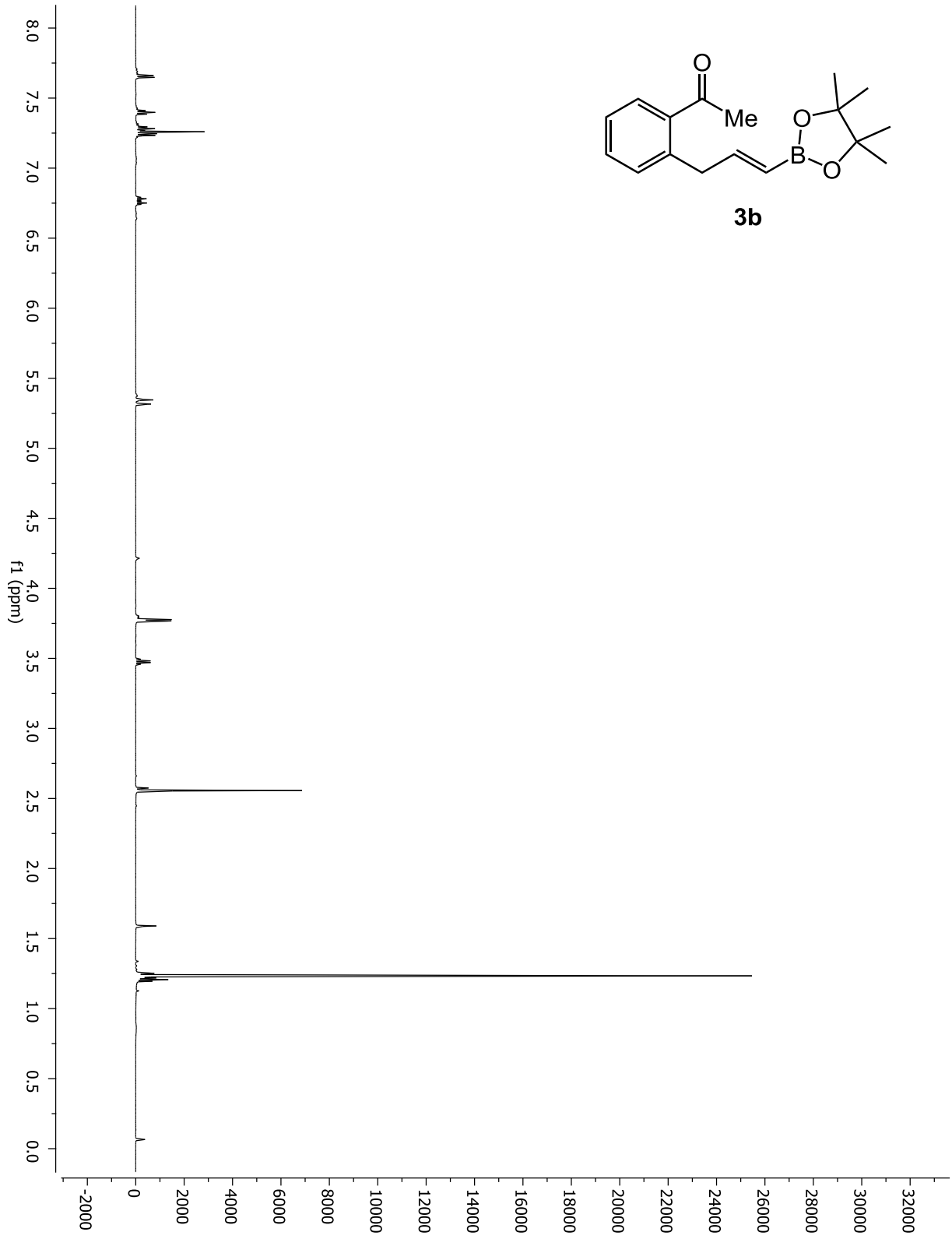

OTBS
B
O
O
B
O
O
S5
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
7500
8000
8500



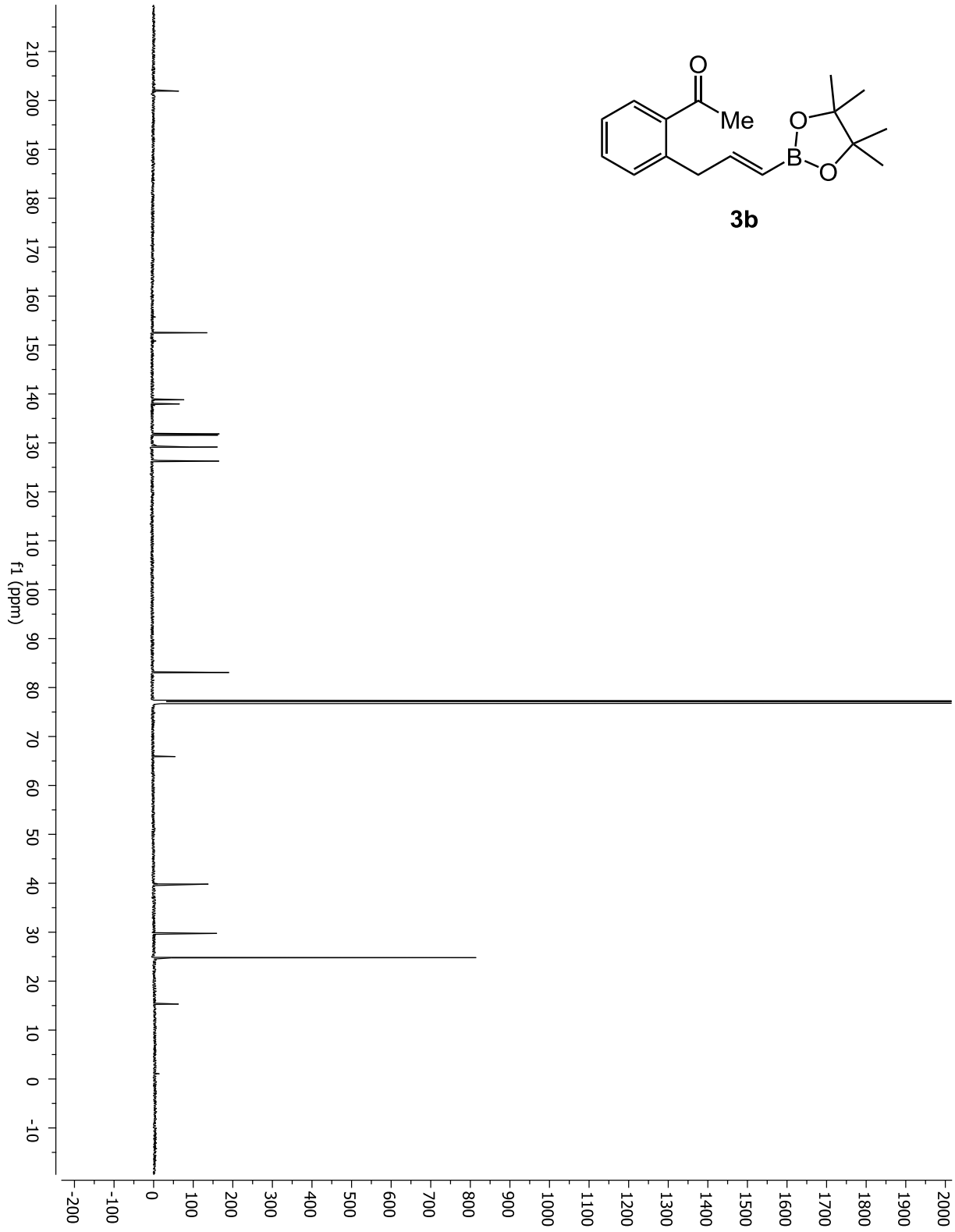
S5

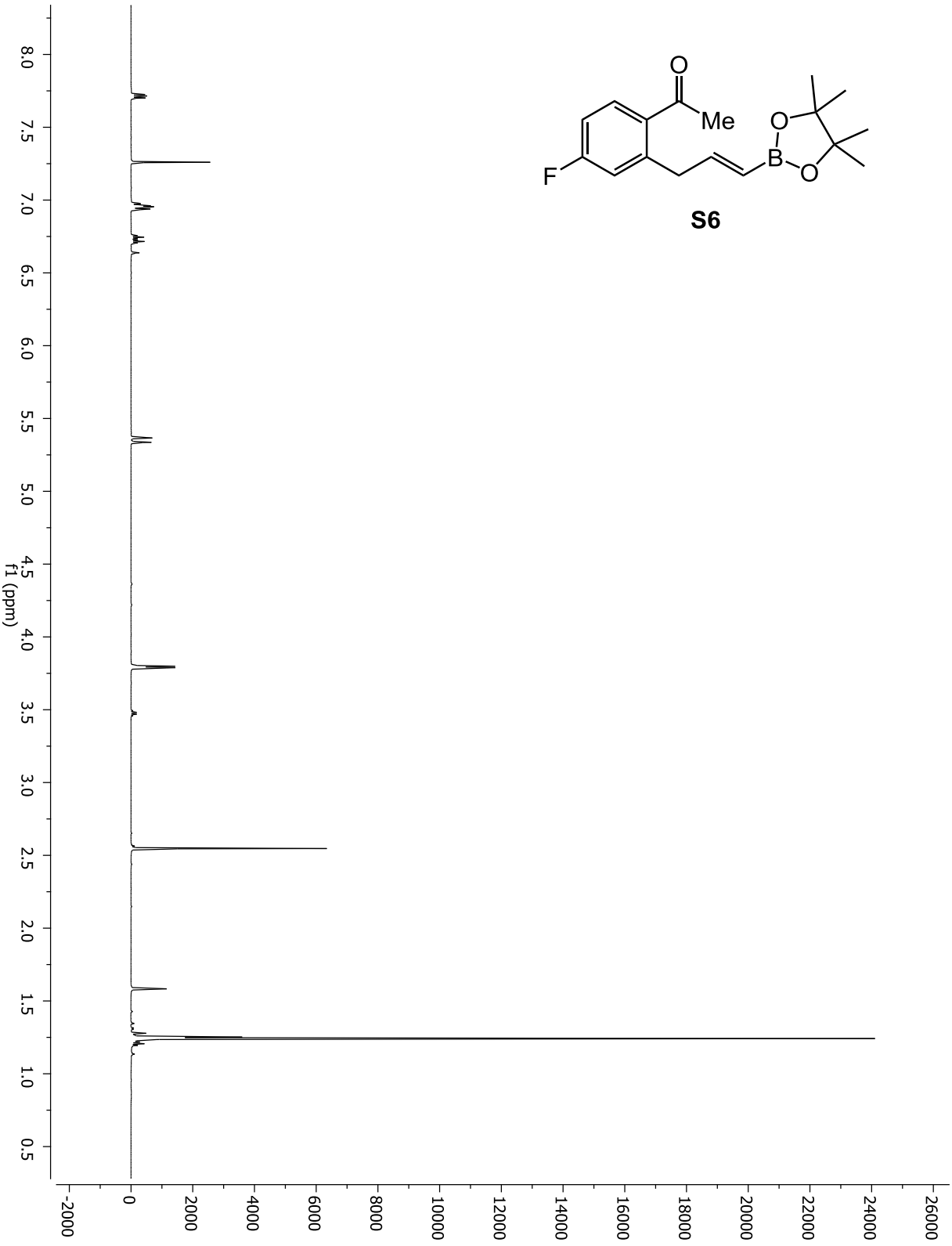

O
H
O
B
O
3a
11.0 10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)
-10000 0 10000 20000 30000 40000 50000 60000 70000 80000 90000 1E+05 1E+05 1E+05


O
H
O
B
O
3a
f1 (ppm)

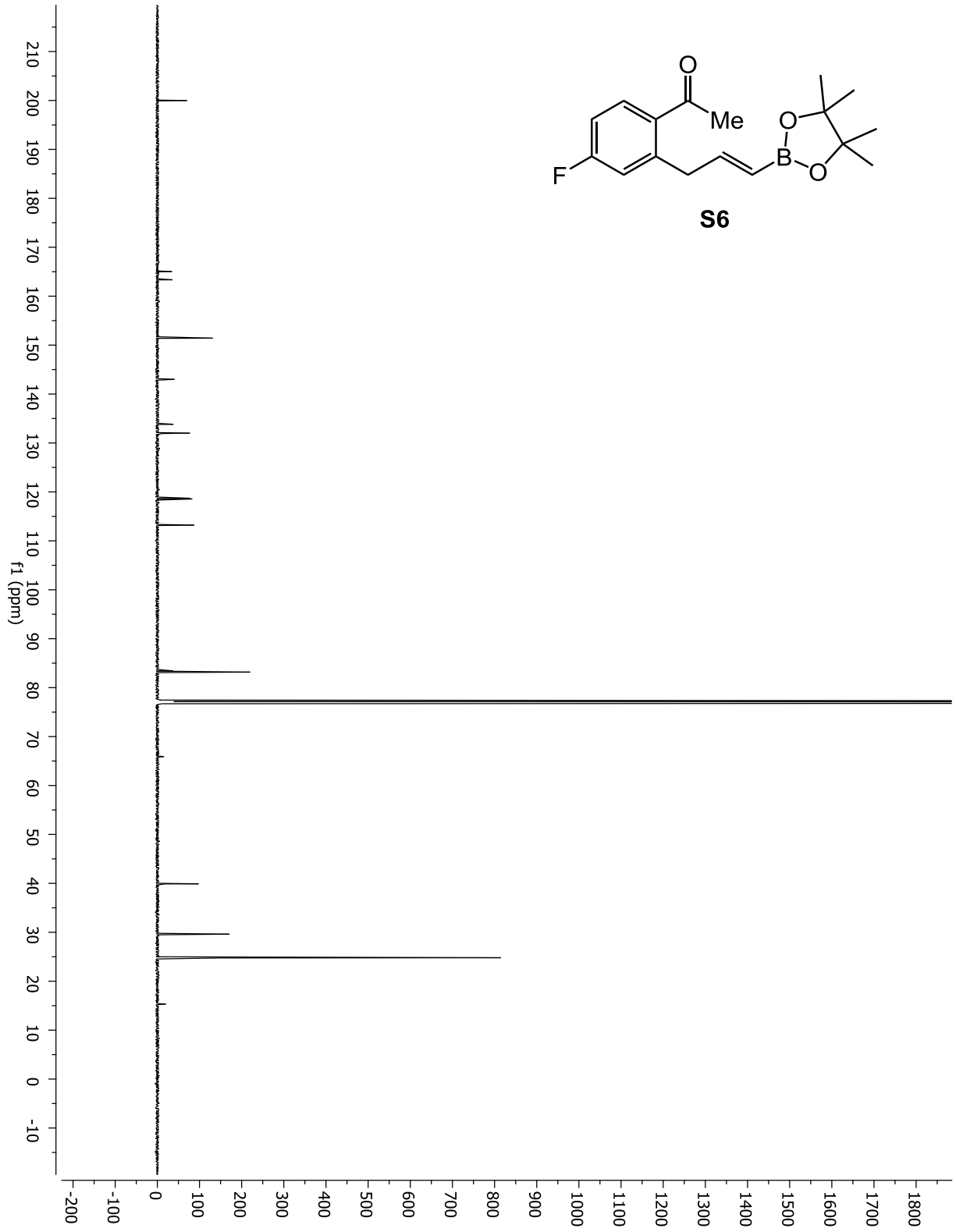

O
Me
O
B
O
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000

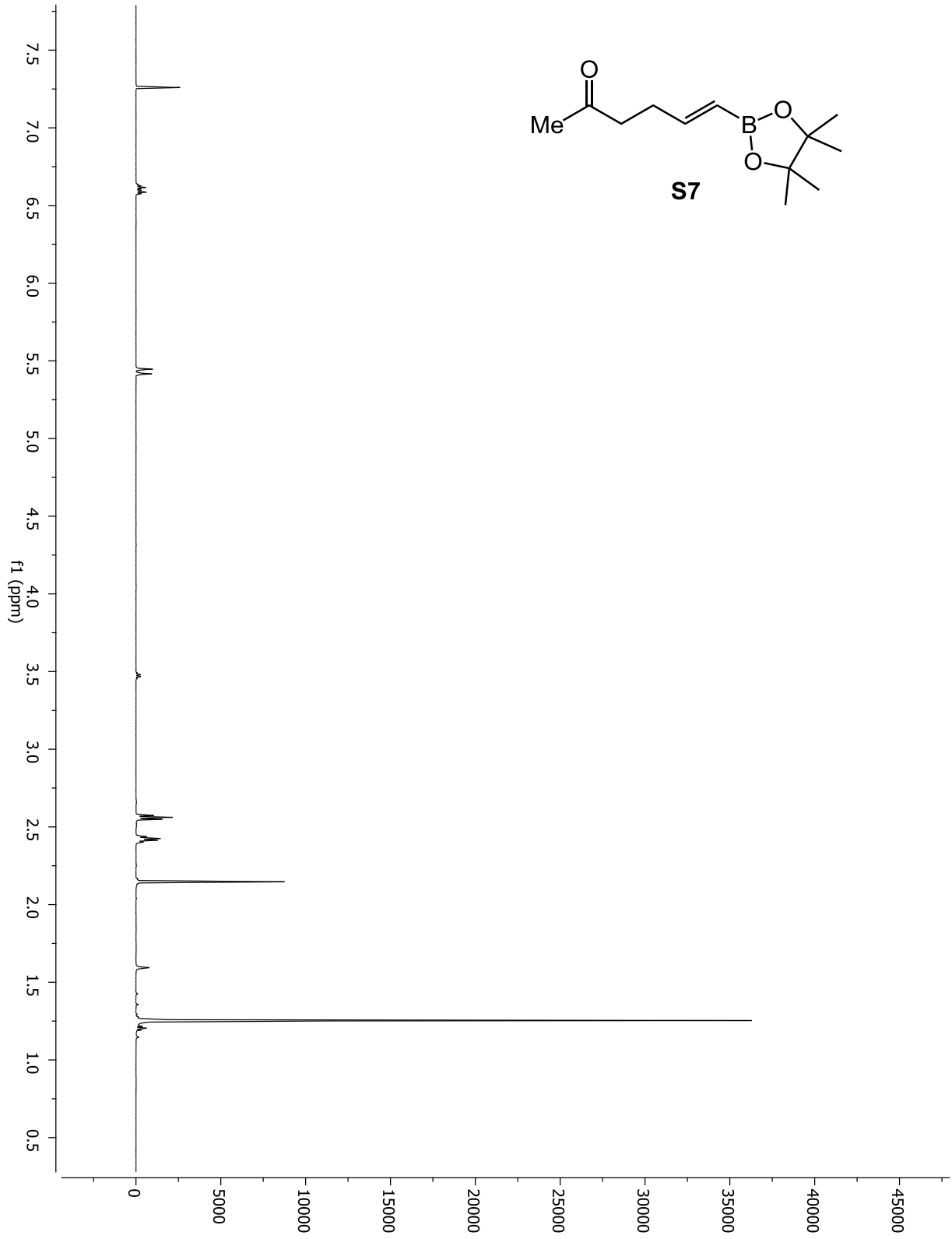
3b

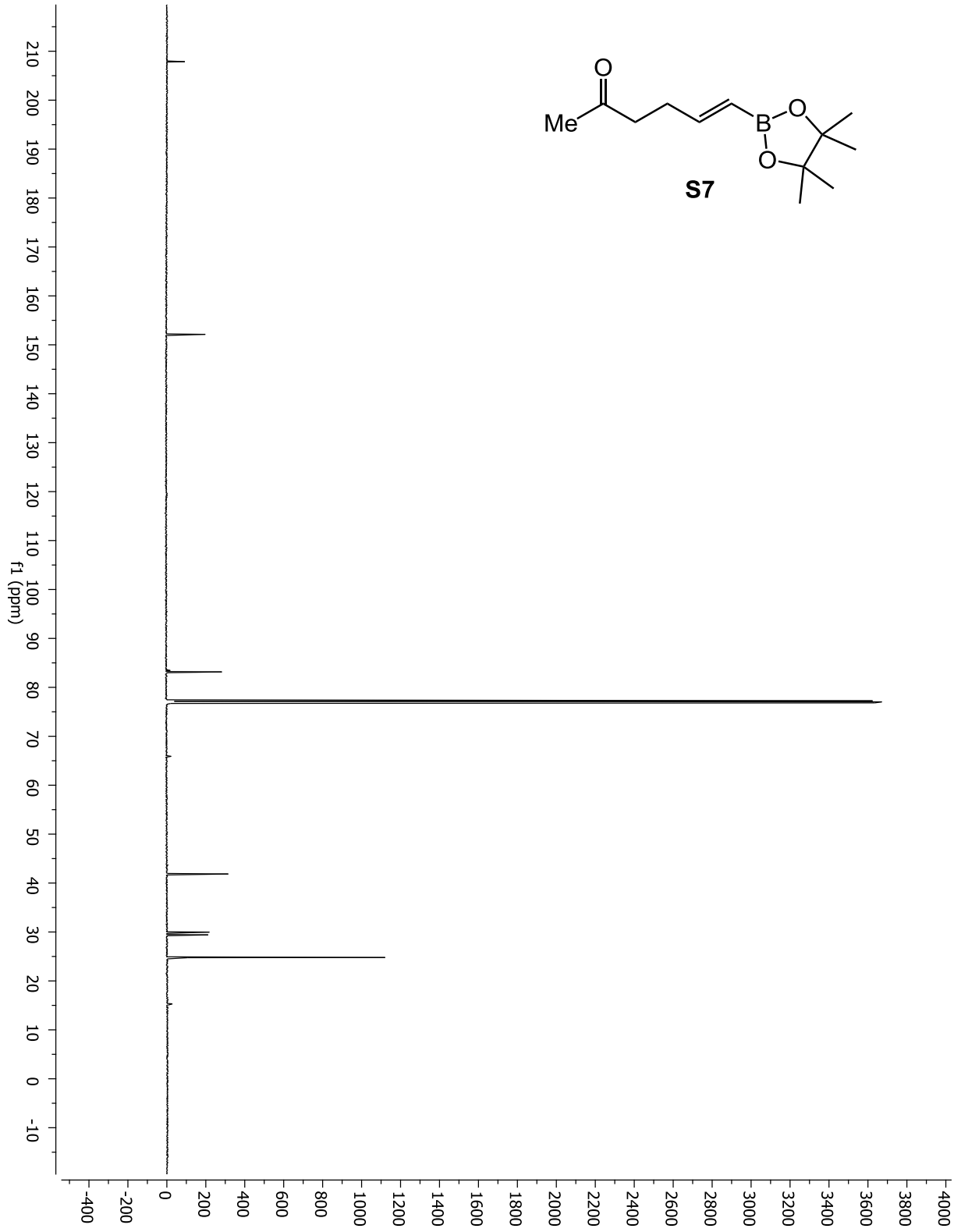

O
Me
O
B
O
3b
f1 (ppm)

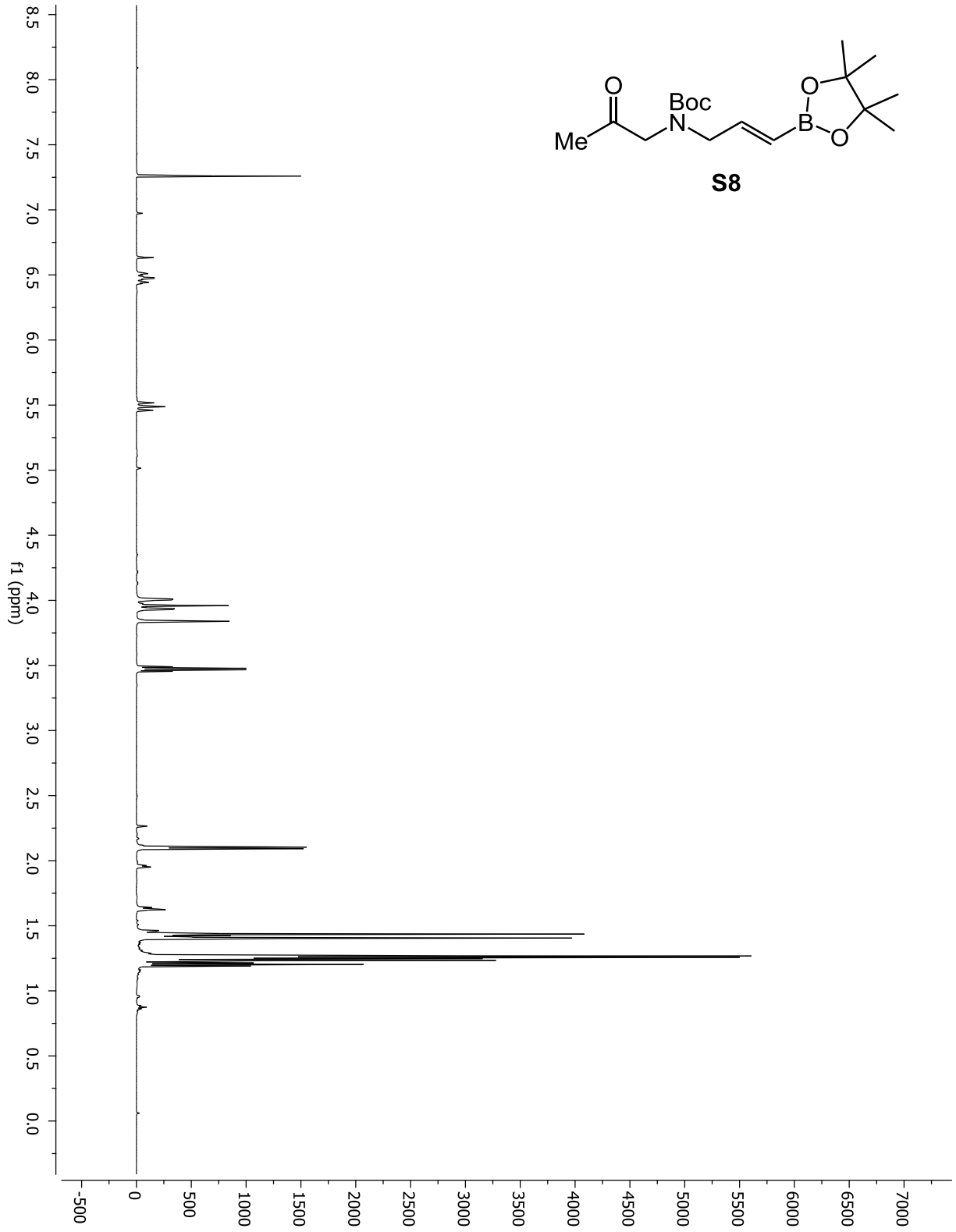

O
Me
O
B
O
F
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000

S6

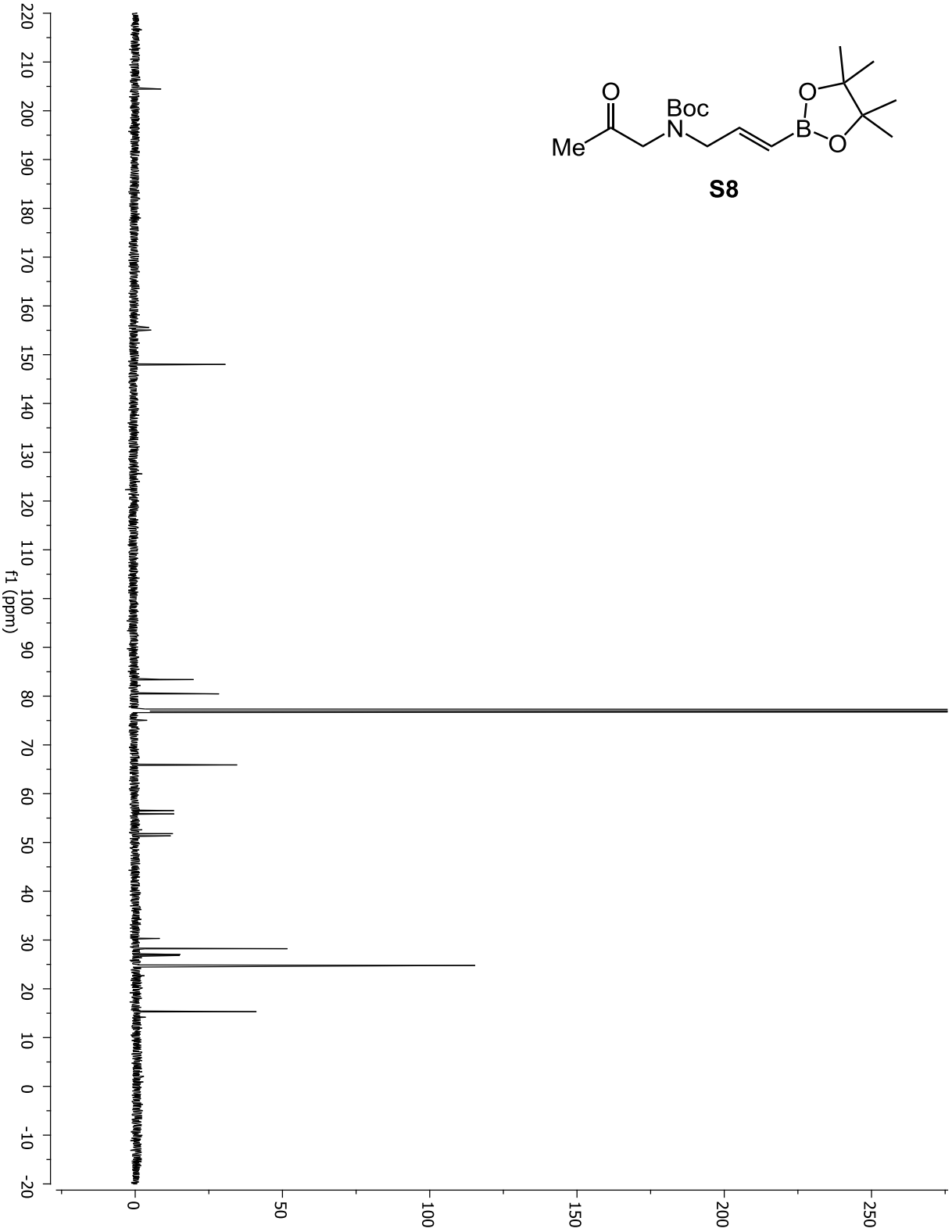

O
Me
O
B
O
F
S6
f1 (ppm)


O
Me
B
O
O
S7
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000

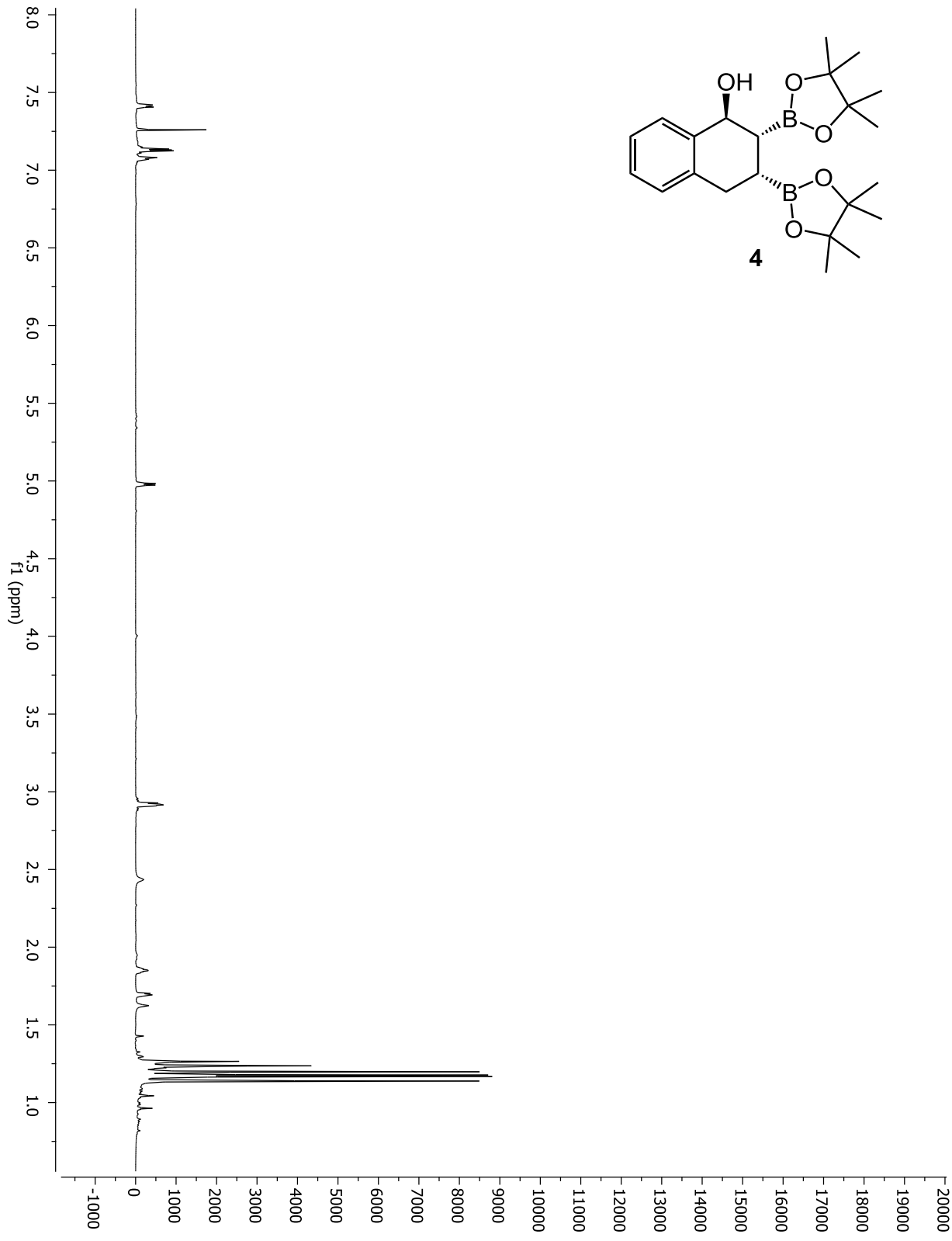

O
Me
B
O
O
S7
f1 (ppm)

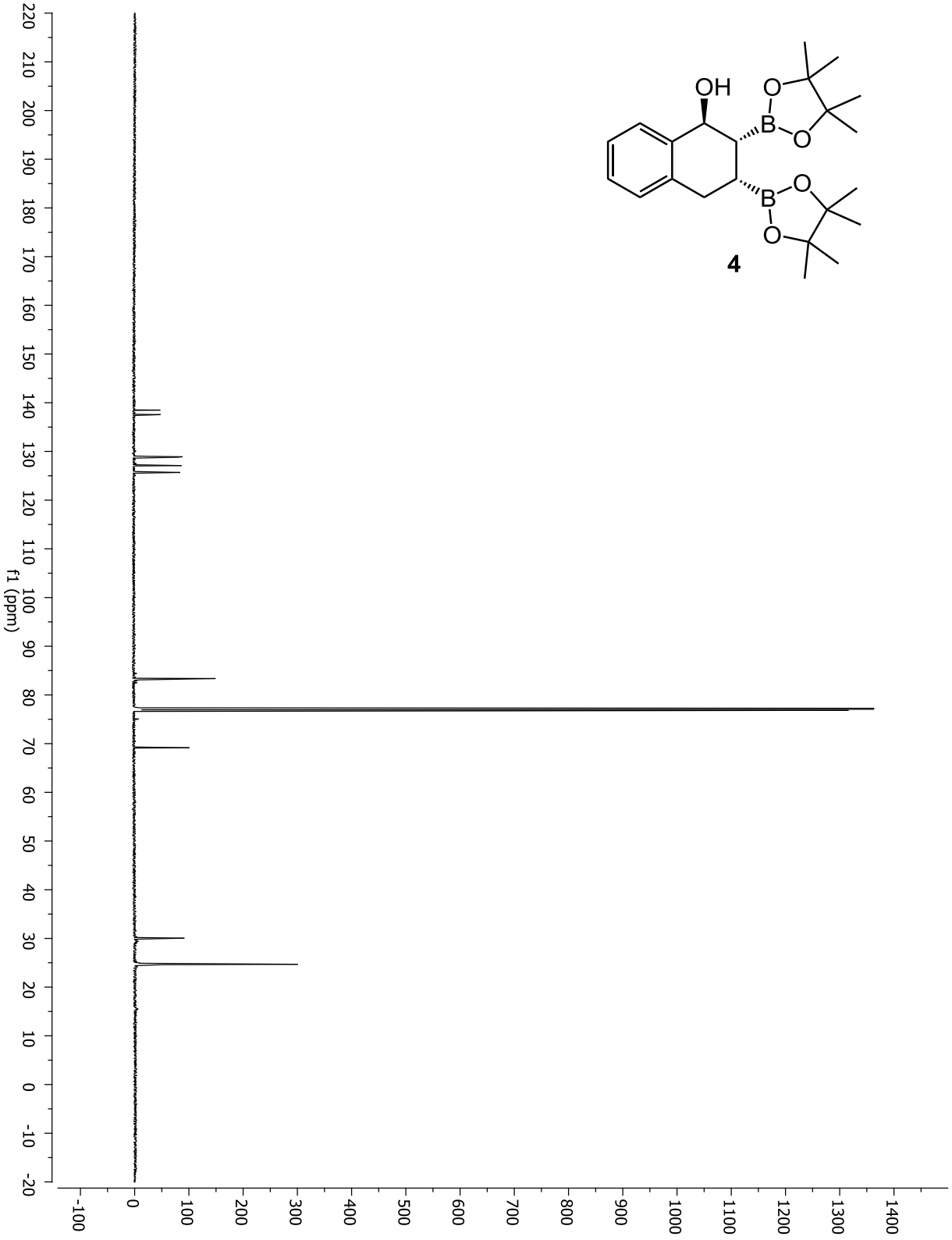

O
Boc
N
Me
O
B
O
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-500
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000

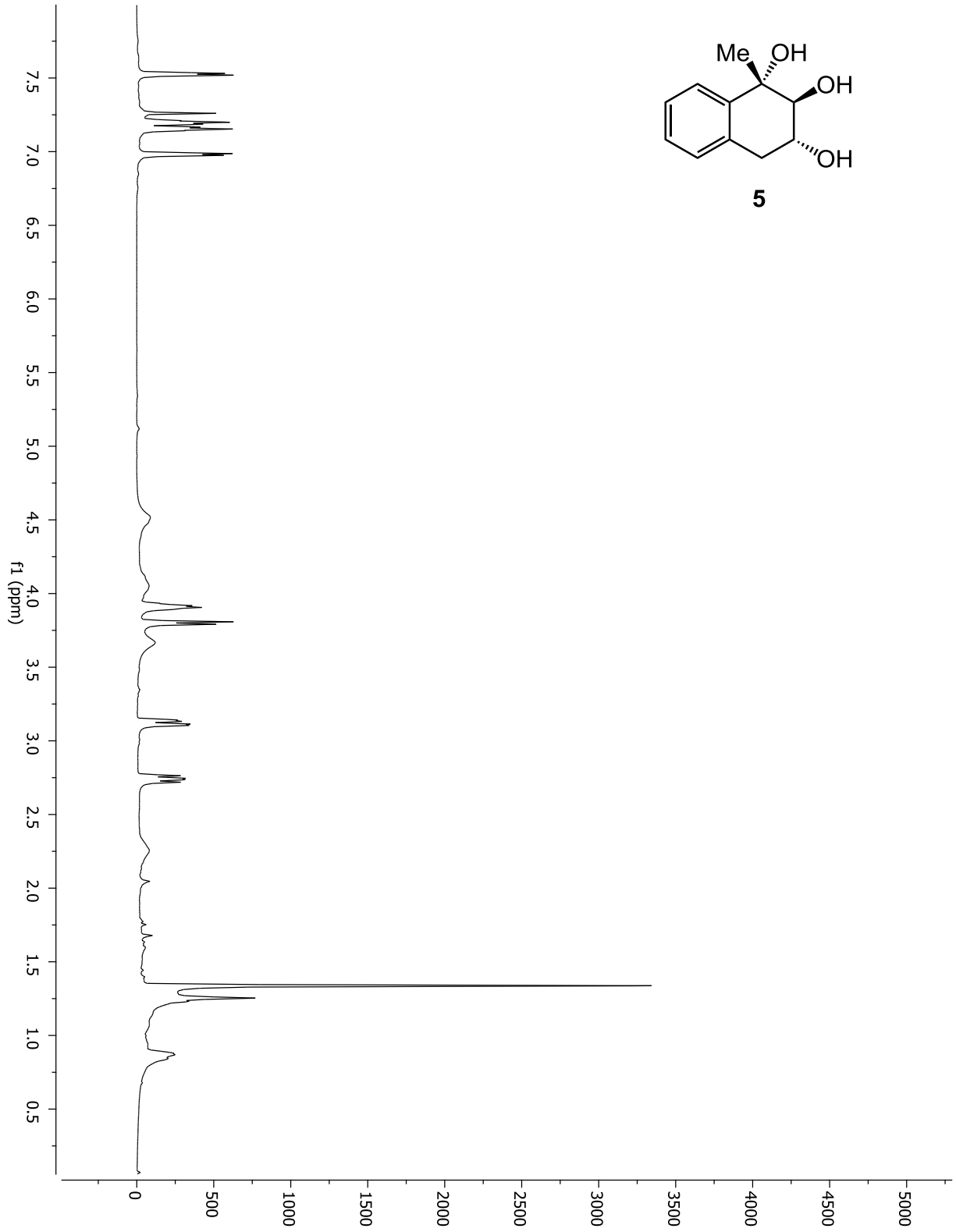
S8

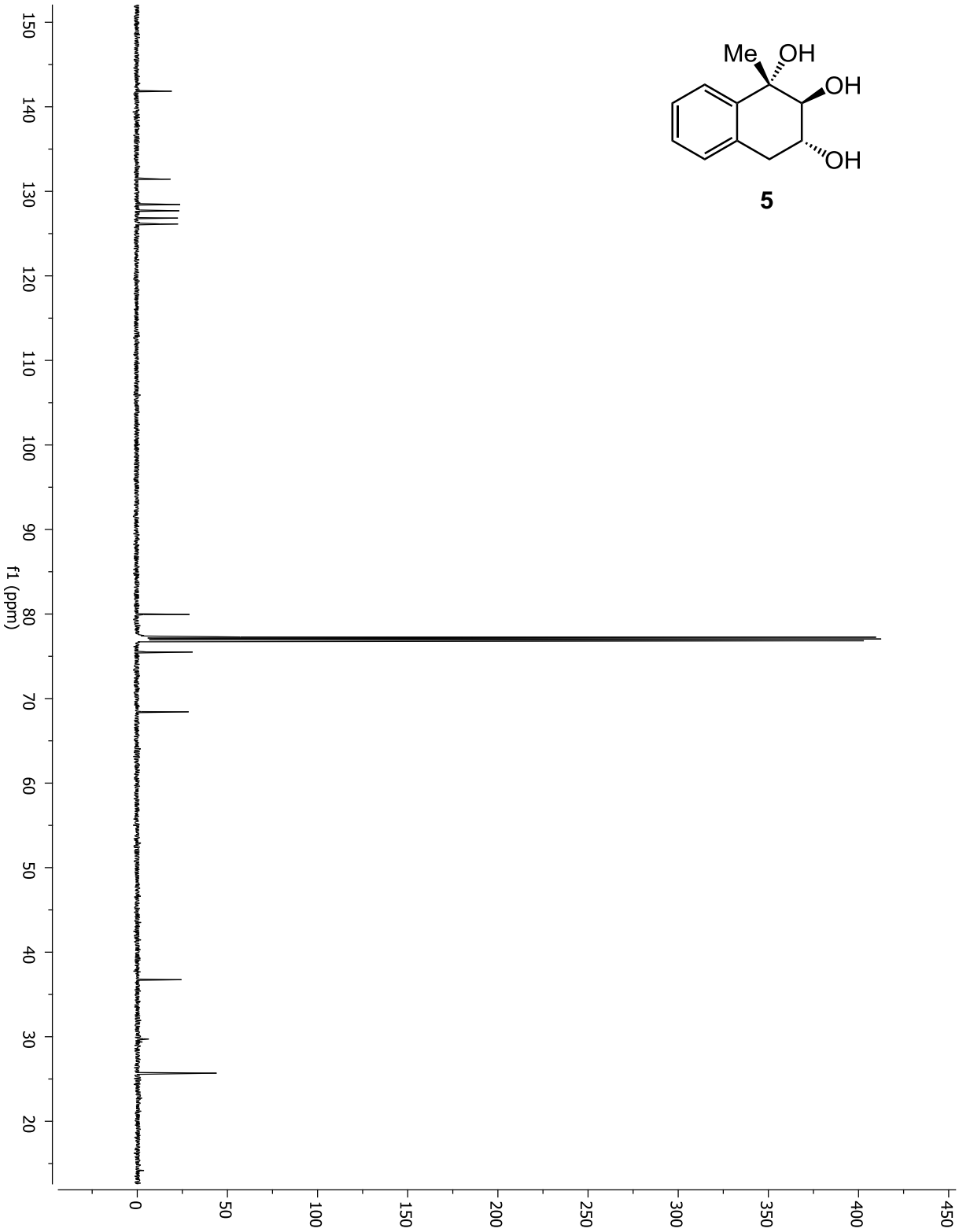

O
Boc
N
Me
O
B
O
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
0 50 100 150 200 250

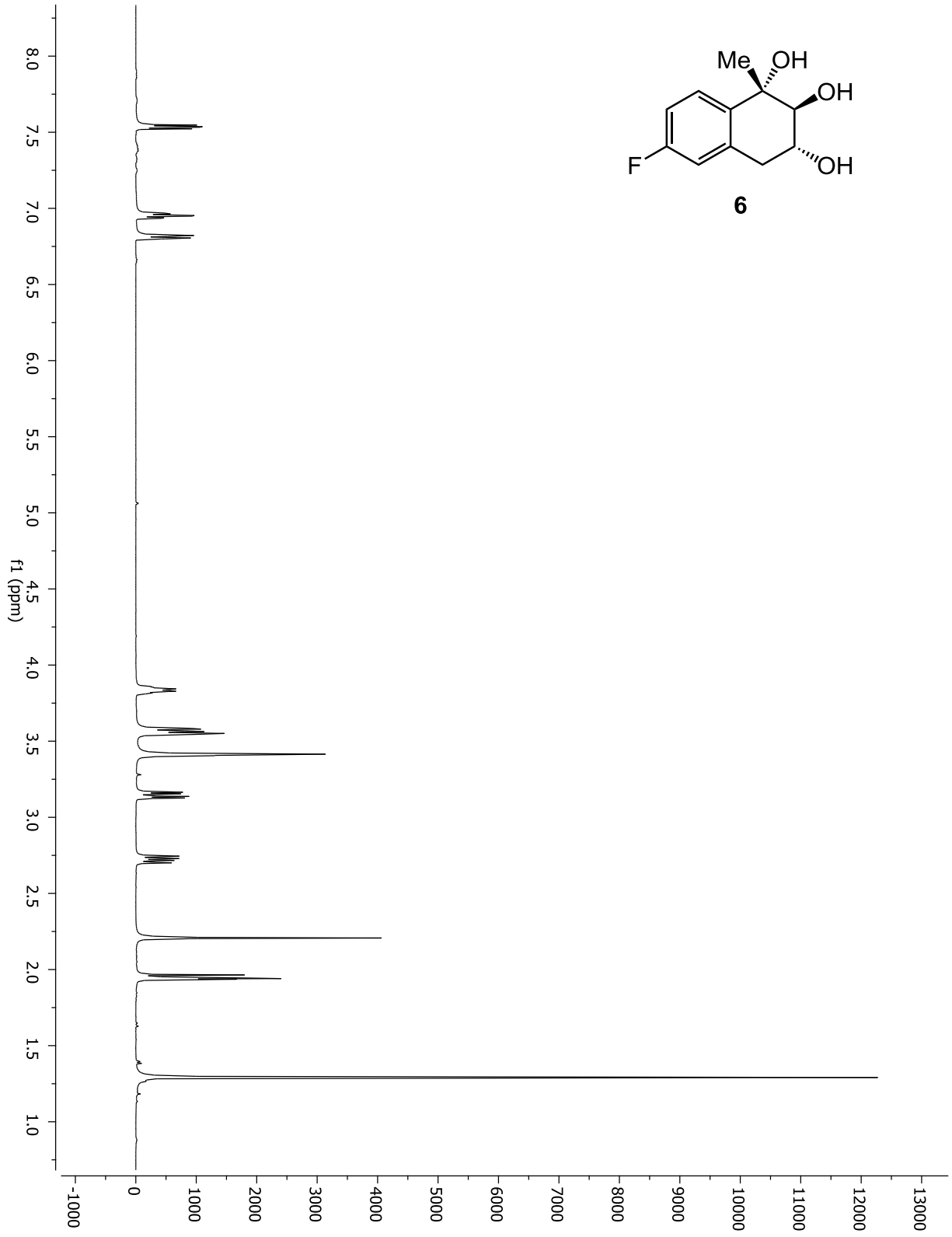
S8

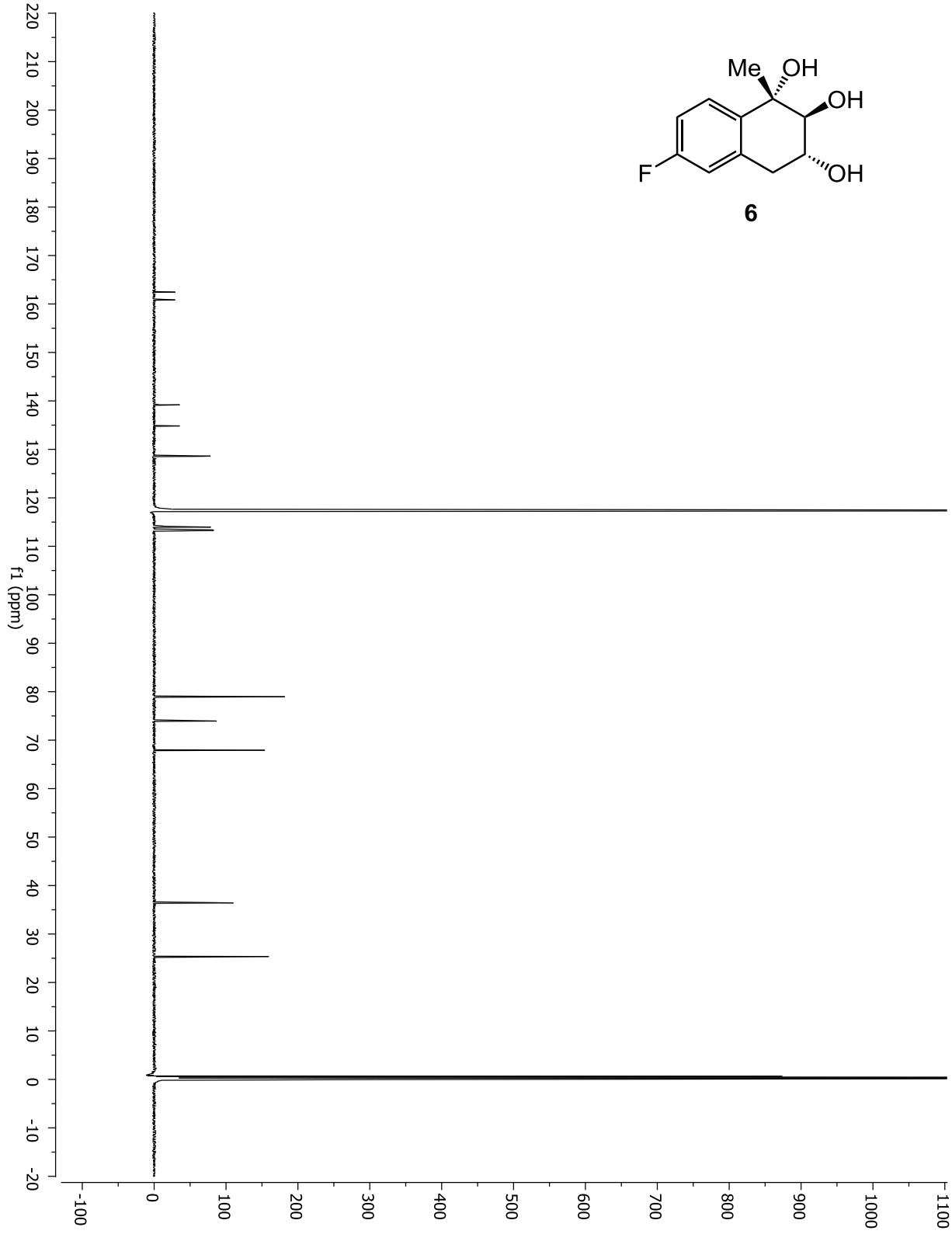

OH
O
B
O
O
B
O
4
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000
19000
20000

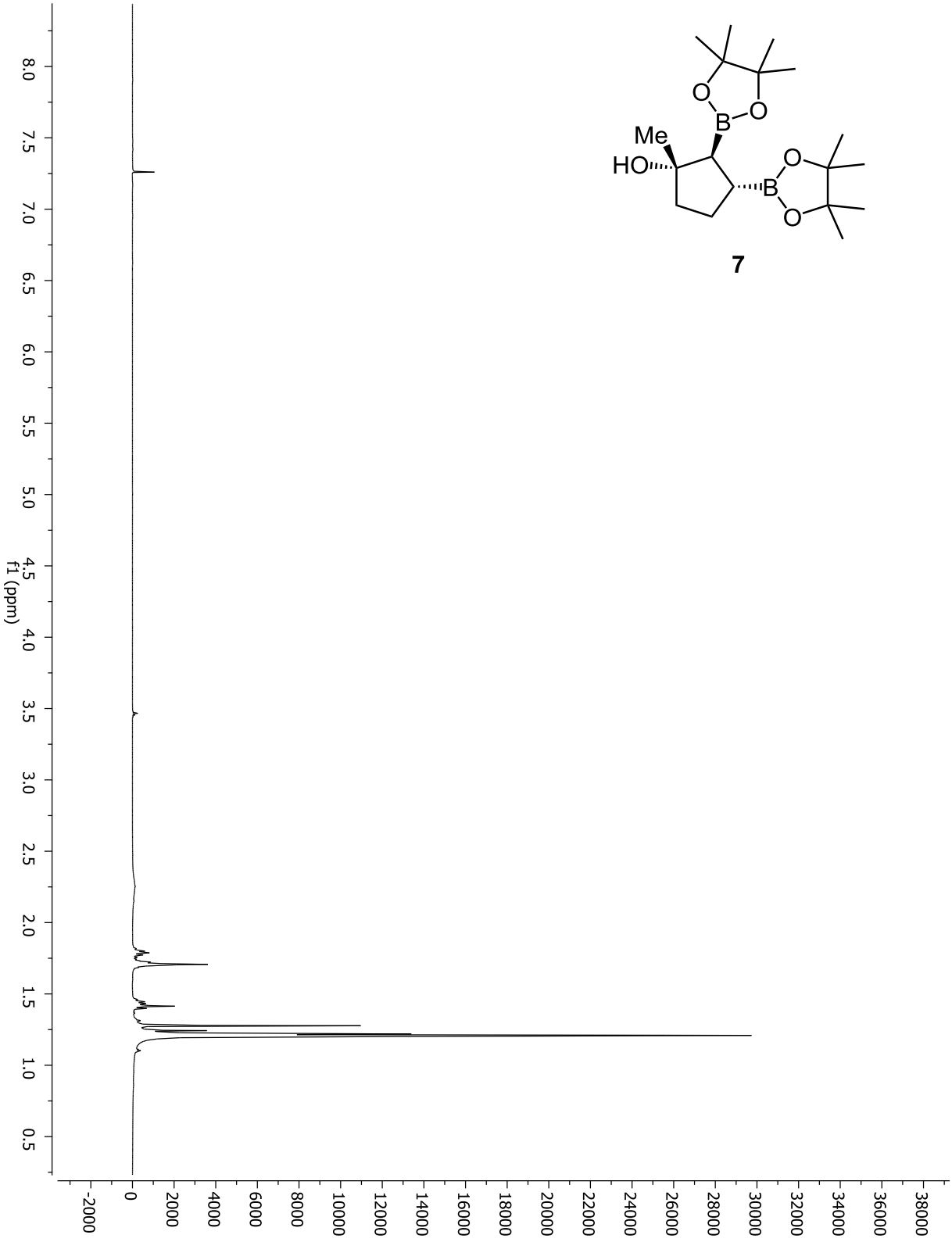

OH
O
B
O
B
O
O
4
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-100 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400


Me
OH
OH
OH
5
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

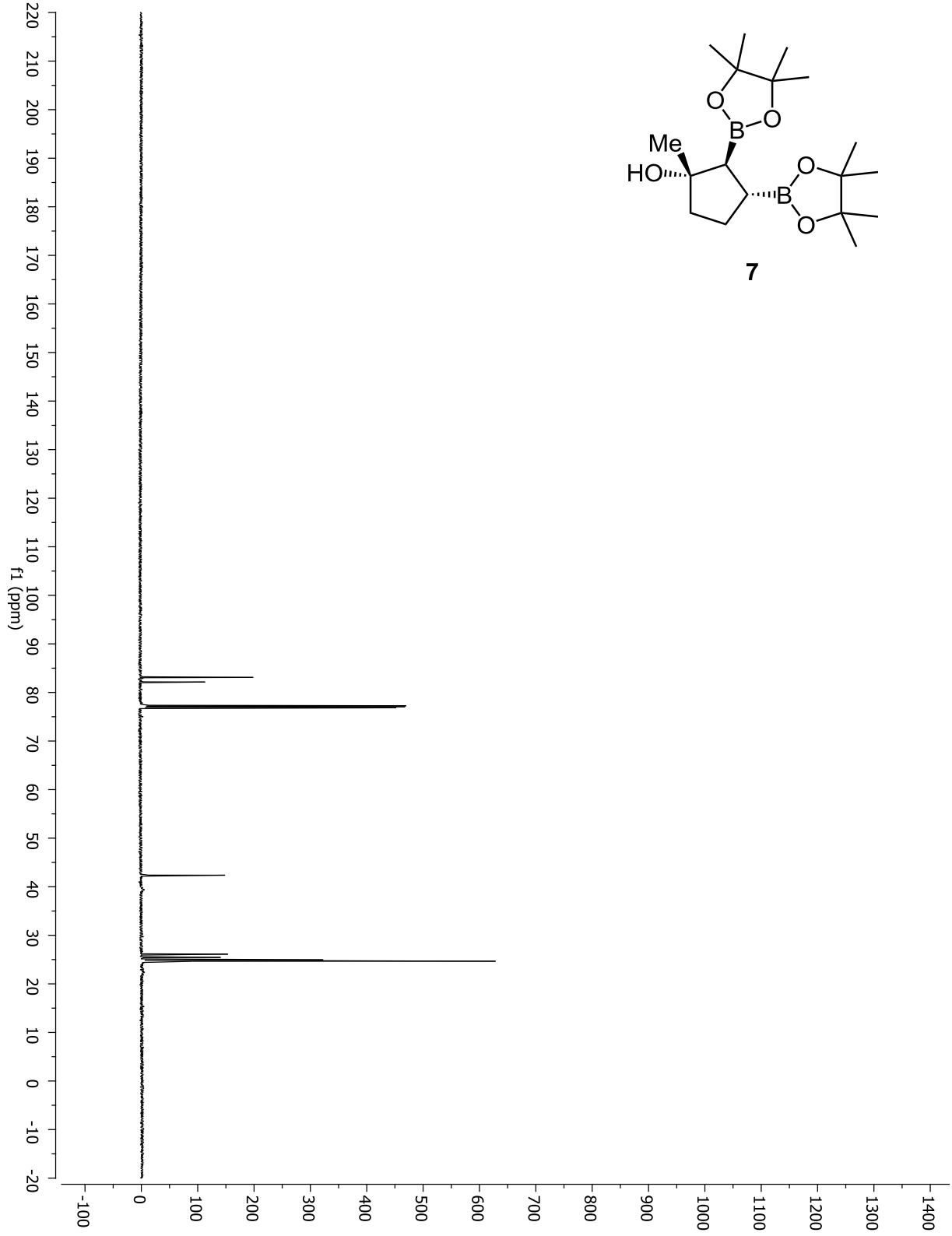

Me
OH
OH
OH
5
f1 (ppm)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
0
50
100
150
200
250
300
350
400
450


Me
OH
OH
F
OH
6
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000

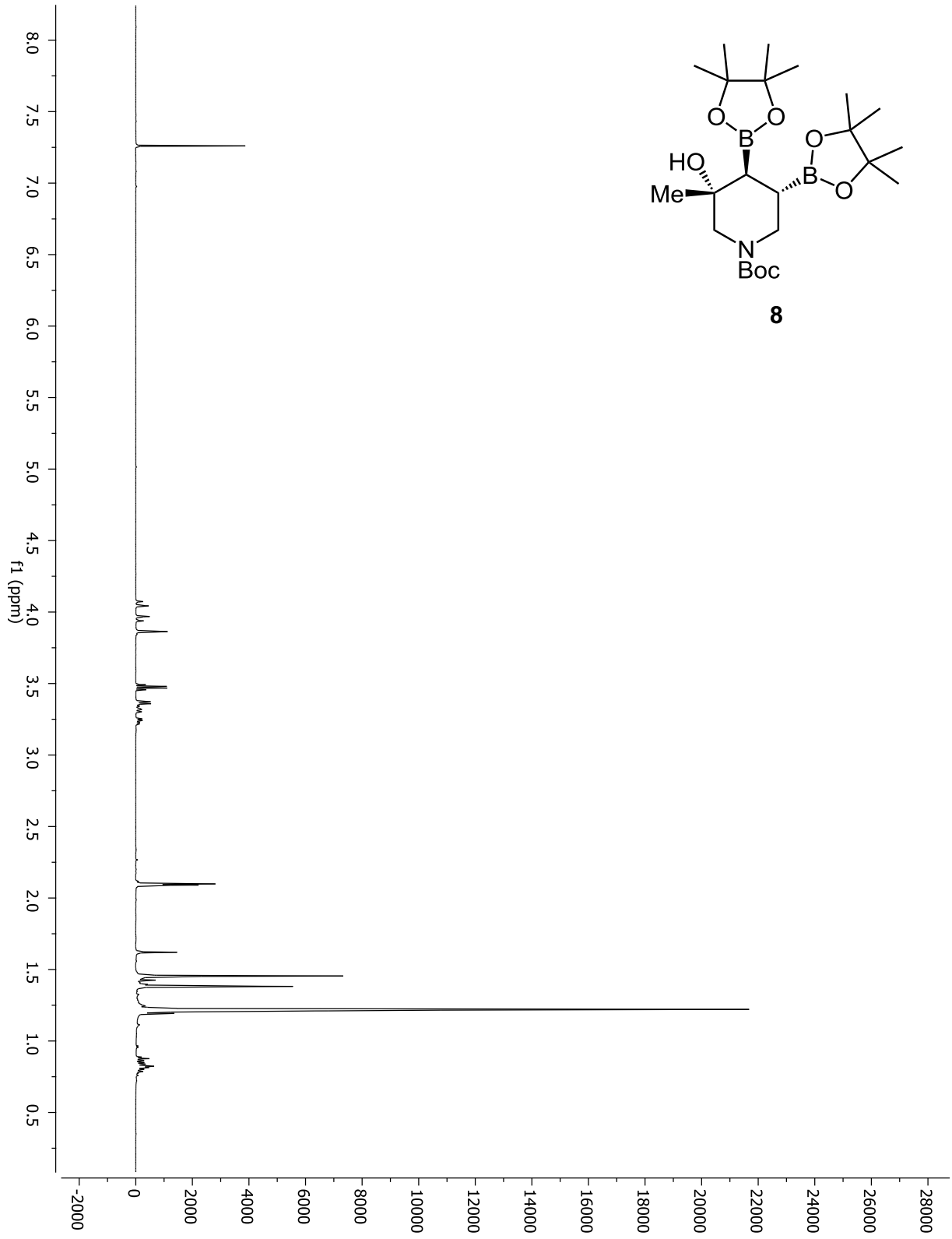

Me
OH
OH
F
OH
6
f1 (ppm)



7

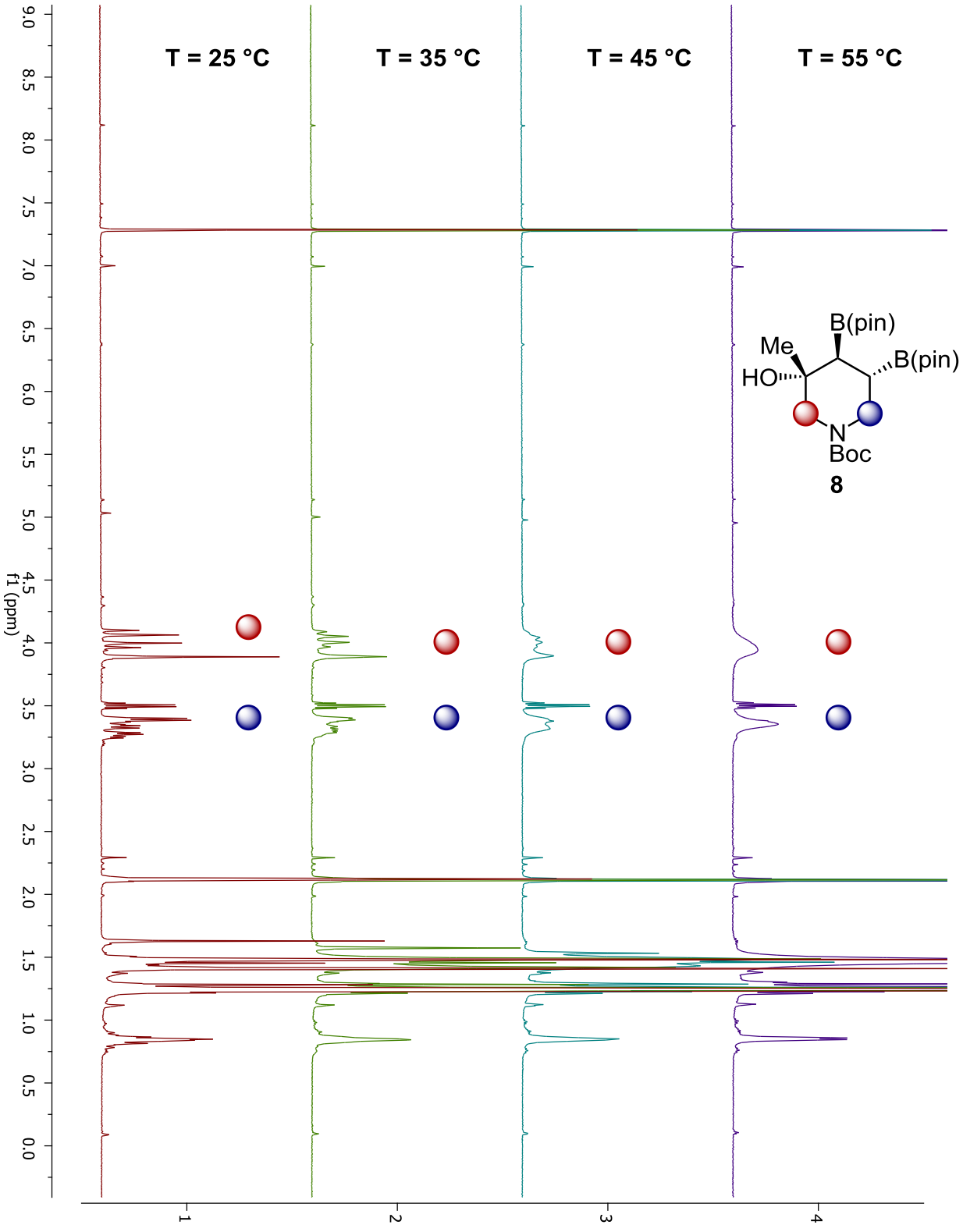


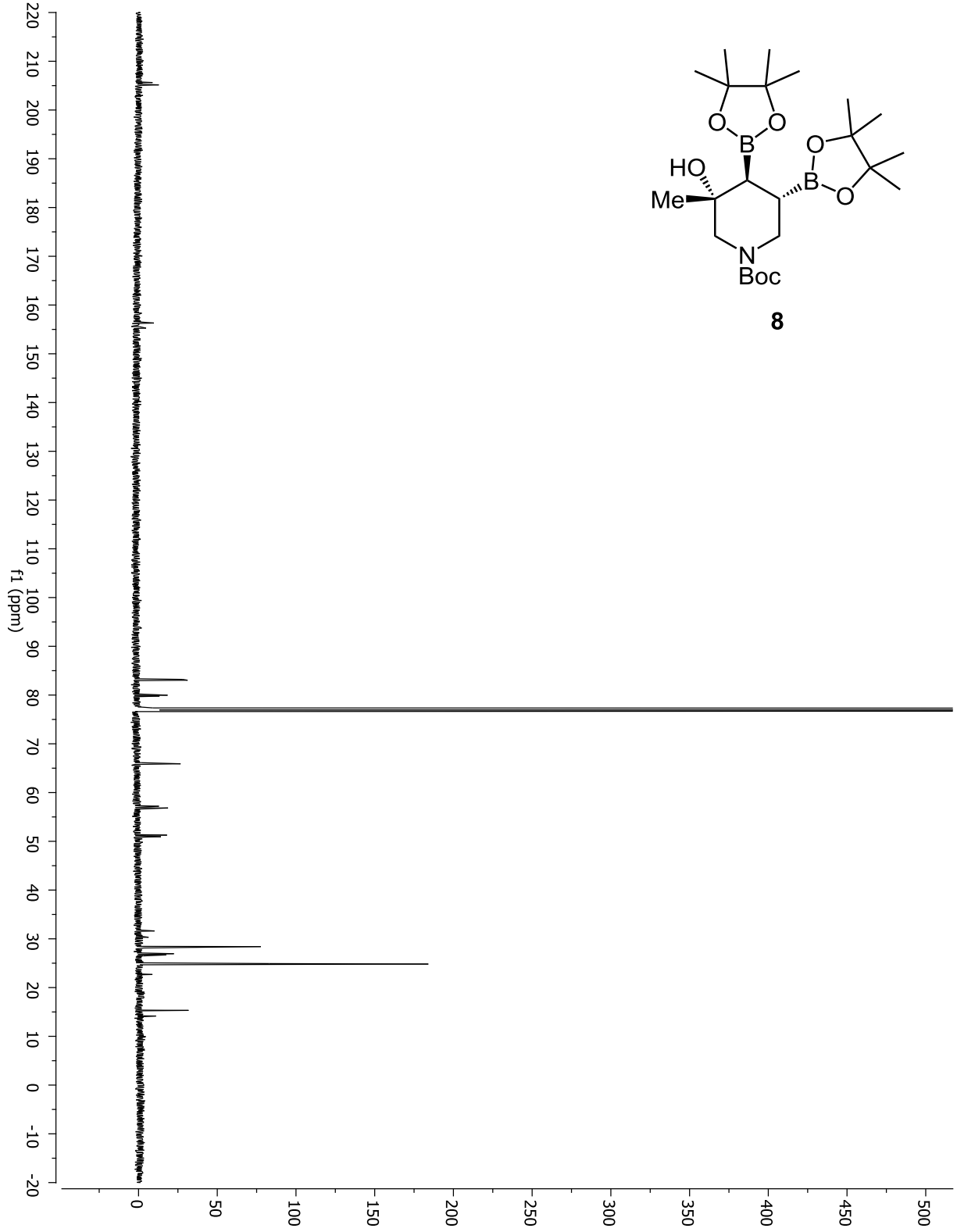
7


f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000

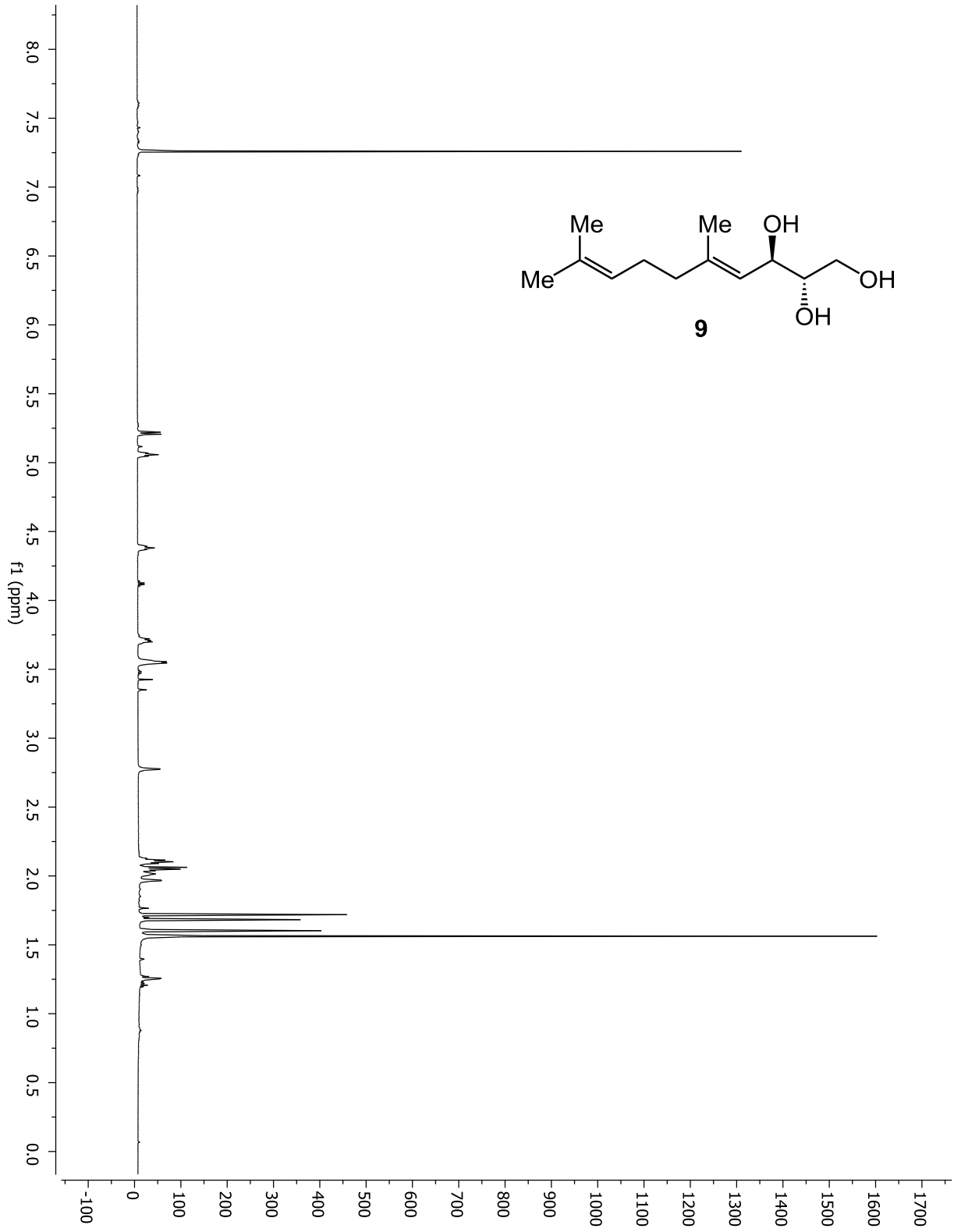
HO
Me
B
O
O
B
O
N
Boc

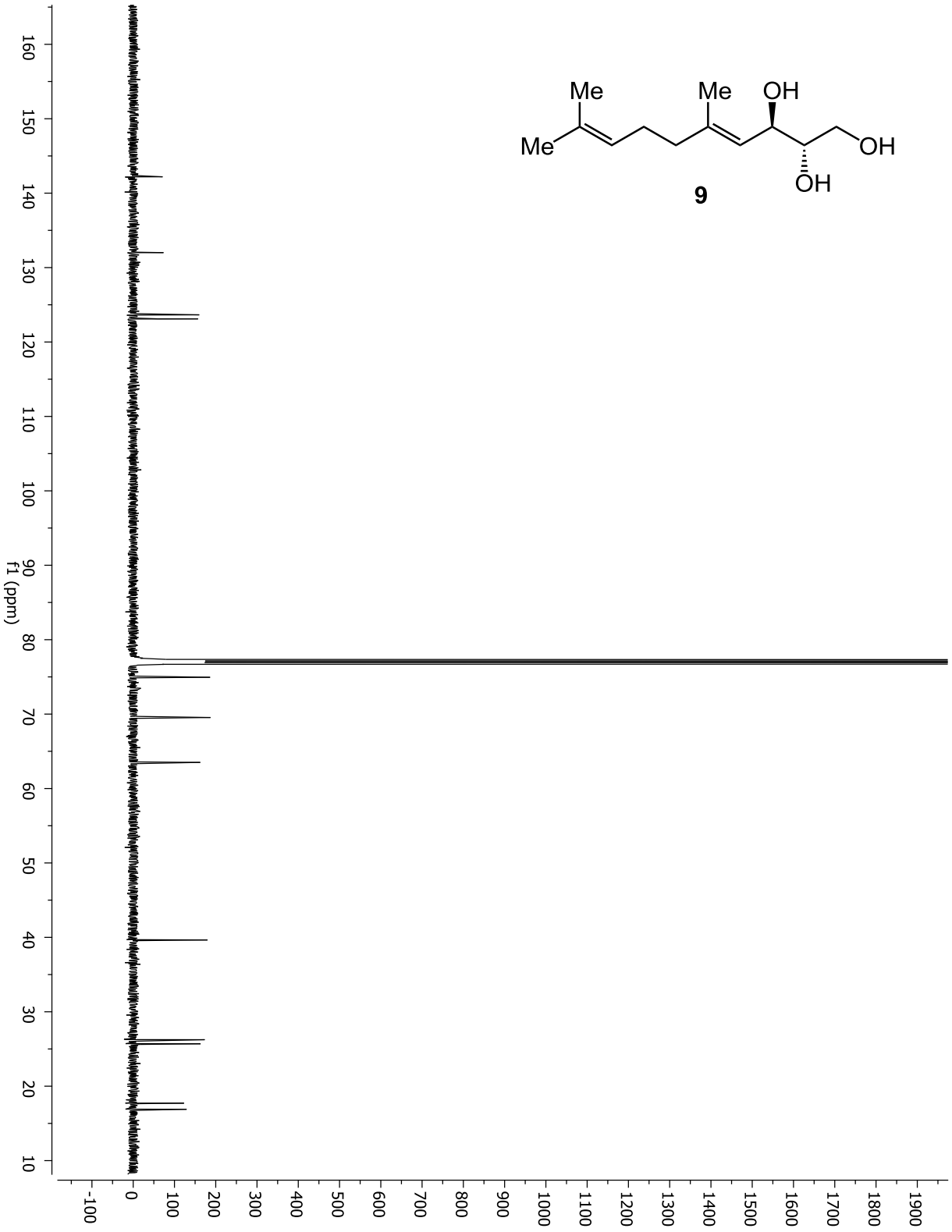
8

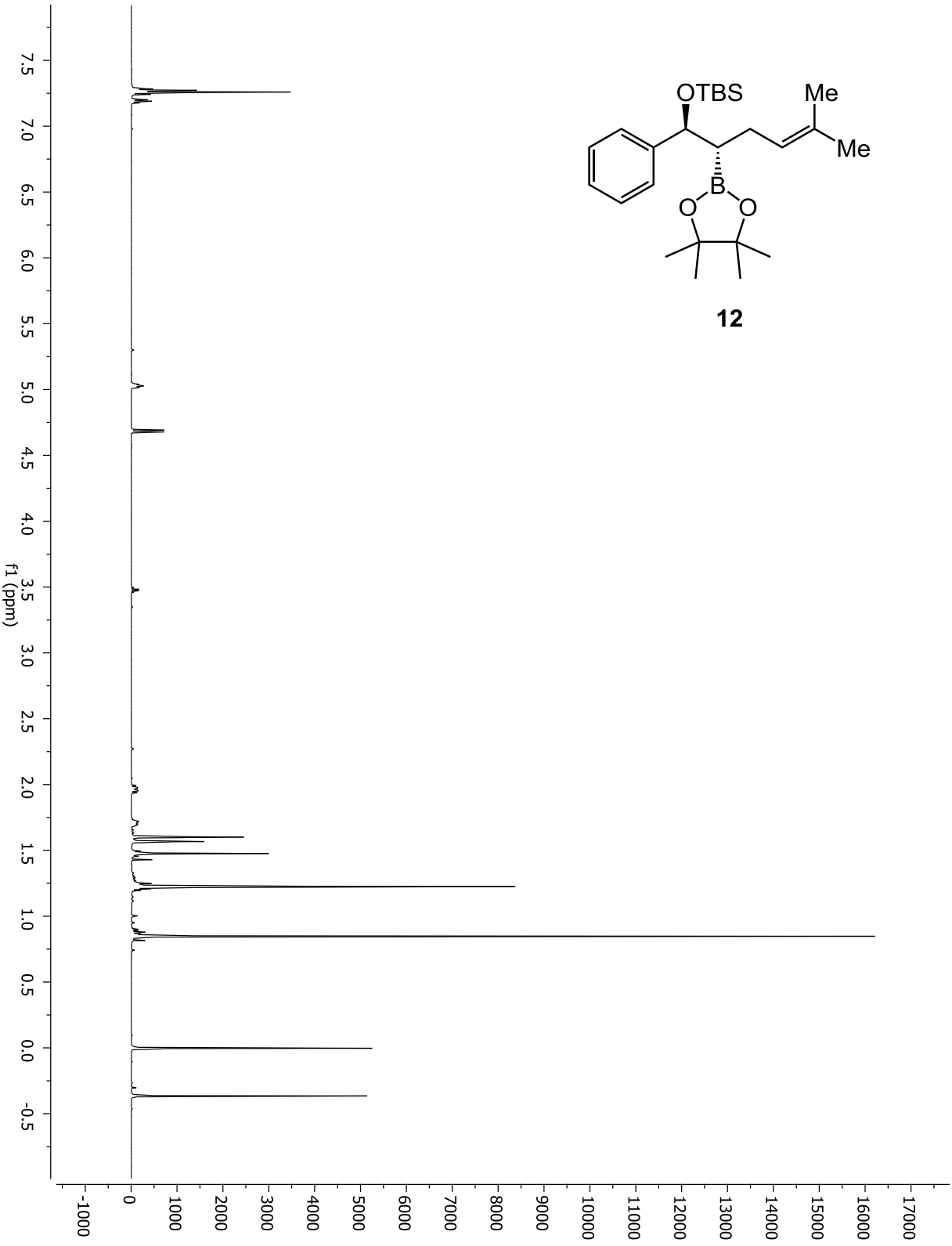

T = 25 °C
T = 35 °C
T = 45 °C
T = 55 °C
B(pin)
Me
HO
B(pin)
N
Boc
8
f1 (ppm)

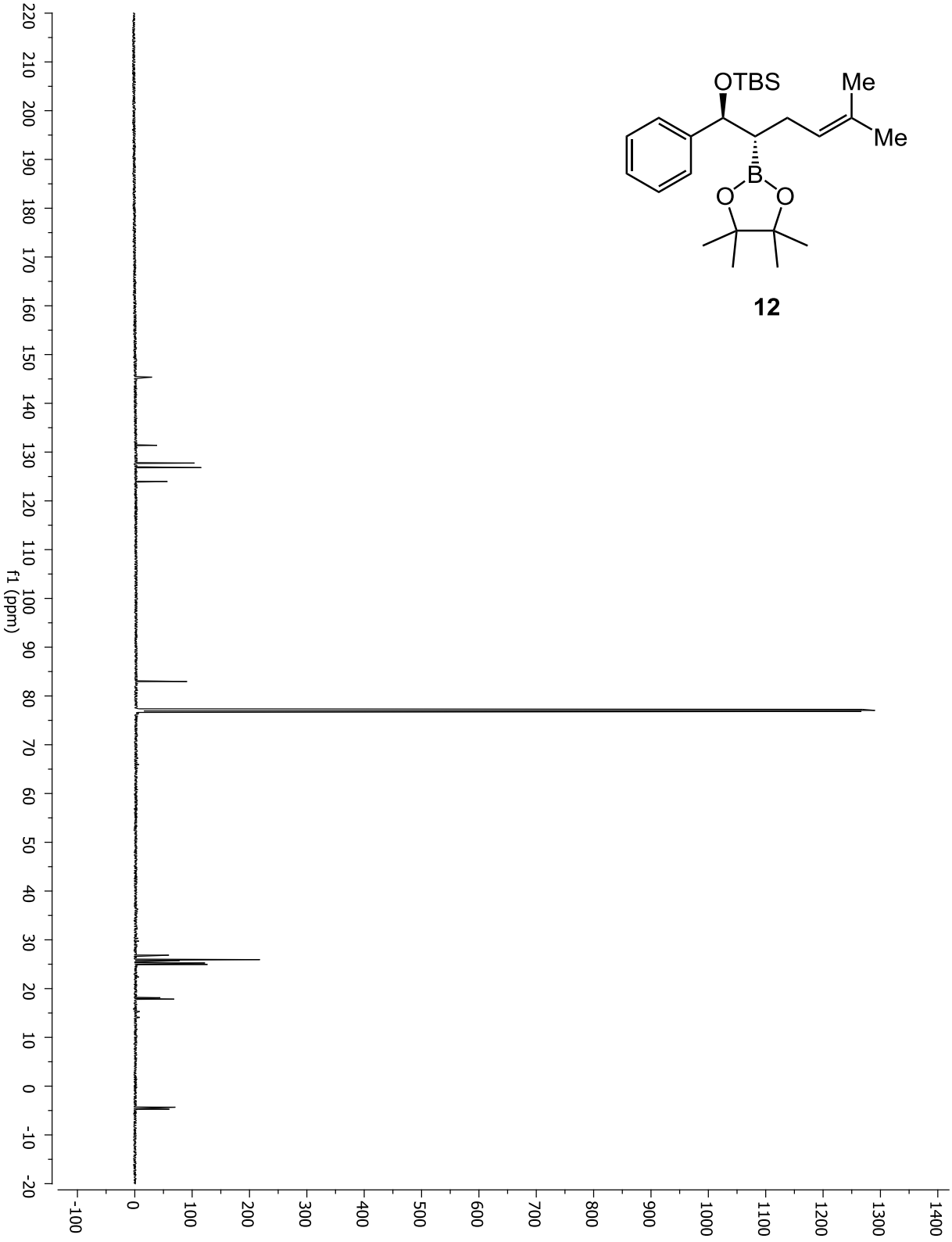

f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
0 50 100 150 200 250 300 350 400 450 500
HO
Me
B
O
O
B
O
O
N
Boc

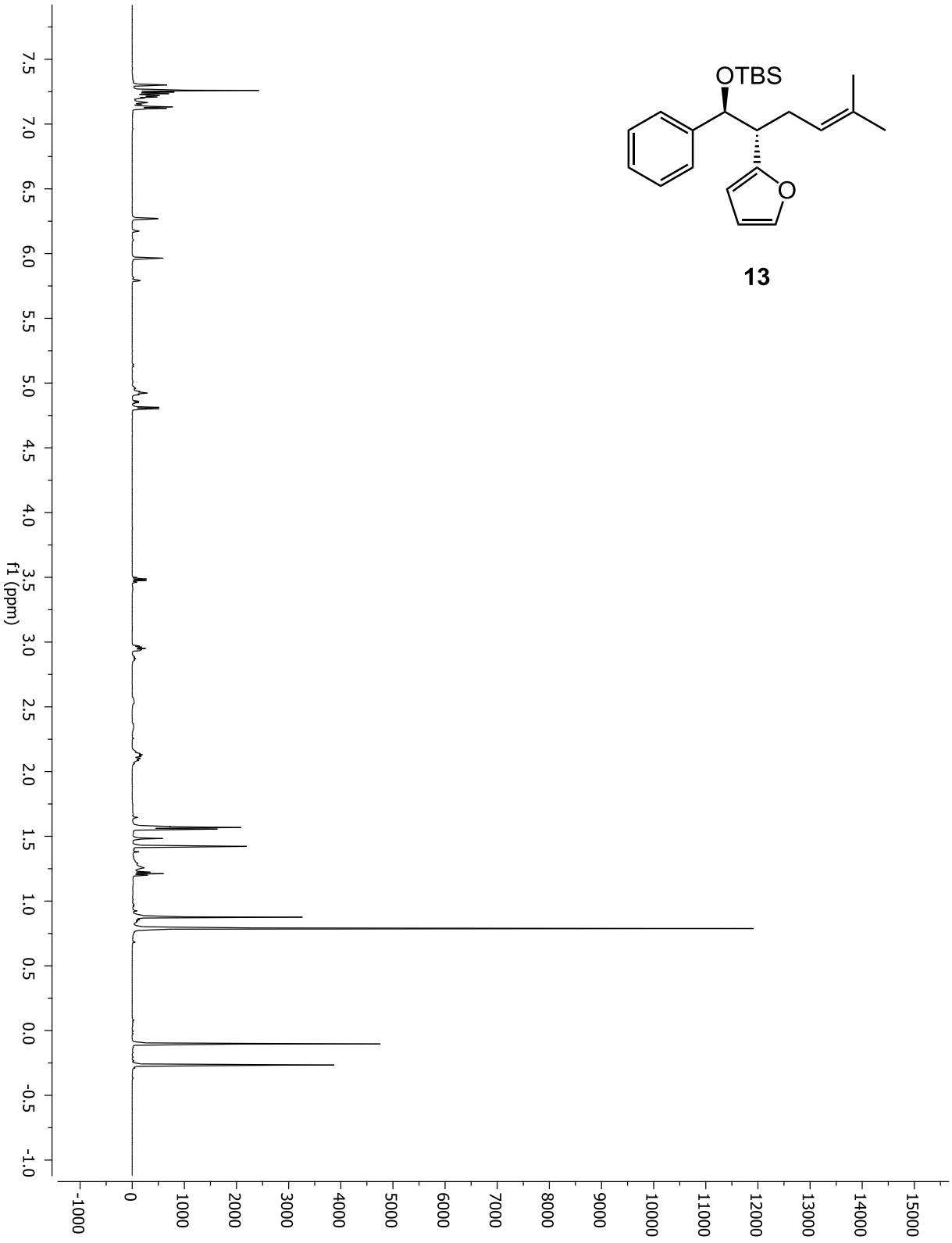
8

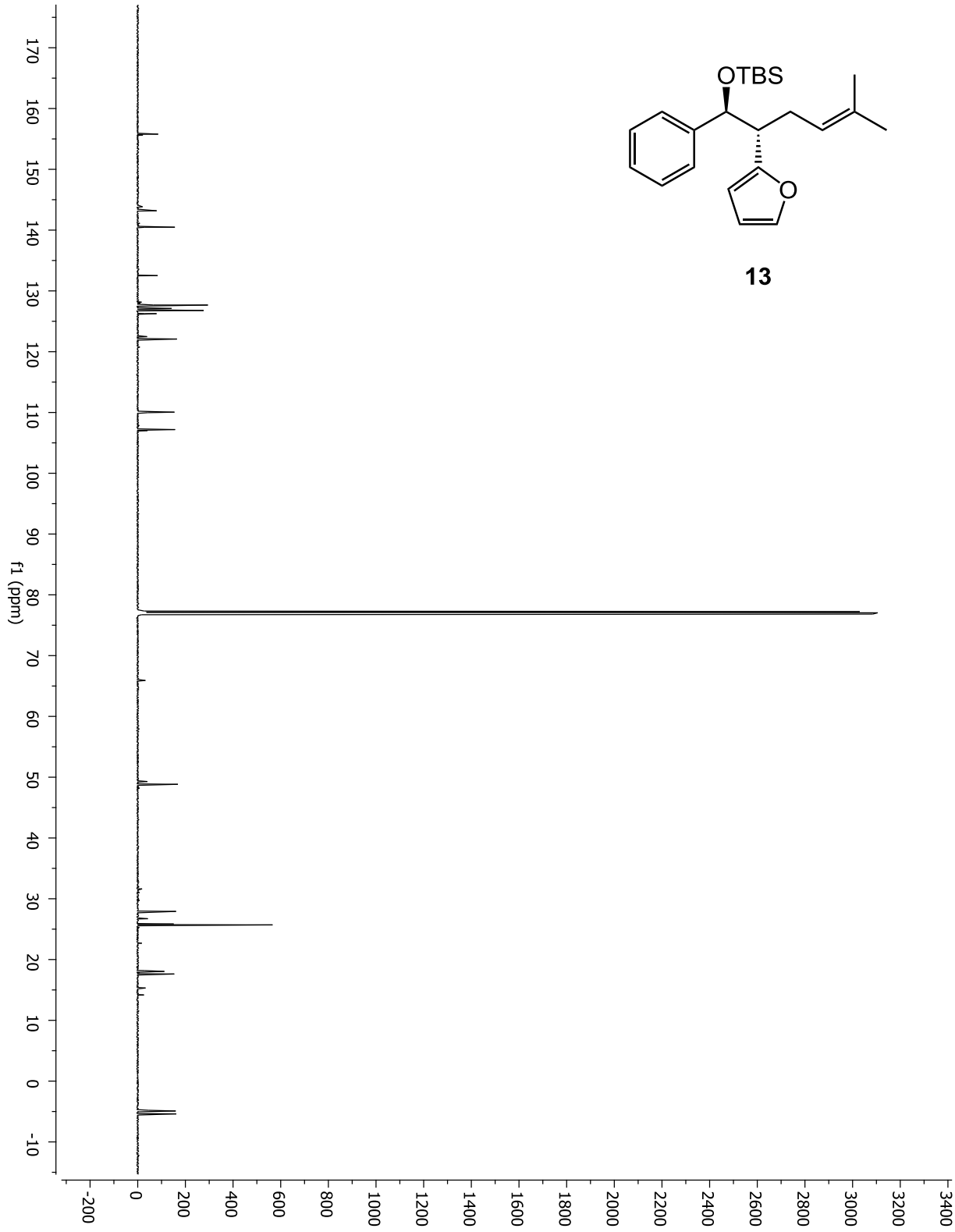

Me
Me
OH
Me
OH
OH
9
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700

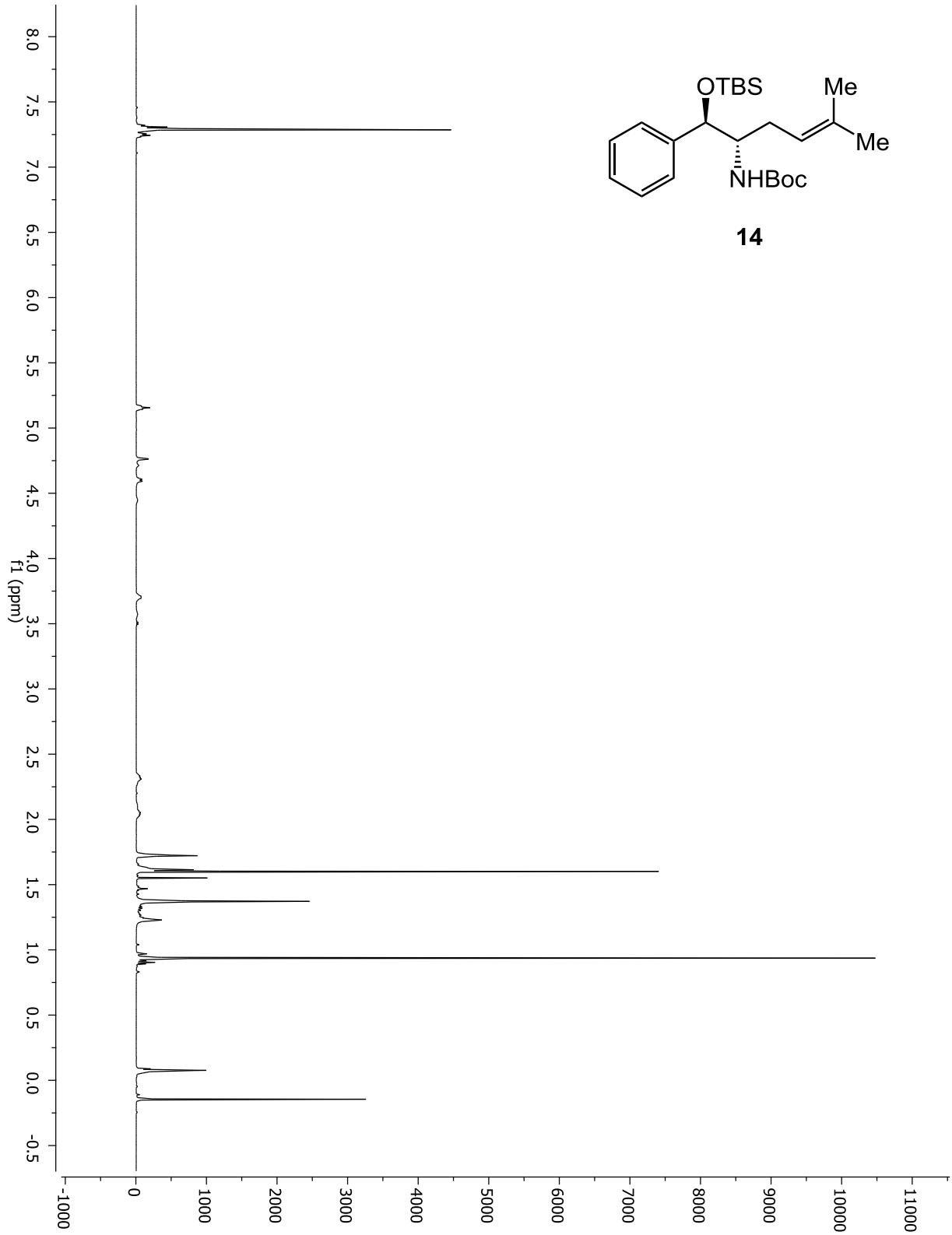

Me
Me
OH
Me
OH
OH
9
f1 (ppm)
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
-100
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900

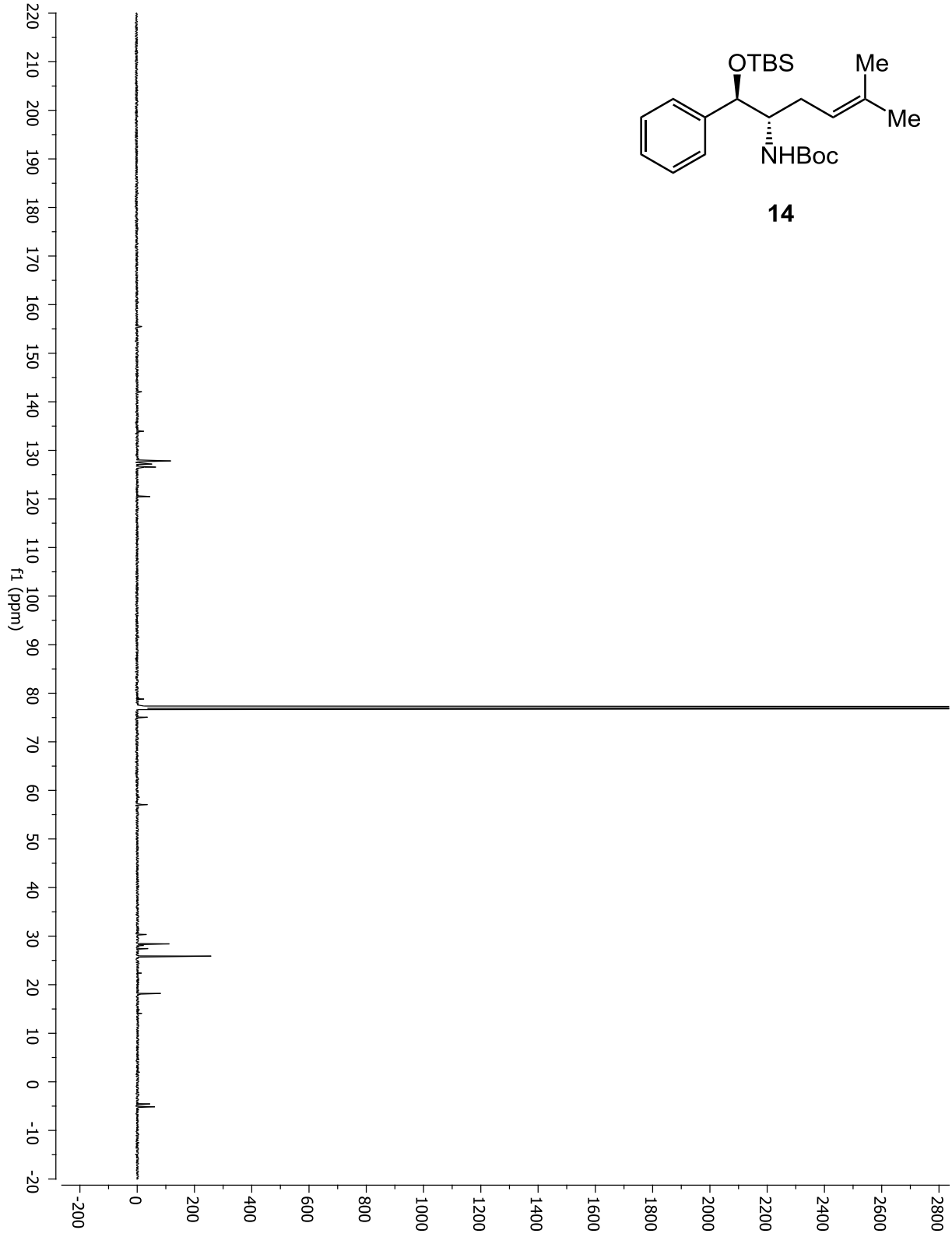

OTBS
Me
Me
B
O
O
12
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000

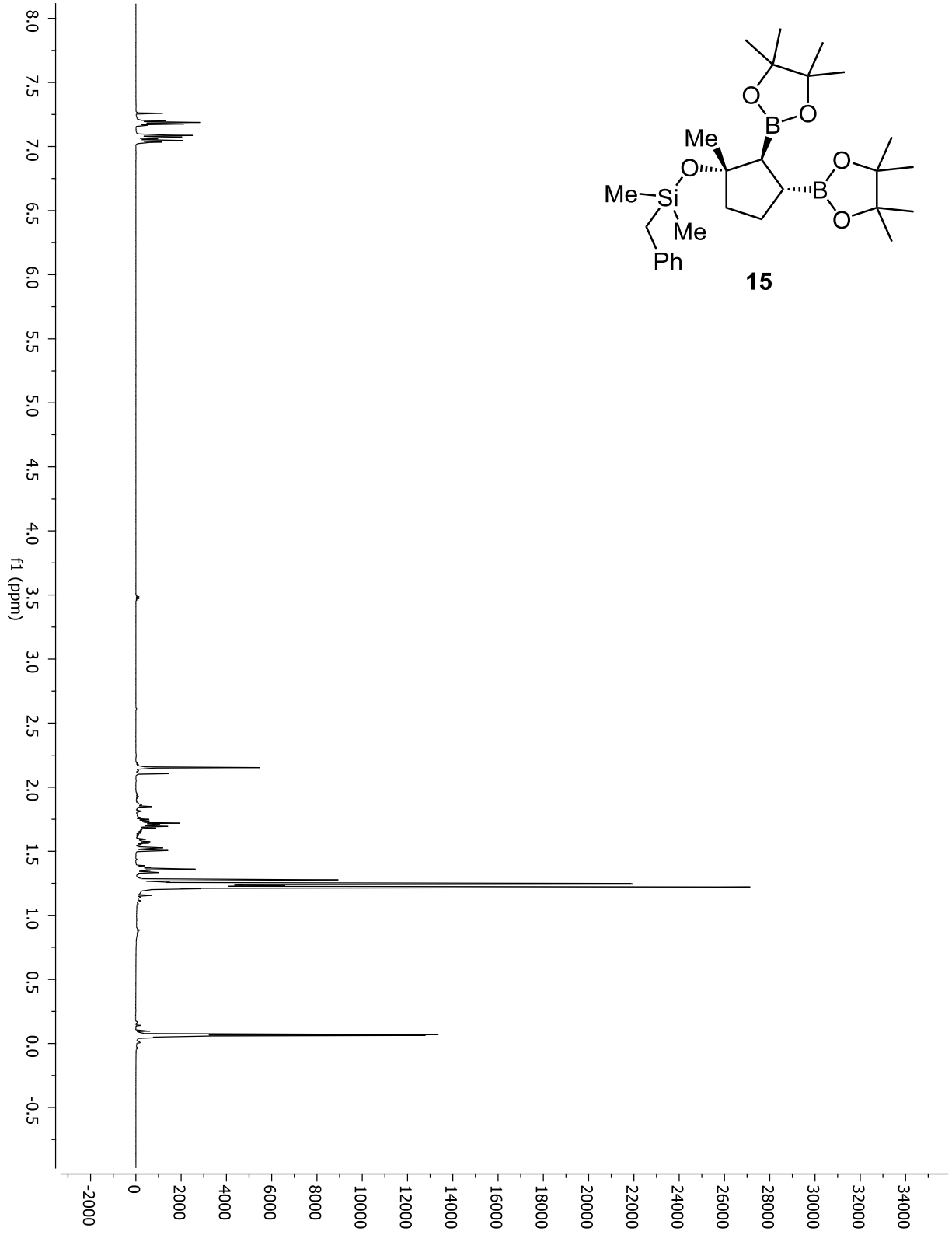

OTBS
Me
Me
B
O
O
12
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0 -10 -20
-100 0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400

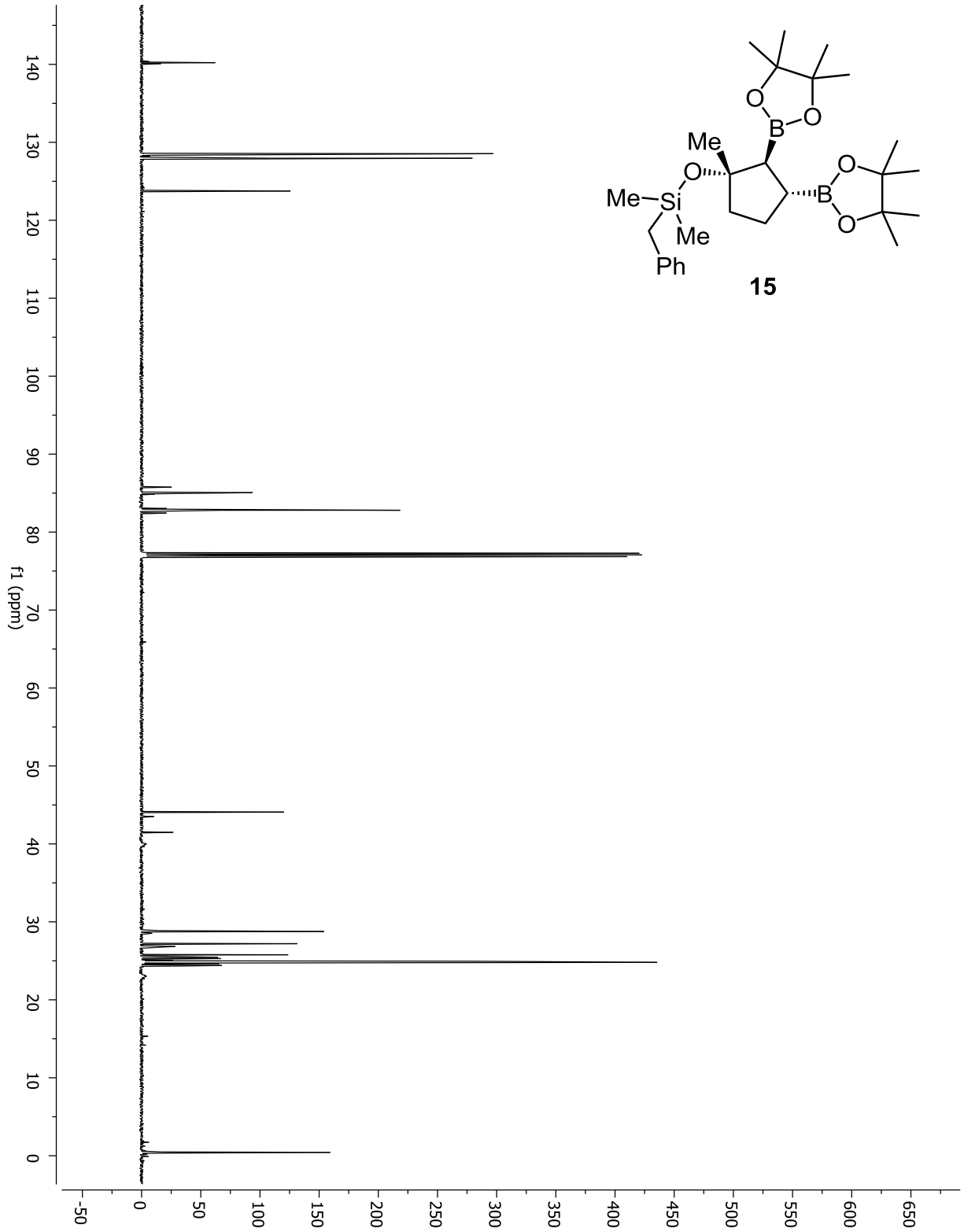

OTBS
O
13
f1 (ppm)
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000


OTBS
O
13
f1 (ppm)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-200
0
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
3200
3400

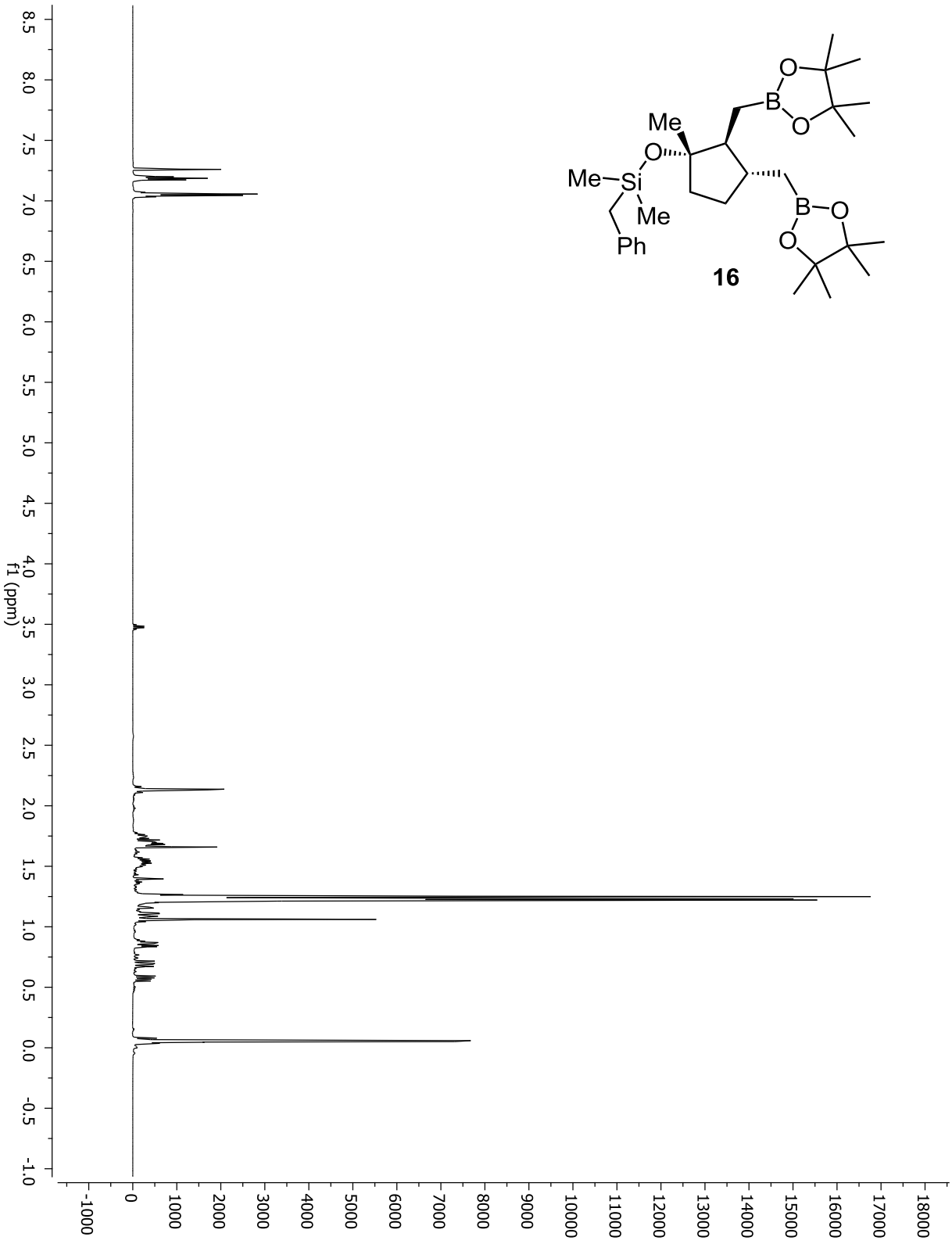

OTBS
Me
Me
NHBoc
14
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000

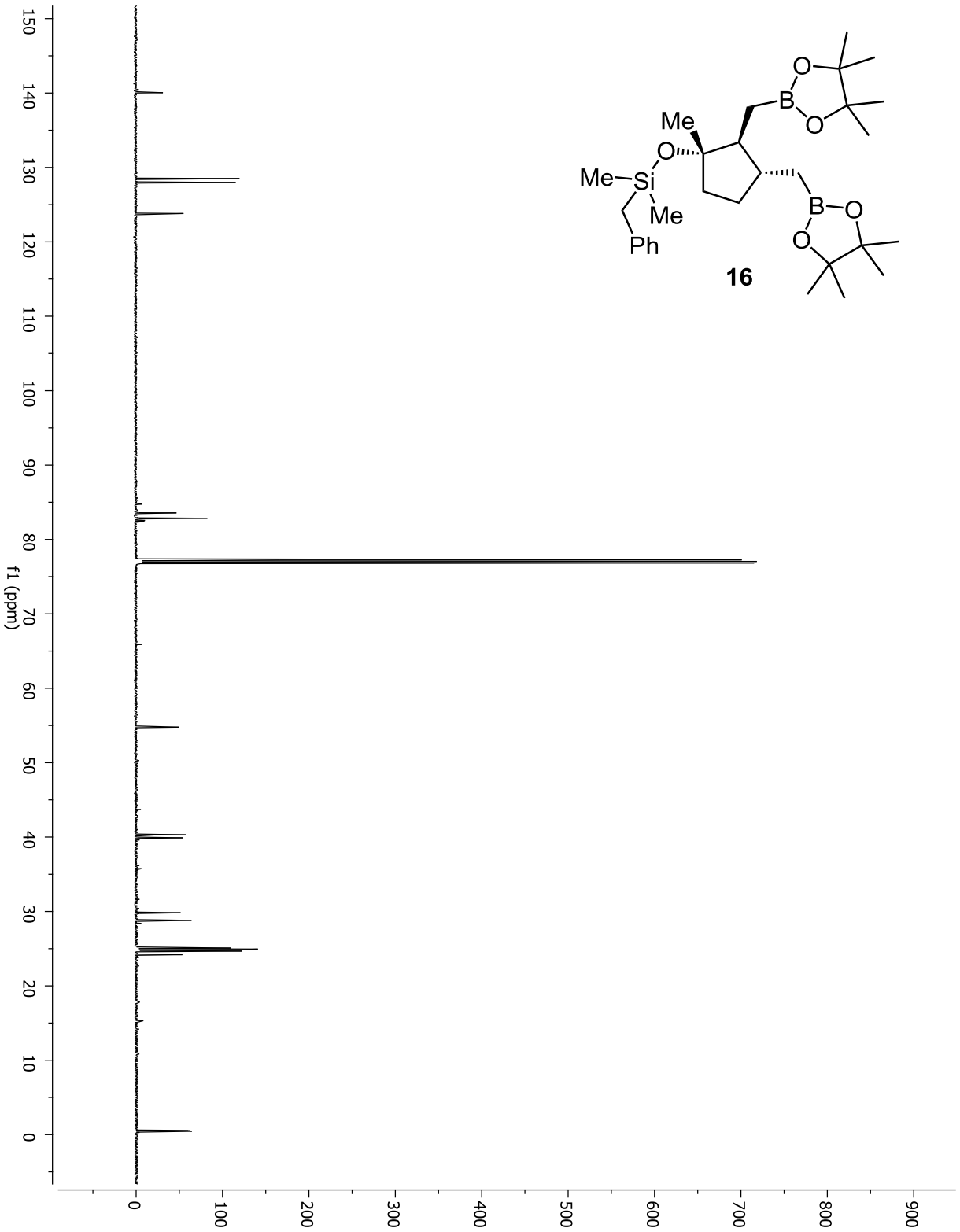

OTBS
Me
Me
NHBoc
14
f1 (ppm)

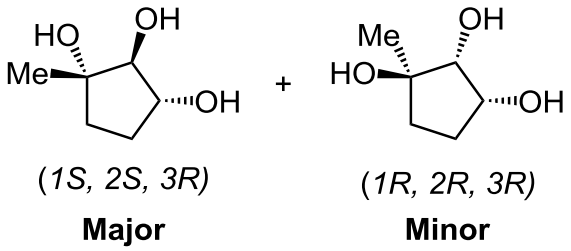

Me
O
Me–Si
Me
Ph
B
O
O
B
O
O
15
f1 (ppm)
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-2000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000
22000
24000
26000
28000
30000
32000
34000


f1 (ppm)
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-50
0
50
100
150
200
250
300
350
400
450
500
550
600
650
Me
O
B
O
O
Me
Si
Me
Ph
B
O
O

15

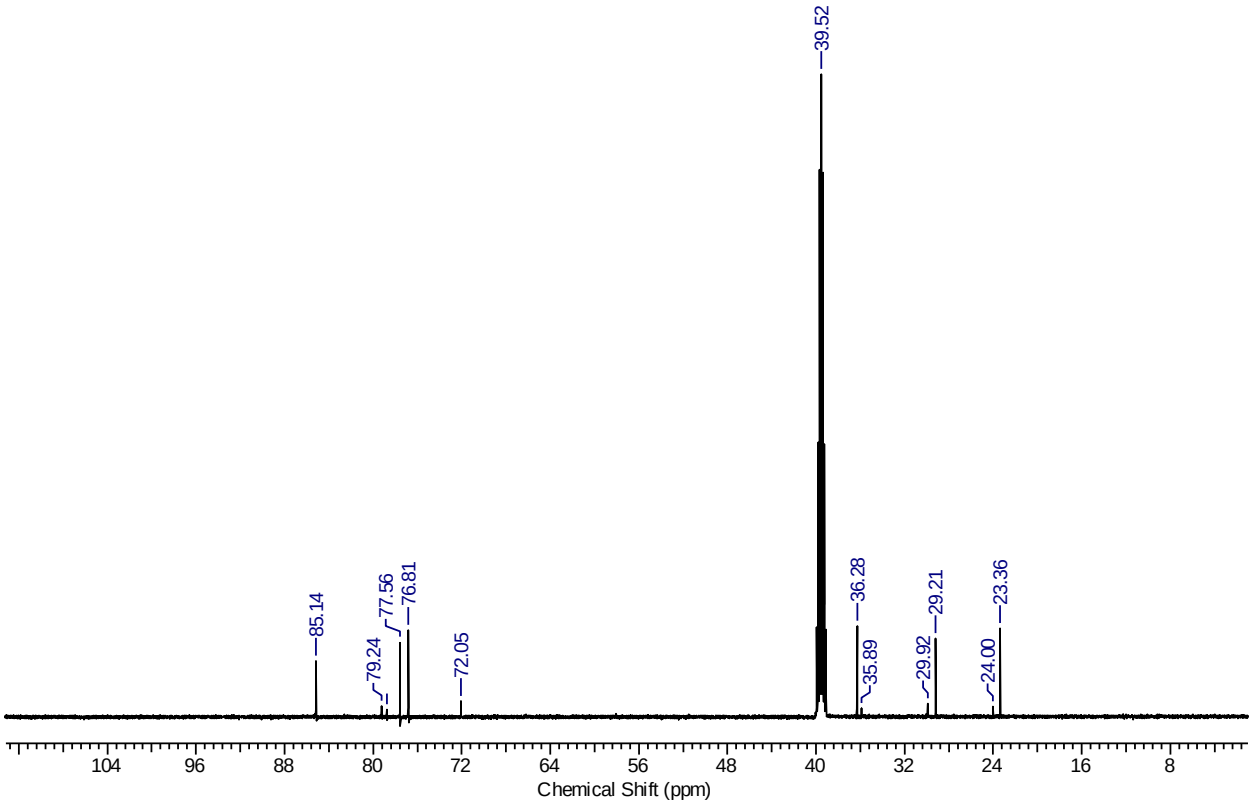

Me
O
Me–Si
Me
Ph
B
O
O
B
O
O
16
f1 (ppm)
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1000
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
11000
12000
13000
14000
15000
16000
17000
18000

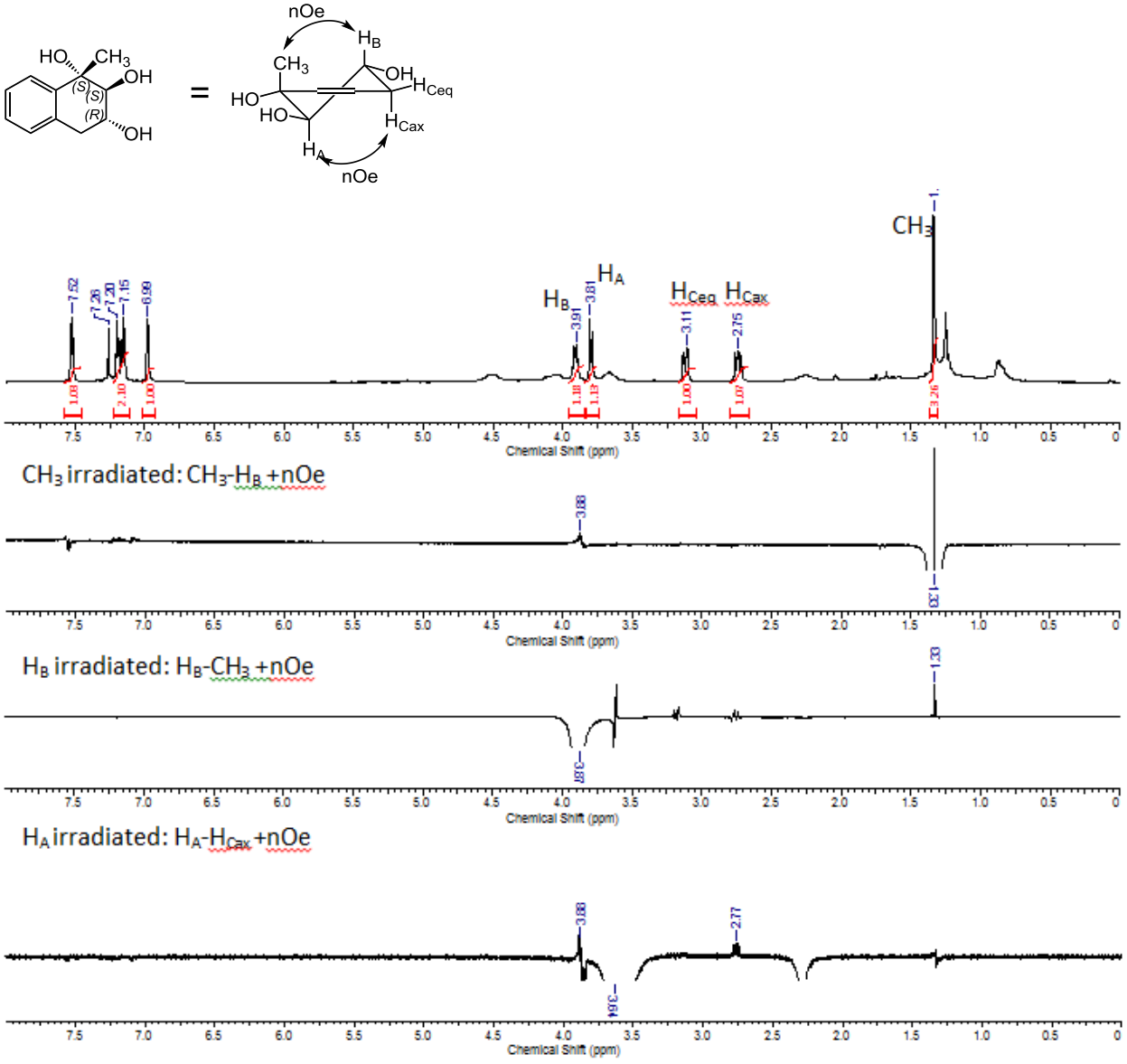

f1 (ppm)
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0
100
200
300
400
500
600
700
800
900
Me
O
Me
Si
Me
Ph
B
O
O
B
O
O
16

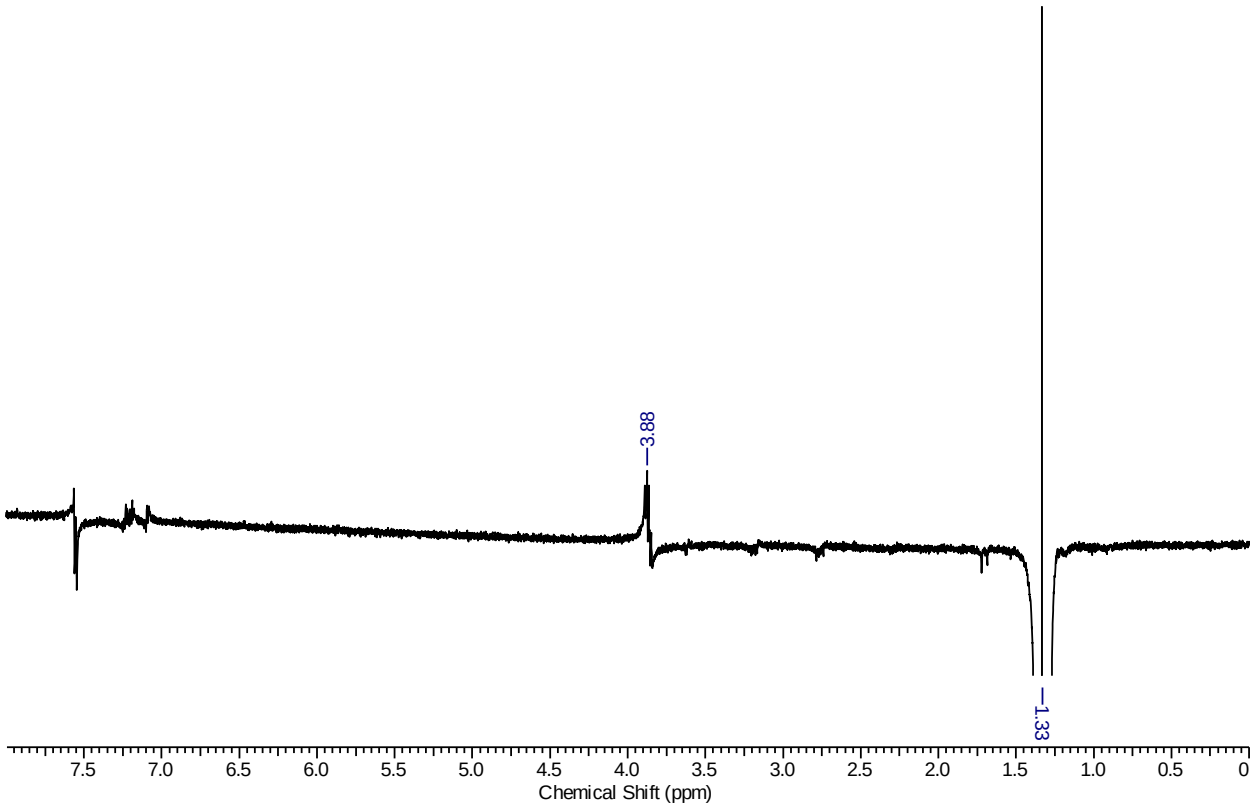


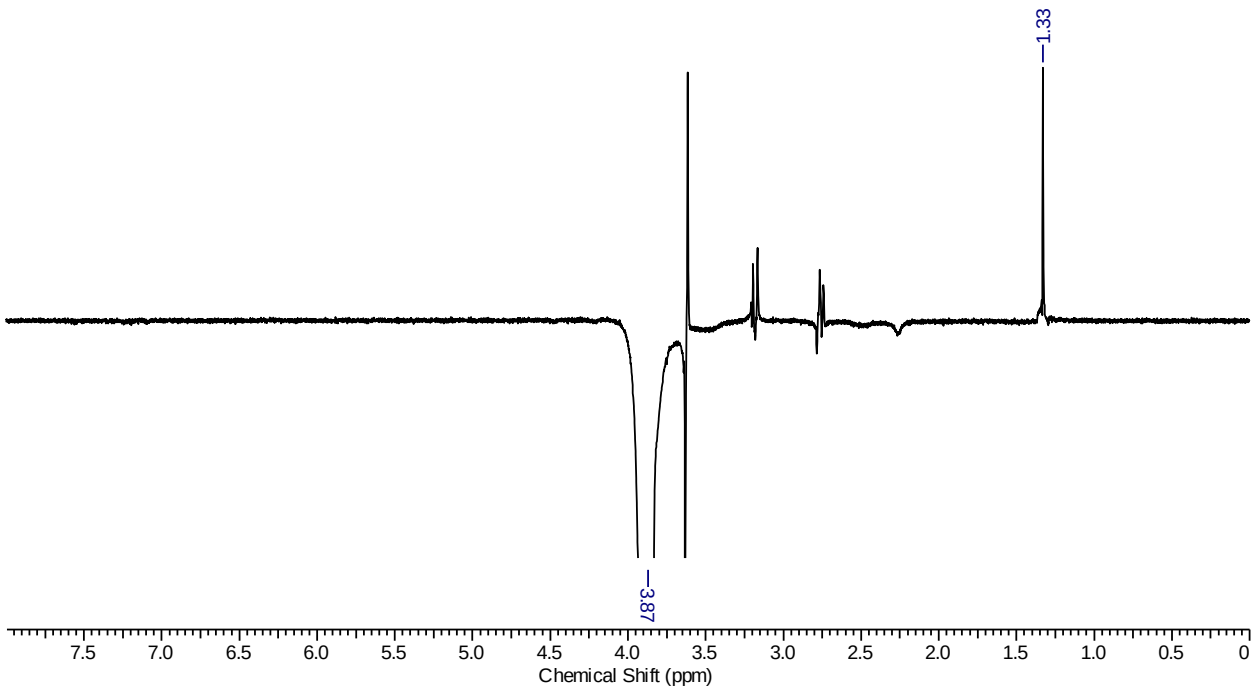
(1S, 2S, 3R)
Major

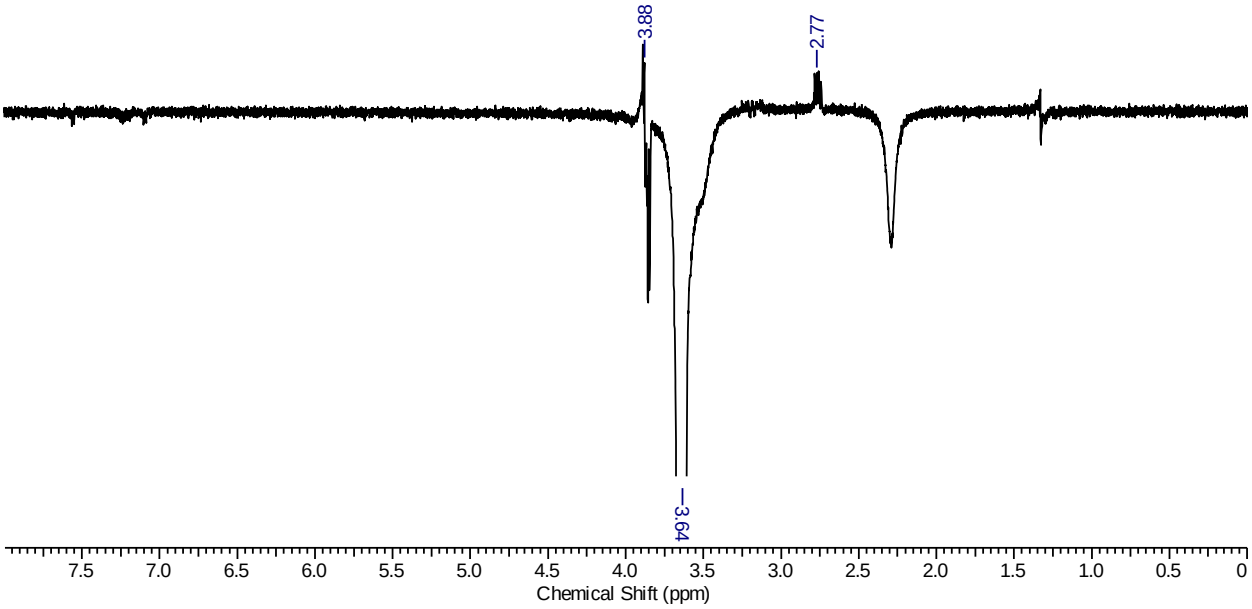
(1R, 2R, 3R)
Minor




nOe
HB
CH3
OH
HCeq
HO
HO
HCax
HA
nOe
HO
CH3
OH
(S)
(S)
(R)
OH
=
CH3
HB
HA
HCeq
HCax
7.52
7.26
7.20
7.15
6.99
3.91
3.81
3.11
2.75
1.03
2.10
1.00
1.18
1.13
1.00
1.07
3.26
Chemical Shift (ppm)
CH3 irradiated: CH3-HB +nOe
3.88
1.20
Chemical Shift (ppm)
HB irradiated: HB-CH3 +nOe
1.33
3.87
Chemical Shift (ppm)
HA irradiated: HA-HCax +nOe
3.88
2.77
3.64
Chemical Shift (ppm)


3.88
1.33
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)


1.33
3.87
7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0
Chemical Shift (ppm)


3.88
2.77
3.64
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
Chemical Shift (ppm)