Stereospecific conversion of alcohols into pinacol boronic esters using lithiation–borylation methodology with pinacolborane.

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Supporting Information

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1. General experimental information

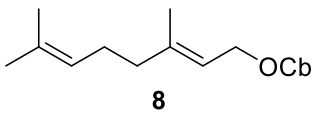
Reaction mixtures were stirred magnetically. Air- and moisture-sensitive reactions were carried out in flame-dried glassware under argon atmosphere using standard Schlenk manifold technique. All required fine chemicals were purchased from Acros Organics, Alfa Aesar, Inochem-Frontier Scientific, or Sigma-Aldrich and used as received unless otherwise mentioned. TMEDA was distilled over CaH_2 before use. Anhydrous solvents were prepared using anhydrous solvent drying columns[1] and were transferred under argon via syringes. Microwave reactions were carried out in a Biotage Initiator EXP EU microwave synthesiser. ^{1}H Nuclear Magnetic Resonance (NMR) spectra were recorded in $CDCl_3$ or DMSO-*d*6 at 301, 400 or 500 MHz on a Joel Lambda 300, Joel ECP (Eclipse) 400, a Varian 400, or a Varian 500 Fourier transform spectrometer. Chemical shifts (δ_H) are quoted in parts per million (ppm) and referred to $CHCl_3$ (7.27 ppm) or DMSO-*d*6 (2.50 ppm). ^{1}H NMR coupling constants are reported in hertz and refer to apparent multiplicities. Data are reported as follows: chemical shift, multiplicity (s = singlet, br. s = broad singlet, d = doublet, t = triplet, q = quartet, quin = quintet, sext = sextet, sept = septet, m = multiplet, dd = doublet of doublet, etc.), coupling constant, integration, and assignment. ^{13}C NMR spectra were recorded at 101 or 126 MHz on a Joel Lambda 300, a Jeol ECP (Eclipse) 400, a Varian 400, or a Varian 500 instrument respectively. Chemical shifts (δ_C) are quoted in ppm referenced to $CHCl_3$ (77.00 ppm) or DMSO-*d*6 (39.51 ppm). ^{11}B NMR spectra were measured using Norell S-200-QTZ quartz NMR tubes at 96 MHz on a Jeol Lambda 300 or a Joel ECP (Eclipse) 300 with complete proton decoupling. Mass spectra were recorded by the University of Bristol, School of Chemistry departmental mass spectrometry service using electron impact ionisation (EI), chemical ionisation (CI) or electrospray ionisation (ESI) techniques for low- and high-resolution mass spectra. All infrared spectra were recorded on the neat compounds using a PerkinElmer Spectrum One FT-IR spectrometer, irradiating between 4000 cm^{-1} and 600 cm^{-1}. Only strong and selected absorbances (ν_{max}) are reported. Analytical TLC was performed on aluminium backed silica plates (Merck, Silica Gel 60 F_{254}, 0.25 mm). Compounds were visualised by exposure to UV light or by staining the plates with 5% solution of phosphomolybdic acid ($H_3PMo_{12}O_{40}$) in EtOH followed by heating. Flash column chromatography was performed on silica gel (Aldrich, Silica Gel 60, 40–63 μm). All mixed solvent eluents are reported as v/v solutions. Optical rotations were obtained using a Bellingham + Stanley Ltd. ADP220 polarimeter. Melting points were measured with a Reichert hot stage apparatus and are uncorrected. Chiral high performance liquid chromatography (HPLC) separations were performed on an Agilent 1100 Series HPLC unit equipped with UV–vis Diode-Array detector using Daicel Chiralpak IA, IB and IC columns (4.6 × 250 mm^2, 5 μm) fitted with guards (4 × 10 mm^2). Supercritical fluid chromatography (SFC) was performed on a Thar SFC investigator using Daicel Chiralpak IA or IB columns (4.6 × 250 mm^2, 5 μm).

2. Detailed procedures and analytical data

2.1 Synthesis of carbamates

General procedure 1 (GP1). The alcohol (1.0 equiv) and *N,N*-diisopropylcarbamoyl chloride (1.2 equiv) were dissolved in anhydrous toluene (1.0 M) under an inert atmosphere in a microwave vial. Et_3N (1.3 equiv) was added, the vial was sealed and heated for 1 h at 150 °C. After cooling to ambient temperature, the salts were removed by filtration through a plug of silica and the solids were thoroughly washed with diethyl ether. The solvent was removed *in vacuo* and the residue was subjected to column chromatography to afford the pure carbamate.

(*E*)-3,7-Dimethylocta-2,6-dien-1-yl diisopropylcarbamate (8)



8

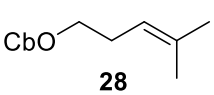
According to GP1, geraniol (500 mg, 3.24 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (637 mg, 3.89 mmol, 1.2 equiv) and Et_3N (507 µL, 4.21 mmol, 1.3 equiv) in anhydrous toluene (4.5 mL) afforded after purification by column chromatography (SiO_2, PE/diethyl ether 9:1) primary carbamate **8** (850 mg, 3.01 mmol, 93%) as a clear colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 5.37 (t, *J* = 6.9 Hz, 1 H, CH), 5.08 (t, *J* = 6.8 Hz, 1 H, CH), 4.59 (d, *J* = 6.9 Hz, 2 H, CH_2OCb), 3.98 (br. m, 1 H, C*H*$(CH_3)_2$), 3.85 (br. m, 1 H, C*H*$(CH_3)_2$), 2.14–2.01 (m, 4 H, CH_2), 1.69 (s, 3 H, CH_3), 1.67 (s, 3 H, CH_3), 1.60 (s, 3 H, CH_3), 1.19 (d, *J* = 6.9 Hz, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_c ppm 156.0 (NCO), 140.8 (C), 131.8 (C), 124.0 (CH), 119.7 (CH), 61.6 (CH_2OCb), 45.9 (br., *C*H$(CH_3)_2$), 45.4 (br., *C*H$(CH_3)_2$), 39.6 (CH_2), 26.5 (CH_2), 25.8 (CH_3), 21.2 (br., CH_3), 17.8 (CH_3), 16.5 (CH_3).

The data are in accordance with that reported in literature.[2]

4-Methylpent-3-en-1-yl diisopropylcarbamate (28)



28

According to GP1, 4-methyl-3-pentene-1-ol (350 µL, 3.00 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (589 mg, 3.60 mmol, 1.2 equiv) and Et_3N (544 µL, 3.90 mmol, 1.3 equiv) in anhydrous toluene (3.0 mL) gave after column chromatography (SiO_2, PE/diethyl ether 9:1) primary carbamate **28** (593 mg, 2.61 mmol, 87%) as a colourless oil.

R_f (hexanes/EtOAc 1:1) 0.65.

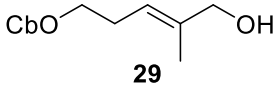
^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 5.13 (tq, *J* = 7.2, 1.2 Hz, 1 H, CH), 4.04 (t, *J* = 6.8 Hz, 2 H, CH_2OCb), 3.73 (br. m, 2 H, C*H*$(CH_3)_2$), 2.33 (q, *J* = 6.9 Hz, 2 H, CH_2), 1.69 (s, 3 H, CH_3(*trans*)), 1.62 (s, 3 H, CH_3(*cis*)), 1.19 (d, *J* = 6.8 Hz, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_c ppm 156.0 (NCO), 134.0 (C), 120.4 (CH), 64.5 (CH_2OCb), 46.0 (br., *C*H$(CH_3)_2$), 45.4 (br., *C*H$(CH_3)_2$), 28.3 (CH_2), 25.9 (CH_3(*trans*)), 21.2 (br., CH_3), 17.9 (s, 3 H, CH_3(*cis*)).

ν_{max} (neat) = 2969, 1688, 1435, 1289, 1133, 1057, 771 cm^{-1}.

HRMS (ESI^+) calc. for $C_{13}H_{25}NO_2Na$ $[M+Na]^+$ 250.1783, found 250.1783.

(*E*)-5-Hydroxy-4-methylpent-3-en-1-yl diisopropylcarbamate (29)



29

A solution of SeO_2 (22.2 mg, 0.20 mmol, 0.2 equiv), *tert*-butyl-hydroperoxide (0.75 mL, 5.0 M in hexanes, 3.75 mmol, 3.75 equiv) and salicylic acid (27.6 mg, 0.20 mmol, 0.2 equiv) in CH_2Cl_2 (1.0 mL) was cooled to 0 °C. To the stirred mixture a solution of carbamate **28** (228 mg, 1.00 mmol, 1.0 equiv) in CH_2Cl_2 (1.0 mL) was added dropwise. The mixture warmed to ambient temperature and stirred for 20 h. The reaction was monitored by TLC and, when all starting material was consumed, the mixture was cooled to 0 °C and a solution of $NaBH_4$ (56.7 mg, 1.50 mmol, 1.5 equiv) and aqueous NaOH (0.32 mL, 0.2 M) in MeOH (1.0 mL) was added dropwise. The reaction mixture was allowed to warm to room temperature, stirred for 6 h and diluted with pentane (15 mL) and water (10 mL). The phases were separated and the aqueous layer was extracted with pentane (2 × 20 mL). The organics were combined and washed with brine (30 mL), dried over $MgSO_4$, filtered, and concentrated. The crude product was purified by column chromatography (SiO_2, PE/EtOAc 9:1 → 7:3) to yield primary alcohol **29** (193 mg, 0.79 mmol, 79%) as clear colourless oil.

R_f (hexanes/EtOAc 7:3) 0.12.

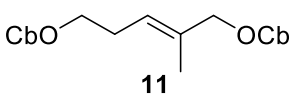
^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 5.45 (tt, *J* = 7.1, 1.3 Hz, 1 H, CH), 4.09 (t, *J* = 6.7 Hz, 2 H, CH_2OCb), 4.08 (br. m, 1 H, C*H*$(CH_3)_2$), 4.01 (s, 2 H, CH_2OH), 3.73 (br. m, 1 H, C*H*$(CH_3)_2$), 2.41 (q, *J* = 7.1 Hz, 2 H, CH_2), 1.89 (s, 3 H, CH_3), 1.53 (br. s, 1 H, OH), 1.19 (d, *J* = 6.8 Hz, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_c ppm 156.0 (NCO), 137.3 (C), 121.9 (CH), 68.8 (CH_2OH), 64.1 (CH_2OCb), 45.3 (br., *C*H(CH_3)$_2$), 27.9 (CH_2), 21.0 (br., CH_3), 13.9 (CH_3).

ν_{max} (neat) = 3439, 2969, 1670, 1437, 1292, 1134, 1069, 771 cm^{-1}.

HMRS (ESI$^+$) calc. for $C_{13}H_{25}NO_3Na$ $[M+Na]^+$ 266.1732, found 266.1731.

(*E*)-2-Methylpent-2-ene-1,5-diyl bis(diisopropylcarbamate) (11)



11

According to GP1, allylic alcohol **29** (200 mg, 0.82 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (188 mg, 1.15 mmol, 1.4 equiv) and Et_3N (138 µL, 0.99 mmol, 1.2 equiv) in anhydrous toluene (0.9 mL) gave after column chromatography (SiO_2, PE/EtOAc 9:1) biscarbamate **11** (271 mg, 0.73 mmol, 89%) as a clear colourless oil.

R_f (hexanes/EtOAc 7:3) 0.43.

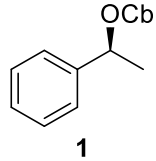
^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 5.49 (tq, *J* = 7.2, 1.2 Hz, 1 H, CH), 4.48 (s, 2 H, CCH_2OCb), 4.10 (t, *J* = 6.7 Hz, 2 H, CH_2CH_2OCb), 3.85 (br. m, 4 H, C*H*(CH_3)$_2$), 2.42 (q, *J* = 6.8 Hz, 2 H, CH_2), 1.70 (s, 3 H, CH_3), 1.21 (d, *J* = 6.8 Hz, 12 H, CH_3), 1.19 (d, *J* = 6.8 Hz, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 155.9 (NCO), 155.7 (NCO), 133.5 (C), 124.2 (CH), 70.3 (C*C*H_2OCb), 64.0 (CH_2CH_2OCb), 45.6 (br., *C*H(CH_3)$_2$), 27.9 (CH_2), 20.9 (br., CH_3), 14.4 (CH_3).

ν_{max} (neat) = 2968, 1685, 1433, 1367, 1286, 1132, 1046 cm^{-1}.

HMRS (ESI$^+$) calc. for $C_{20}H_{38}N_2O_4Na$ $[M+Na]^+$ 393.2729, found 393.2718.

(*S*)-1-Phenylethyl diisopropylcarbamate (1)



1

According to GP1, (*S*)-1-phenylethanol (1.53 g, 12.5 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (2.45 g, 15 mmol, 1.2 equiv), Et_3N (2.25 mL, 16.3 mmol, 1.3 equiv) in anhydrous toluene (12 mL) gave after purification by flash chromatography (SiO_2, pentane/EtOAc 6:1) 2.60 g of carbamate **1** (10.4 mmol, 83%) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 7.39–7.33 (m, 4 H, H_{Ar}), 7.28 (m, 1 H, H_{Ar}), 5.86 (q, J = 6.7 Hz, 1 H, CHOCb), 4.08 (br. m, 1 H, C*H*$(CH_3)_2$), 3.83 (br. m, 1 H, C*H*$(CH_3)_2$), 1.56 (d, J = 6.7 Hz, 3 H, CH_3), 1.28–1.17 (br. m, 12 H, CH_3).

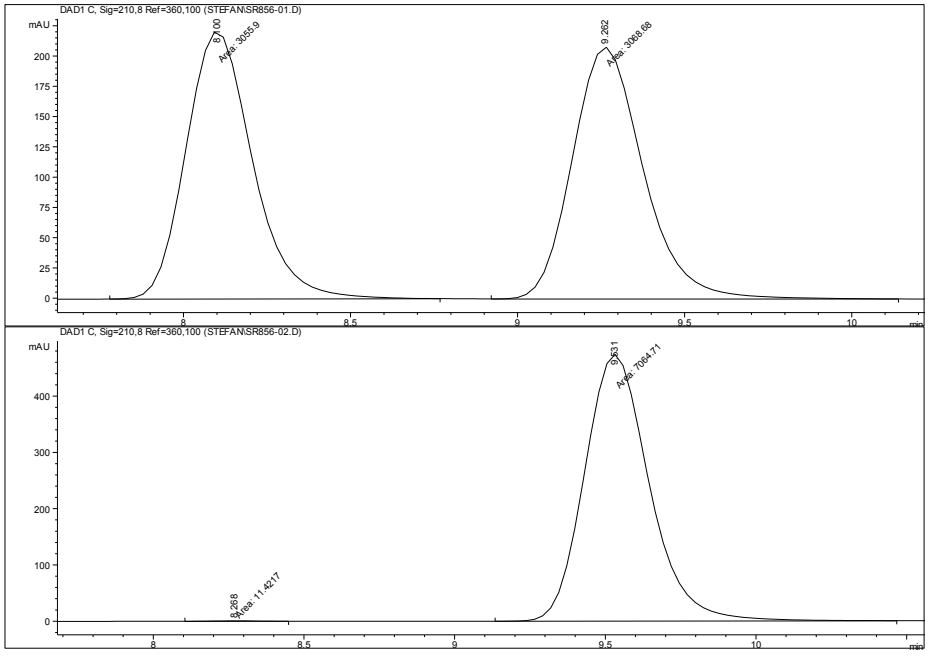
^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 155.0 (NCO), 142.8 (C), 128.3 (CH), 127.4 (CH), 126.0 (CH), 72.7 (CHOCb), 46.1 (br., *C*H$(CH_3)_2$), 45.3 (br., *C*H$(CH_3)_2$), 22.8 (CH_3), 21.3 (br., CH_3), 20.8 (br., CH_3).

[α]$_D^{22}$ −6.5 (*c* 1.0, $CHCl_3$, for 99% ee). Lit. [α]$_D^{20}$ −5.5 (*c* 1.2, CH_2Cl_2, for 99% ee).[3]

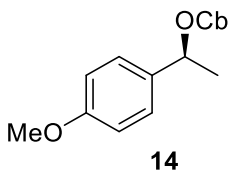
The NMR data are consistent with the literature known compound.[4]

HPLC separation conditions: Chiralpak IA column with guard, 5.0% *i*PrOH in hexane, flow rate 0.7 mL/min, 20 °C; t_R 8.3 min for (*R*)-enantiomer (minor) and t_R 9.5 min for (*S*)-enantiomer (major).

e.r. = 99.9:0.1.



(*S*)-1-(4-Methoxyphenyl)ethyl diisopropylcarbamate (14)



14

According to GP1, (*S*)-1-(4-methoxyphenyl)ethanol (1.52 g, 10.0 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (1.96 g, 12.0 mmol, 1.2 equiv) and Et_3N (1.80 mL, 13.0 mmol, 1.3 equiv) in anhydrous toluene (10 mL) afforded after purification by column chromatography (SiO_2, pentane/EtOAc 4:1) secondary benzylic carbamate **14** (2.05 g, 7.34 mmol, 73%) as a colourless oil.

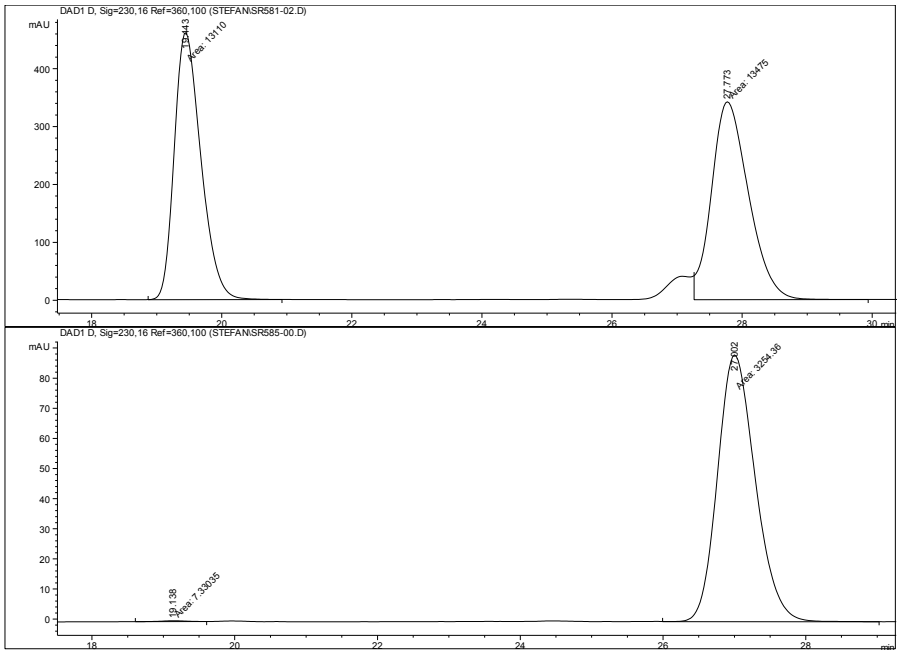
^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 7.31 (AA'BB', J = 8.5 Hz, 2 H, H_{Ar}), 6.88 (AA'BB', J = 8.5 Hz, 2 H, H_{Ar}), 5.81 (q, J = 6.5 Hz, 1 H, CHOCb), 4.12 (br. m, 1 H, C*H*$(CH_3)_2$), 3.80 (s, 3 H, OCH_3), 3.73 (br. m, 1 H, C*H*$(CH_3)_2$), 1.54 (d, J = 6.5 Hz, 3 H, CH_3), 1.19 (d, J = 6.8 Hz, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 158.9 (COMe), 155.1 (NCO), 134.9 (C), 127.4 (CH), 113.7 (CH), 72.3 (CHOCb), 55.2 (OCH_3), 46.3 (br., *C*H$(CH_3)_2$), 45.1 (br., *C*H$(CH_3)_2$), 22.6 (CH_3), 21.5 (br., CH_3), 20.8 (br., CH_3).

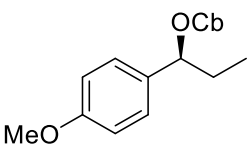
[α]$_D^{22}$ −14.3 (*c* 1.12, CH_2Cl_2, for 99% ee). Lit. [α]$_D^{24}$ −40.0 (*c* 1.0, CH_2Cl_2, for 96% ee).[5]

The analytical data are consistent with the literature known compound.[5]

HPLC separation conditions: Chiralpak IC column with guard, 2.0% *i*PrOH in hexane, flow rate 0.7 mL/min, 20 °C; t_R 19.1 min for (*R*)-enantiomer (minor) and t_R 27.0 min for (*S*)-enantiomer (major).
e.r. = 99.9:0.1.



(*S*)-1-(4-Methoxyphenyl)propyl diisopropylcarbamate (16)



16

According to GP1, (*S*)-1-(4-methoxyphenyl)propan-1-ol (1.80 g, 10.8 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (2.13 g, 13.0 mmol, 1.2 equiv) and Et_3N (1.95 mL, 14.0 mmol, 1.3 equiv) in anhydrous toluene (10 mL) afforded after purification by column

chromatography (SiO_2, pentane/EtOAc 4:1) secondary benzylic carbamate **16** (3.12 g, 10.6 mmol, 98%) as a colourless oil.

R_f (pentane/EtOAc 4:1) 0.48.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 7.27 (AA'BB', J = 8.8 Hz, 2 H, H_{Ar}), 6.87 (AA'BB', J = 8.8 Hz, 2 H, H_{Ar}), 5.59 (t, J = 6.9 Hz, 1 H, CHOCb), 4.07 (br. m, 1 H, C*H*$(CH_3)_2$), 3.80 (s, 3 H, OCH_3), 3.79 (br. m, 1 H, C*H*$(CH_3)_2$), 1.96 (m, 1 H, C*H*H), 1.80 (m, 1 H, CH*H*), 1.21 (br. m, 12 H, CH_3), 0.88 (t, J = 7.3 Hz, 3 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 158.8 (COMe), 155.2 (NCO), 133.6 (C), 127.9 (CH), 113.6 (CH), 77.5 (CHOCb), 55.2 (OCH_3), 45.8 (br., *C*H$(CH_3)_2$), 29.7 (CH_2), 21.2 (br., CH_3), 10.1 (CH_3).

ν_{max} (neat) = 2968, 1682, 1514, 1435, 1285, 1247, 1047, 828 cm^{-1}.

m/z (%) (CI^+) 294 ($[M+H]^+$, 24), 220 (7), 177 (9), 149 ($[M–OCb]^+$, 95), 121 (12), 102 ($[NH(iPr)_2+H]^+$, 40).

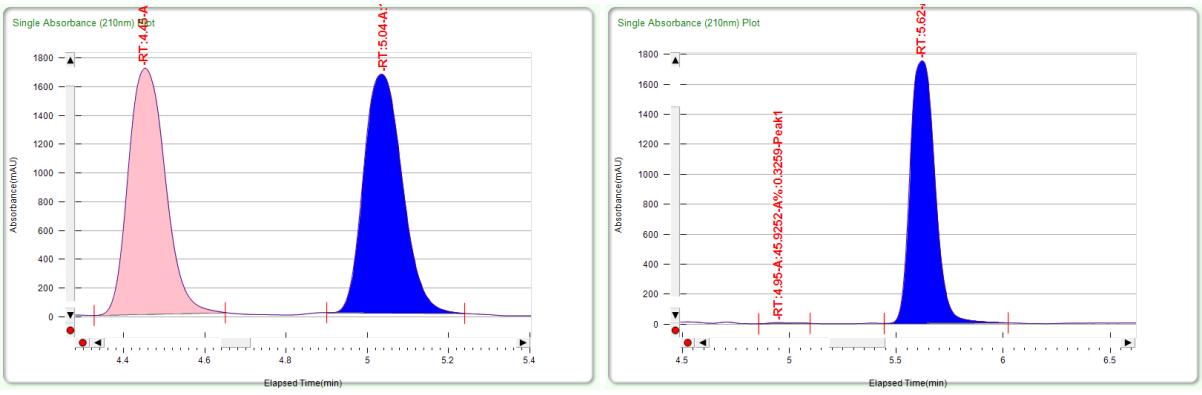
HRMS (CI^+) calcd. for $C_{17}H_{28}NO_3$ $[M+H]^+$ 294.2069, found 294.2065.

[α]$_D^{23}$ –9.0 (*c* 1.0, $CHCl_3$, for 98% ee).

SFC separation conditions: Chiralpak IA column, eluent: 80% CO_2, 18% hexane, 2% *i*PrOH, flow rate 4.0 mL/min, 39.8 °C, 122 bar; t_R 4.95 min for (*R*)-enantiomer (minor) and t_R 5.62 min for (*S*)-enantiomer (major).
e.r. = 99.7:0.3

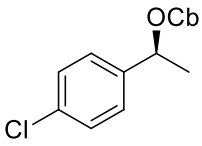
Run Information

Instrument Method	Inj. Vol.	Solvent	Column	Sample	Well Location	Temp.	Flow	% Modifier	Pressure
iso 20%, 4 ml per min, 125 bar	10	10% IPA/Hex	IA	SR448S	21E	39.8	4	20	122



[redacted]

(*S*)-1-(4-Chlorophenyl)ethyl diisopropylcarbamate (18)



18

According to GP1, (*S*)-1-(4-chlorophenyl)ethan-1-ol (99.5:0.5 er) (705 mg, 4.50 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (884 mg, 5.40 mmol, 1.2 equiv) and Et_3N (811 µL, 5.85 mmol, 1.3 equiv) in anhydrous toluene (4.5 mL) afforded after purification by column chromatography (SiO_2, PE/EtOAc 20:1) secondary benzylic carbamate **18** (1.14 g, 4.02 mmol, 89%) as a white solid.

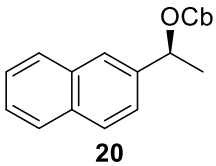
^{1}H NMR (500 MHz, $CDCl_3$) δ_H ppm 7.33–7.27 (m, 4 H, H_{Ar}), 5.80 (q, J = 6.6 Hz, 1 H, CHOCb), 4.08 (br. m, 1 H, C*H*$(CH_3)_2$), 3.78 (br. m, 1 H, C*H*$(CH_3)_2$), 1.52 (d, J = 6.6 Hz, 3 H, CH_3), 1.21 (br. m, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 155.0 (NCO), 141.5 (C), 133.3 (CCl), 128.7 (CH), 127.6 (CH), 72.1 (CHOCb), 45.6 (br., *C*H$(CH_3)_2$), 22.8 (CH_3), 20.9 (br., CH_3).

[α]$_D^{21}$ –18.0 (*c* 0.9, $CHCl_3$, for 99% ee).

The data are in accordance with that reported in literature.[5]

((*S*)-1-(Naphthalen-2-yl)ethyl diisopropylcarbamate (20)



20

According to GP1, (*S*)-1-(naphthalen-2-yl)ethan-1-ol (99.6:0.4 er) (758 mg, 4.40 mmol, 1.0 equiv), *N,N*-diisopropylcarbamoyl chloride (864 mg, 5.30 mmol, 1.2 equiv) and Et_3N (804 µL, 5.80 mmol, 1.3 equiv) in anhydrous toluene (5.0 mL) afforded after purification by column chromatography (SiO_2, pentane/Et_2O 6:1) secondary benzylic carbamate **20** (1.09 g, 3.65 mmol, 83%) as a white solid.

mp 58 °C (pentane/Et_2O).

R_f (pentane/Et_2O 6:1) 0.30.

^{1}H NMR (500 MHz, DMSO-*d*6) δ_H ppm 7.92–7.84 (m, 4 H, H_{Ar}), 7.53–7.48 (m, 3 H, H_{Ar}), 5.90 (q, J = 6.6 Hz, 1 H, CHOCb), 3.95 (br. m, 1 H, C*H*$(CH_3)_2$), 3.83 (br. m, 1 H, C*H*$(CH_3)_2$), 1.55 (d, J = 6.6 Hz, 3 H, CH_3), 1.13 (br. m, 12 H, CH_3).

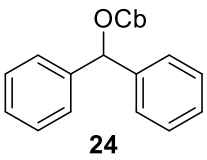
^{13}C NMR (126 MHz, DMSO-*d*6) δ_C ppm 153.9 (NCO), 140.1 (C), 132.7 (C), 132.4 (C), 128.0 (CH), 127.7 (CH), 127.4 (CH), 126.2 (CH), 125.9 (CH), 124.3 (CH), 124.1 (CH), 71.9 (CHOCb), 45.3 (br., *C*H$(CH_3)_2$), 22.5 (CH_3), 20.8 (br., CH_3).

ν_{max} (neat) = 2988, 1675, 1434, 1282, 1054 cm^{-1}.

HRMS (ESI$^+$) calcd. for $C_{19}H_{25}NNaO_2$ $[M+Na]^+$ 322.1782, found 322.1777.

[α]$_D^{21}$ −15.0 (*c* 1.6, MeOH, for 99% ee).

Benzhydryl diisopropylcarbamate (24)



24

To a solution of diphenylmethanol (9.00 g, 48.9 mmol, 1.0 equiv) in anhydrous THF (100 mL) was added sodium hydride (60% dispersion in mineral oil, 2.93 g, 73.3 mmol, 1.5 equiv) portionwise and the mixture was stirred for 75 min at room temperature. A solution of *N*,*N*-diisopropyl-carbamoyl chloride (9.59 g, 58.6 mmol, 1.2 equiv) in anhydrous THF (50 mL) was added and the reaction mixture was heated under reflux for 44 h. The solvent was removed *in vacuo* and the residue was portioned between water (80 mL) and diethyl ether (80 mL). The phases were separated and the aqueous layer was re-extracted with diethyl ether (3 × 50 mL). The combined organic layers were dried over anhydrous $MgSO_4$ and concentrated under reduced pressure. The residue was subjected to flash chromatography (SiO_2, pentane/EtOAc 9:1) to give 12.2 g carbamate **24** (39.3 mmol, 80%) as a white solid.

mp 63−64 °C (pentane/EtOAc).

R_f (pentane/EtOAc 9:1) 0.27.

^{1}H NMR (500 MHz, $CDCl_3$) δ_H ppm 7.41–7.31 (m, 8 H, H_{Ar}), 7.30–7.24 (m, 2 H, H_{Ar}) 6.88 (s, 1 H, CHOCb), 4.01 (br. m, 2 H, C*H*$(CH_3)_2$), 1.26 (br. m, 12 H, CH(C*H*$_3)_2$).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 154.6 (NCO), 141.2 (C), 128.4 (CH), 127.5 (CH), 127.0 (CH), 77.7 (CHOCb), 46.4 (br., *C*H$(CH_3)_2$), 45.5 (br., *C*H$(CH_3)_2$), 21.6 (br., CH(*C*H$_3)_2$), 20.6 (br., CH(*C*H$_3)_2$).

ν_{max} (neat) = 2925, 1690, 1432, 1317, 1056, 703 cm^{-1}.

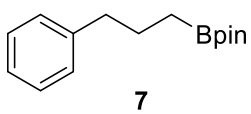
m/z (%) (CI^+) 312 ($[M+H]^+$, 23), 311 ($[M]^+$, 14), 268 ($[M–iPr]^+$, 5), 195 (27), 168 ($[M+H–OCb]^+$, 51), 167 ($[M–OCb]^+$, 100), 128 (16), 91 (26).

HRMS (ESI^+) calcd. for $C_{20}H_{25}NNaO_2$ $[M+Na]^+$ 334.1771, found 334.1777.

2.2 Synthesis of boronic esters

General procedure 2 (GP2). A solution of carbamate *or* benzoate (1.0 equiv) in anhydrous diethyl ether (0.33 M) was cooled to −78 °C, where necessary TMEDA (1.3 equiv) was added. *sec*-Butyllithium (solution in cyclohexane/hexane 92:8, 1.3 equiv) was added dropwise and the reaction mixture was stirred at this temperature for a given amount of time. A solution of pinacolborane (2.0 equiv) in anhydrous diethyl ether (1.33 M) was added slowly and the mixture was stirred for a given amount of time at −78 °C. The cooling bath was removed and the reaction mixture was stirred at ambient temperature *or* –20 °C until complete disappearance of the boron ate complex (monitored by ^{11}B NMR). Then, the reaction mixture was cooled to 0 °C and 1 M aqueous KH_2PO_4 was added slowly. After stirring for 10 min at room temperature, the phases were separated, and the aqueous phase was extracted with diethyl ether (4 × 20 mL). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and the solvent was removed *in vacuo*. The crude product was purified by column chromatography (SiO_2) to give the pure boronic ester.

4,4,5,5-Tetramethyl-2-(3-phenylpropyl)-1,3,2-dioxaborolane (7)



7

According to GP2, 3-phenylpropyl diisopropylcarbamate[6] (**5**) (200 mg, 0.76 mmol, 1.0 equiv), *sec*-butyllithium (696 µL, 1.31 M solution in cyclohexane/hexane 92:8, 0.91 mmol, 1.2 equiv) and TMEDA (148 µL, 0.99 mmol, 1.3 equiv) in anhydrous diethyl ether (4.0 mL) were stirred for 5 h at –78 °C. A solution of pinacolborane (221 µL, 1.52 mmol, 2.0 equiv) in anhydrous diethyl ether (2.0 mL) was added and the mixture was stirred for 1 h at –78 °C. After heating under reflux for 12 h and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) primary boronic ester **7** (109 mg, 0.44 mmol, 58%) was obtained as a colourless oil.

According to GP2, 3-phenylpropyl 2,4,6-triisopropylbenzoate[7] (**6**) (169 mg, 0.50 mmol, 1.0 equiv), *sec*-butyllithium (500 µL, 1.30 M solution in cyclohexane/hexane 92:8, 0.65 mmol, 1.3 equiv) and TMEDA (97 µL, 0,65 mmol, 1.3 equiv) in anhydrous diethyl ether (2.0 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (145 µL, 1.00 mmol,

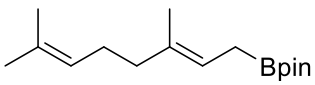
2.0 equiv) in anhydrous diethyl ether (1.0 mL) was added and the mixture was stirred for 1 h at –78 °C. After stirring for 1 h at ambient temperature and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) primary boronic ester **7** (102 mg, 0.41 mmol, 83%) was afforded as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 7.29–7.25 (m, 2 H, H_{Ar}), 7.19–7.15 (m, 3 H, H_{Ar}), 2.62 (t, J = 7.8 Hz, 2 H, $PhCH_2$), 1.79–1.71 (m, 2 H, $PhCH_2CH_2$), 1.25 (s, 12 H, CH_3), 0.84 (t, J = 7.9 Hz, 2 H, CH_2Bpin).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 142.7 (C), 128.5 (CH), 128.2 (CH), 125.6 (CH), 82.9 (C), 38.6 ($PhCH_2$), 26.1 ($PhCH_2CH_2$), 24.8 (CH_3), 11.0 (br., CH_2Bpin).

The spectral data match those reported in literature.[8]

(*E*)-2-(3,7-Dimethylocta-2,6-dien-1-yl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (10)



10

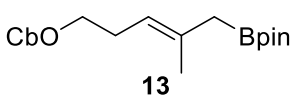
According to GP2, carbamate **8** (141 mg, 0.50 mmol, 1.0 equiv), *sec*-butyllithium (528 µL, 1.23 M solution in cyclohexane/hexane 92:8, 0.65 mmol, 1.3 equiv) and TMEDA (97 µL, 0.65 mmol, 1.3 equiv) in anhydrous diethyl ether (1.5 mL) were stirred for 15 min at –78 °C. A solution of pinacolborane (145 µL, 1.00 mmol, 2.0 equiv) in anhydrous diethyl ether (0.75 mL) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 2 h at –20 °C and purification by column chromatography (SiO_2, PE/diethyl ether 49:1) allylic boronic ester **10** (92 mg, 0.35 mmol, 70%) was afforded as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 5.24 (tq, J = 7.6, 1.2 Hz, 1 H, $CHCH_2Bpin$), 5.09 (tsept, J = 6.9, 1.3 Hz, 1 H, $CHC(CH_3)_2$), 2.08–1.96 (m, 4 H, CH_2), 1.66 (s, 3 H, CH_3), 1.62–1.56 (m, 8 H, 2 × CH_3 + CH_2Bpin), 1.23 (s, 12 H, CH_3).

^{13}C NMR (126 MHz, $CDCl_3$) δ_C ppm 135.2 (C), 131.2 (C), 124.6 (CH), 118.6 (CH), 83.2 (C), 39.9 (CH_2), 27.0 (CH_2), 25.8 (CH_3), 24.9 (CH_3), 17.8 (CH_3), 16.0 (CH_3).

The data are in accordance with that reported in literature.[9]

(*E*)-4-Methyl-5-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)pent-3-en-1-yl diisopropylcarbamate (13)



13

According to GP2, biscarbamate **11** (74 mg, 0.20 mmol, 1.0 equiv), *sec*-butyllithium (211 µL, 1.23 M solution in cyclohexane/hexane 92:8, 0.26 mmol, 1.3 equiv) and TMEDA (40 µL, 0.26 mmol, 1.3 equiv) in anhydrous diethyl ether (0.6 mL) were stirred for 15 min at –78 °C. Pinacolborane (58 µL, 0.4 mmol, 2.0 equiv) was added slowly and the mixture was stirred for 2 h at –78 °C. After stirring for additional 2 h at –20 °C and purification by column chromatography (SiO_2, PE/diethyl ether 19:1) allylic boronic ester **13** (47 mg, 0.10 mmol, 49%) was obtained as a colourless oil.

R_f (hexanes/EtOAc 4:1) 0.47.

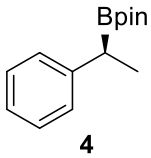
^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 5.12 (tq, *J* = 7.2, 1.2 Hz, 1 H, CH), 4.08 (br. m, 1 H, C*H*$(CH_3)_2$), 4.03 (t, *J* = 7.0 Hz, 2 H, CH_2OCb), 3.73 (br. m, 1 H, C*H*$(CH_3)_2$), 2.35 (q, *J* = 7.1 Hz, 2 H, CH_2), 1.72–1.66 (m, 2 H, CH_2Bpin), 1.69 (s, 3 H, CH_3), 1.23 (s, 12 H, CH_3), 1.19 (d, *J* = 6.9 Hz, 12 H, CH_3).

^{13}C NMR (126 MHz, $CDCl_3$) δ_C ppm 156.2 (NCO), 134.6 (C), 120.0 (CH), 83.1 (C), 64.7 (CH_2OCb), 45.9 (br., *C*H$(CH_3)_2$), 45.3 (br., *C*H$(CH_3)_2$), 28.5 (CH_2), 25.0 (CH_3), 21.1 (br., CH_3), 18.3 (CH_3).

ν_{max} (neat) = 2929, 1472, 1253, 1088, 831, 771 cm^{-1}.

HMRS (ESI^+) calc. for $C_{19}H_{36}BNO_4Na$ $[M+Na]^+$ 376.2635, found 376.2625.

(*S*)-4,4,5,5-Tetramethyl-2-(1-phenylethyl)-1,3,2-dioxaborolane (4)



4

According to GP2, (*S*)-1-phenylethyl diisopropylcarbamate (**1**) (748 mg, 3.00 mmol, 1.0 equiv) and *sec*-butyllithium (3.00 mL, 1.30 M solution in cyclohexane/hexane 92:8, 3.90 mmol, 1.3 equiv) in anhydrous diethyl ether (9.0 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (871 µL, 6.00 mmol, 2.0 equiv) in anhydrous diethyl ether (4.5 mL) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 2 h at ambient temperature and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) secondary benzylic boronic ester **4** (641 mg, 2.76 mmol, 92%, 98% ee*) was afforded as a colourless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ_H ppm 7.30–7.22 (m, 4 H, H_{Ar}), 7.17–7.12 (m, 1 H, H_{Ar}), 2.45 (q, *J* = 7.6 Hz, 1 H, CHBpin), 1.34 (d, *J* = 7.6 Hz, 3 H, CH_3), 1.22 (s, 6 H, CH_3), 1.21 (s, 6 H, CH_3).

^{13}C NMR (126 MHz, $CDCl_3$) δ_C ppm 144.9 (C), 128.3 (CH), 127.8 (CH), 125.0 (CH), 83.3 (C), 24.62 (CH_3), 24.57 (CH_3), 17.0 (CH_3).

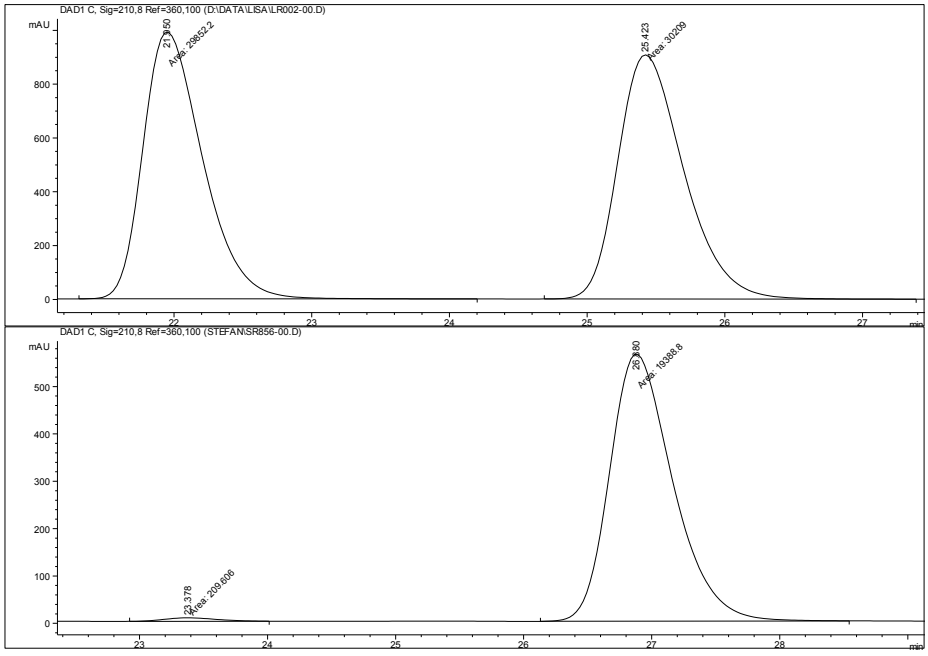
^{11}B NMR (96 MHz, $CDCl_3$) δ_B ppm 32.6 (br. s).

$[\alpha]_D^{21}$ +10.0 (*c* 1.0, $CHCl_3$, for 98% ee). Lit. $[\alpha]_D^{20}$ −12.0 (*c* 1.5, $CHCl_3$, for 95% ee of the (*R*)-isomer).[10]

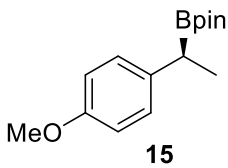
The spectral data match those reported in literature.[11]

*Enantiomeric excess of the chiral boronic ester was determined by HPLC analysis of an aliquot oxidised to the corresponding secondary benzylic alcohol with H_2O_2/NaOH. HPLC separation conditions: Chiralpak IB column with guard, 2.0% *i*PrOH in hexane, flow rate 0.7 mL/min, 20 °C; t_R 23.4 min for (*R*)-enantiomer (minor) and t_R 26.9 min for (*S*)-enantiomer (major).

e.r. = 98.9:1.1.



(*S*)-2-(1-(4-Methoxyphenyl)ethyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (15)



15

According to GP2, (*S*)-1-(4-methoxyphenyl)ethyl diisopropylcarbamate (**14**) (140 mg, 0.50 mmol, 1.0 equiv), *sec*-butyllithium (500 µL, 1.30 M solution in cyclohexane/hexane 92:8, 0.65 mmol, 1.3 equiv) and TMEDA (97 µL, 0.65 mmol, 1.3 equiv) in anhydrous diethyl ether (2.0 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (145 µL, 1.0 mmol, 2.0 equiv) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 3 h at –30 °C

and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) secondary benzylic boronic ester **15** (81 mg, 0.31 mmol, 62%, 94% ee*) was obtained as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 7.15 (AA'BB', J = 8.5 Hz, 2 H, H_{Ar}), 6.83 (AA'BB', J = 8.5 Hz, 2 H, H_{Ar}), 3.79 (s, 3 H, OCH_3), 2.38 (q, J = 7.5 Hz, 1 H, CHBpin), 1.31 (d, J = 7.5 Hz, 3 H, CH_3), 1.22 (s, 6 H, CH_3), 1.21 (s, 6 H, CH_3).

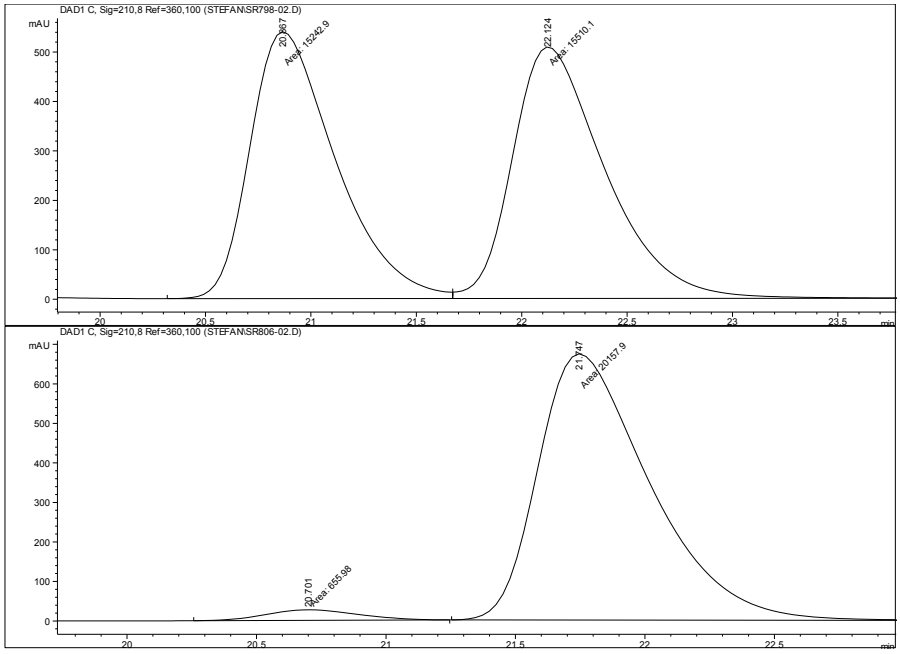
^{13}C NMR (126 MHz, $CDCl_3$) δ_C ppm 157.2 (COMe), 137.0 (C), 128.6 (CH), 113.7 (CH), 83.2 (C), 55.2 (OCH_3), 24.62 (CH_3), 24.59 (CH_3), 17.4 (CH_3).

^{11}B NMR (96 MHz, $CDCl_3$) δ_B ppm 32.8 (br. s).

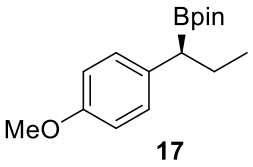
[α] $^{19}_{D}$ +15.3 (*c* 0.29, $CHCl_3$, for 94% ee).

The spectral data match those reported in literature for the racemic boronic ester.[12]

*Enantiomeric excess of the chiral boronic ester was determined by HPLC analysis of an aliquot oxidised to the corresponding secondary benzylic alcohol with H_2O_2/NaOH. HPLC separation conditions: Chiralpak IB column with guard, 3.0% *i*PrOH in hexane, flow rate 0.7 mL/min, 20 °C; t_R 20.7 min for (*R*)-enantiomer (minor) and t_R 21.7 min for (*S*)-enantiomer (major).
e.r. = 96.9:3.1.



(*S*)-2-(1-(4-Methoxyphenyl)propyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (17)



17

According to GP2, (*S*)-1-(4-methoxyphenyl)propyl diisopropyl-carbamate (**16**) (440 mg, 1.50 mmol, 1.0 equiv), *sec*-butyllithium (1.50 mL, 1.30 M solution in cyclohexane/hexane 92:8, 1.95 mmol, 1.3 equiv) and TMEDA (291 µL, 1.95 mmol, 1.3 equiv) in anhydrous diethyl ether (4.5 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (435 µL, 3.0 mmol, 2.0 equiv) in anhydrous diethyl ether (2.25 mL) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 2 h at –20 °C and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) secondary benzylic boronic ester **17** (264 mg, 0.96 mmol, 64%, 97% ee*) was obtained as a colourless oil.

^{1}H NMR (300 MHz, $CDCl_3$) δ_H ppm 7.13 (AA'BB', J = 8.8 Hz, 2 H, H_{Ar}), 6.81 (AA'BB', J = 8.8 Hz, 2 H, H_{Ar}), 3.79 (s, 3 H, OCH_3), 2.17 (t, J = 7.8 Hz, 1 H, CHBpin), 1.90–1.78 (m, 1 H, C*H*H), 1.69–1.57 (m, 1 H, CH*H*), 1.22 (s, 6 H, CH_3), 1.20 (s, 6 H, CH_3), 0.90 (t, J = 7.3 Hz, 3 H, CH_3).

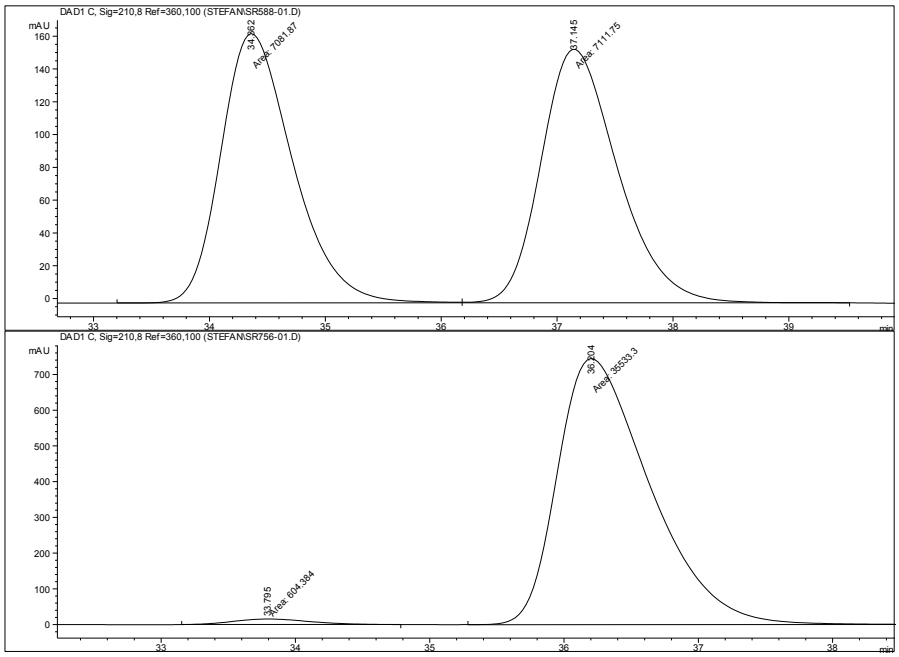
^{13}C NMR (126 MHz, $CDCl_3$) δ_C ppm 157.2 (COMe), 135.3 (C), 129.2 (CH), 113.6 (CH), 83.1 (C), 55.2 (OCH_3), 33.1 (br., CHBpin), 26.0 (CH_2), 24.7 (CH_3), 24.6 (CH_3), 13.9 (CH_3).

^{11}B NMR (96 MHz, $CDCl_3$) δ_B ppm 32.3 (br. s).

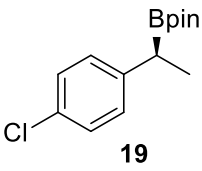
$[\alpha]_D^{23}$ +24.0 (*c* 1.0, $CHCl_3$, for 97% ee).

The analytical data are consistent with the known racemic product.[12]

*Enantiomeric excess of the chiral boronic ester was determined by HPLC analysis of an aliquot oxidised to the corresponding secondary benzylic alcohol with H_2O_2/NaOH. HPLC separation conditions: Chiralpak IB column with guard, 3.0% *i*PrOH in hexane, flow rate 0.7 mL/min, 20 °C; t_R 33.8 min for (*R*)-enantiomer (minor) and t_R 36.2 min for (*S*)-enantiomer (major).
e.r. = 98.3:1.7.



(*S*)-2-(1-(4-Chlorophenyl)ethyl)-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (19)



19

According to GP2, (*S*)-1-(4-chlorophenyl)ethyl diisopropylcarbamate (**18**) (99 mg, 0.35 mmol, 1.0 equiv) and *sec*-butyllithium (350 µL, 1.30 M solution in cyclohexane/hexane 92:8, 0.46 mmol, 1.3 equiv) in anhydrous diethyl ether (1.0 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (102 µL, 0.70 mmol, 2.0 equiv) in anhydrous diethyl ether (0.5 mL) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 48 h at ambient temperature and purification by column chromatography (SiO_2, pentane/CH_2Cl_2 2:1) secondary benzylic boronic ester **19** (41 mg, 0.15 mmol, 43%, 97% ee*) was obtained as a colourless oil.

^{1}H NMR (500 MHz, $CDCl_3$) δ_H ppm 7.22 (AA'BB', J = 8.6 Hz, 2 H, H_{Ar}), 7.14 (AA'BB', J = 8.6 Hz, 2 H, H_{Ar}), 2.40 (q, J = 7.5 Hz, 1 H, CHBpin), 1.30 (d, J = 7.5 Hz , 3 H, CH_3), 1.20 (s, 6 H, CH_3), 1.19 (s, 6 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 143.6 (C), 130.8 (CCl), 129.2 (CH), 128.4 (CH), 83.5 (C), 24.8 (CH_3), 24.7 (CH_3), 17.0 (CH_3).

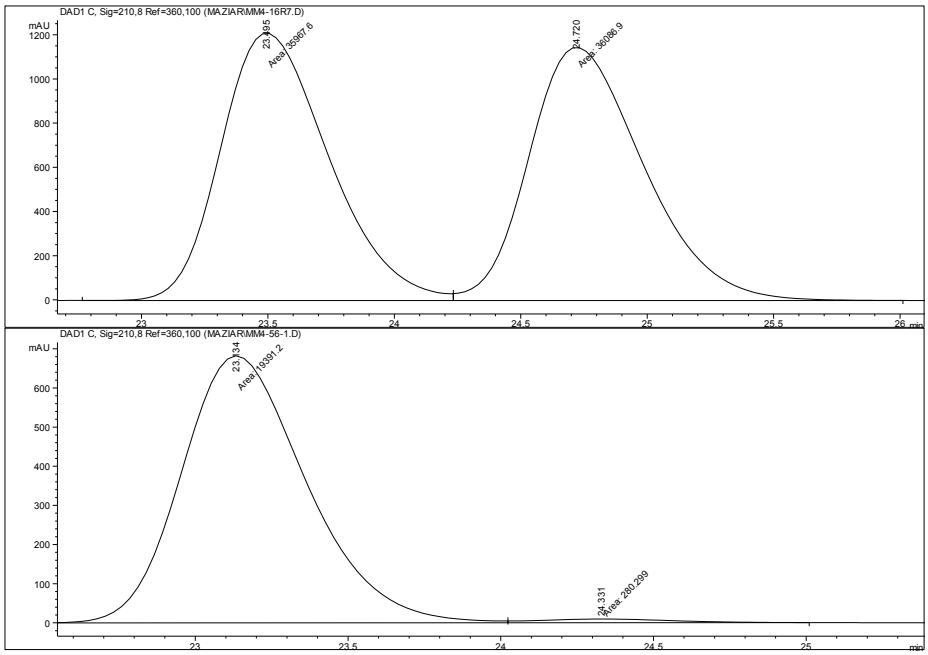
[α]$_D^{21}$ –37.0 (*c* 1.0, MeOH, for 97% ee). Lit. [α]$_D^{20}$ –40.1 (*c* 0.75, $CHCl_3$, for 87% ee).[13]

The spectral data match the literature values.[13]

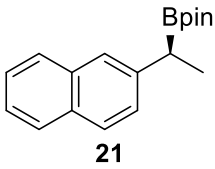
*Enantiomeric excess of the chiral boronic ester was determined by HPLC analysis of an aliquot oxidised to the corresponding secondary benzylic alcohol with H_2O_2/NaOH. HPLC

separation conditions: Chiralpak IB column with guard, 2.0% *i*PrOH in hexane, flow rate 1.0 mL/min, 20 °C; t_R 23.1 min for (*S*)-enantiomer (major) and t_R 24.3 min for (*R*)-enantiomer (minor).

e.r. = 98.6:1.4.



(*S*)-4,4,5,5-Tetramethyl-2-(1-(naphthalen-2-yl)ethyl)-1,3,2-dioxaborolane (21)



21

According to GP2, (*S*)-1-(naphthalen-2-yl)ethyl diisopropylcarbamate (**20**) (149 mg, 0.50 mmol, 1.0 equiv) and *sec*-butyllithium (500 µL, 1.30 M solution in cyclohexane/hexane 92:8, 0.65 mmol, 1.3 equiv) in anhydrous diethyl ether (1.5 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (145 µL, 1.00 mmol, 2.0 equiv) in anhydrous diethyl ether (1.0 mL) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 2 h at ambient temperature and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) secondary benzylic boronic ester **21** (108 mg, 0.38 mmol, 76%, 90% ee*) was afforded as a white solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ_H ppm 7.80–7.74 (m, 3 H, H_{Ar}), 7.65 (s, 1 H, H_{Ar}), 7.45–7.37 (m, 3 H, H_{Ar}), 2.63 (q, J = 7.2 Hz, 1 H, CHBpin), 1.44 (d, J = 7.2 Hz , 3 H, CH_3), 1.22 (s, 6 H, CH_3), 1.21 (s, 6 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 142.7 (C), 134.0 (C), 131.9 (C), 127.8 (CH), 127.7 (CH), 127.6 (CH), 127.4 (CH), 125.8 (CH), 125.4 (CH), 124.9 (CH), 83.5 (C), 24.8 (CH_3), 24.7 (CH_3), 17.0 (CH_3).

$[\alpha]_D^{21}$ –6.0 (*c* 2.8, MeOH, for 80% ee). Lit. $[\alpha]_D^{20}$ –24.5 (*c* 0.67, $CHCl_3$, for 51% ee).[13]

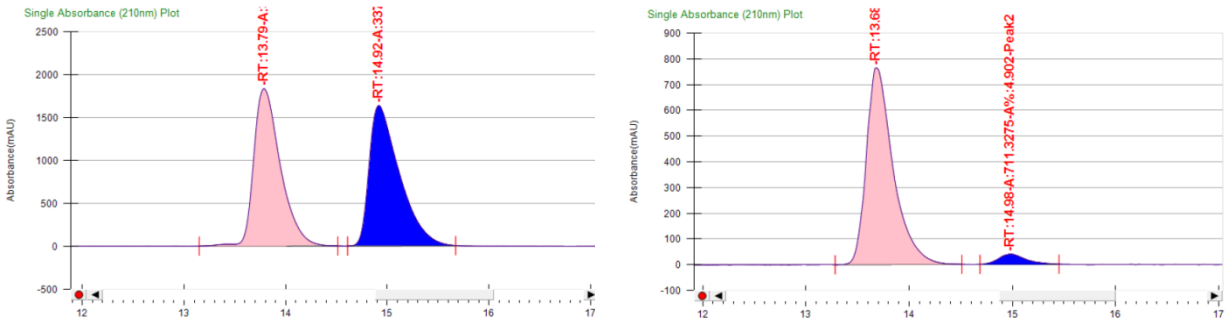
The spectral data match the literature values.[13]

*Enantiomeric excess of the chiral boronic ester was determined by HPLC analysis of an aliquot oxidised to the corresponding secondary benzylic alcohol with H_2O_2/NaOH. SFC separation conditions: Chiralpak IB column, eluent: 95% CO_2, 5% MeOH, flow rate 2.0 mL/min, 39.9 °C, 99 bar; t_R 13.68 min for (*S*)-enantiomer (major) and t_R 14.98 min for (*R*)-enantiomer (minor).

e.r. = 95.1:4.9.

Run Information

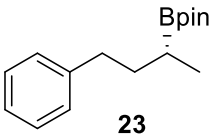
Instrument Method	Inj. Vol.	Solvent	Column	Sample	Well Location	Temp.	Flow	% Modifier	Pressure
iso 5%, 2 ml per min, 100 bar	10	MeOH	IB	SR945b	21B	39.9	2	5	99



Peak Information

Peak No	% Area	Area	Ret. Time	Height	Cap. Factor
1	95.098	13799.5899	13.68 min	764.5903	13678.2833
2	4.902	711.3275	14.98 min	40.5077	14981.5333

(*R*)-4,4,5,5-Tetramethyl-2-(4-phenylbutan-2-yl)-1,3,2-dioxaborolane (23)



23

According to GP2, (*R*)-4-phenylbutan-2-yl 2,4,6-triisopropylbenzoate[14] (**22**) (381 mg, 1.00 mmol, 1.0 equiv), *sec*-butyllithium (1.23 mL, 1.30 M solution in cyclohexane/hexane 92:8, 1.60 mmol, 1.6 equiv) and TMEDA (0.92 mL, 6.00 mmol, 6.0 equiv) in anhydrous CPME (6.0 mL) were stirred for 2 h at –60 °C. A solution of pinacolborane (290 µL, 2.00 mmol, 2.0 equiv) in anhydrous diethyl ether (2.25 mL) was added and the mixture was stirred for 1 h at –60 °C. After stirring for additional 16 h at 90 °C and purification by column chromatography (SiO_2, pentane/toluene 11:9) secondary boronic ester **23** (140 mg, 0.54 mmol, 54%, 95% ee*) was afforded as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ_H ppm 7.30–7.24 (m, 2 H, H_{Ar}), 7.22–7.14 (m, 3 H, H_{Ar}), 2.69–2.57 (m, 2 H, CH_2Ph), 1.85–1.74 (m, 1 H, C*H*H), 1.67–1.54 (m, 1 H, CH*H*), 1.26 (s, 12 H, CH_3), 1.14–1.01 (m, 4 H, CHBpin + CH_3).

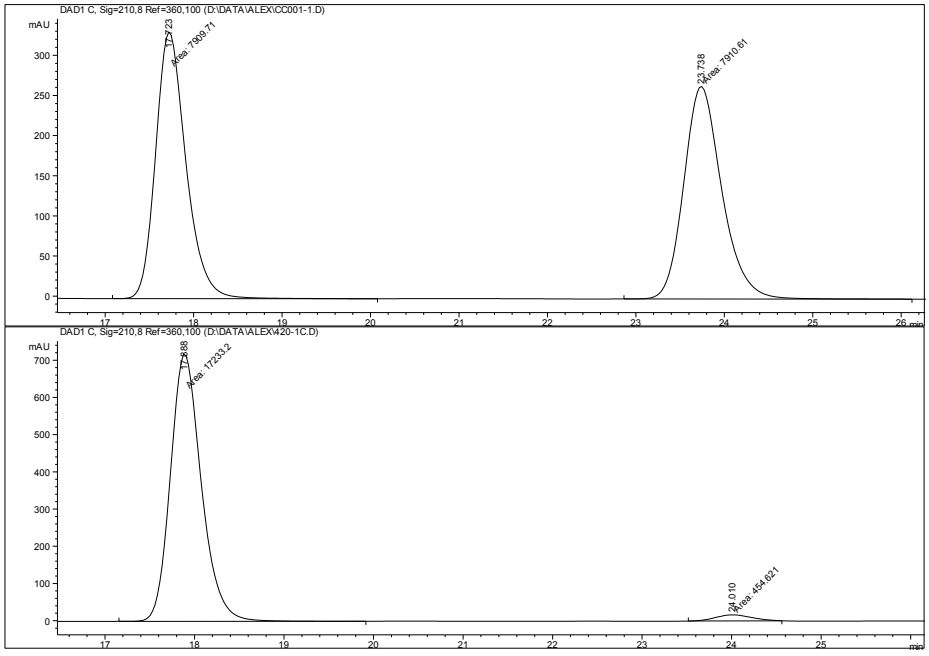
^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 143.1 (C), 128.4 (CH), 128.2 (CH), 125.5 (CH), 82.9 (C), 35.29 (CH_2), 35.27 (CH_2), 24.8 (CH_3), 24.7 (CH_3), 16.7 (br., CHBpin), 15.4 (CH_3).

The analytical data are in accordance with those reported in literature.[15]

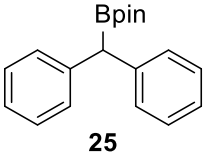
*Determined after oxidation to the corresponding alcohol with H_2O_2/NaOH. Optical rotation of (*R*)-4-phenylbutan-2-ol obtained was in accordance with the absolute stereochemistry of **23** being (*R*).

[α]$_D^{22}$ −15.7 (*c* 1.7, $CHCl_3$, for 95% ee), Lit. [α]$_D^{22}$ +15.8 (*c* 0.57, $CHCl_3$, for 92% ee of (*S*)-isomer).[7]

HPLC separation conditions: Chiralpak IB column with guard, 4.0% *i*PrOH in hexane, flow rate 0.7 mL/min, 20 °C; t_R 17.9 min for (*R*)-enantiomer (major) and t_R 24.0 min for (*S*)-enantiomer (minor).
e.r. = 97.5:2.5.



2-Benzhydryl-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (25)



25

According to GP2, benzhydryl diisopropylcarbamate (**24**) (311 mg, 1.0 mmol, 1.0 equiv) and *sec*-butyllithium (1.00 mL, 1.30 M solution in cyclohexane/hexane 92:8, 1.30 mmol, 1.3 equiv) in anhydrous diethyl ether (4.0 mL) were stirred for 1 h at –78 °C. A solution of pinacolborane (290 µL, 2.00 mmol, 2.0 equiv) in anhydrous diethyl ether (2.0 mL) was added and the mixture was stirred for 2 h at –78 °C. After stirring for additional 2 h at ambient temperature

and purification by column chromatography (SiO_2, pentane/EtOAc 30:1) pure secondary benzylic boronic ester **25** (231 mg, 0.79 mmol, 79%) was afforded as a white solid.

mp 75−77 °C (pentane/EtOAc).

R_f (pentane/EtOAc 30:1) 0.27.

^{1}H NMR (500 MHz, $CDCl_3$) δ_H ppm 7.29–7.25 (m, 8 H, H_{Ar}), 7.20–7.14 (m, 2 H, H_{Ar}), 3.87 (s, 1 H, CH), 1.24 (s, 12 H, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ_C ppm 142.1 (C), 129.1 (CH), 128.4 (CH), 125.6 (CH), 83.7 (C), 24.6 (CH_3).

^{11}B NMR (96 MHz, $CDCl_3$) δ_B ppm 32.1 (br. s).

ν_{max} (neat) = 2977, 1597, 1494, 1450, 1351, 1311, 1137, 967, 849, 698 cm^{-1}.

m/z (%) (CI^+) 295 ($[M+H]^+$, 100), 294 ($[M]^+$, 49), 279 ($[M–CH_3]^+$, 5), 217 ($[M–Ph]^+$, 51), 167 ($[M–Bpin]^+$, 7), 101 (57).

HRMS (CI^+) calcd. for $C_{19}H_{24}O_2B$ $[M+H]^+$ 295.1869, found 295.1862.

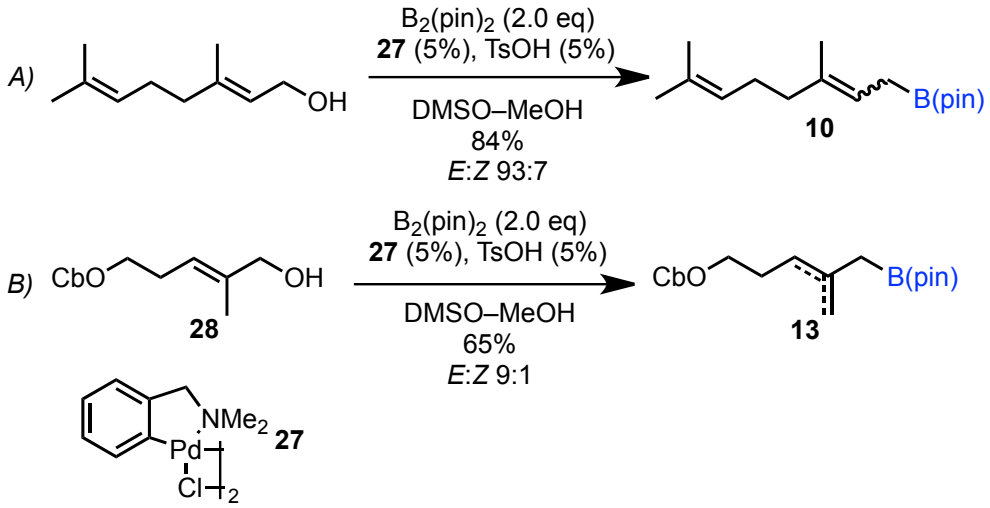
The spectroscopic data are in accordance with the literature.[16]

2.3 Reversibility test

A solution of (*S*)-1-(naphthalen-2-yl)ethyl diisopropylcarbamate (**20**) (149 mg, 1.00 mmol, 1.0 equiv) in anhydrous diethyl ether (1.5 mL) was cooled to −78 °C and *sec*-butyllithium (500 µL, 1.30 M solution in cyclohexane/hexane 92:8, 0.65 mmol, 1.3 equiv) was added dropwise. The reaction mixture was stirred at this temperature for 1 h. A solution of pinacolborane (145 µL, 1.00 mmol, 2.0 equiv) in anhydrous diethyl ether (1.0 mL) was added slowly and the mixture was stirred for 1 h at −78 °C. Then, a solution of EtBpin[6] (156 mg, 1.00 mmol, 2.0 equiv) in anhydrous diethyl ether (1.0 mL) was added dropwise and the reaction mixture was stirred for 1 h at –78 °C. The cooling bath was removed and the reaction mixture was stirred at ambient temperature for 2 h. Then, the reaction mixture was cooled to 0 °C and 1 M aqueous KH_2PO_4 was added slowly. After stirring for 10 min at room temperature, the phases were separated, and the aqueous phase was extracted with diethyl ether (4 × 20 mL). The combined organic layers were dried over anhydrous $MgSO_4$, filtered, and the solvent was removed *in vacuo*. The ratio of secondary boronic ester **21** and tertiary boronic ester **27** was determined by ^{1}H NMR spectroscopy using $CDCl_3$ as solvent.

A second experiment followed the procedure described above, but a solution of pinacolborane (145 µL, 1.00 mmol, 2.0 equiv) and EtBpin (156 mg, 1.00 mmol, 2.0 equiv) in anhydrous diethyl ether (1.0 mL) was added dropwise to lithiated carbamate **20**. The reaction mixture was stirred for 2 h at –78 °C before warming to ambient temperature.

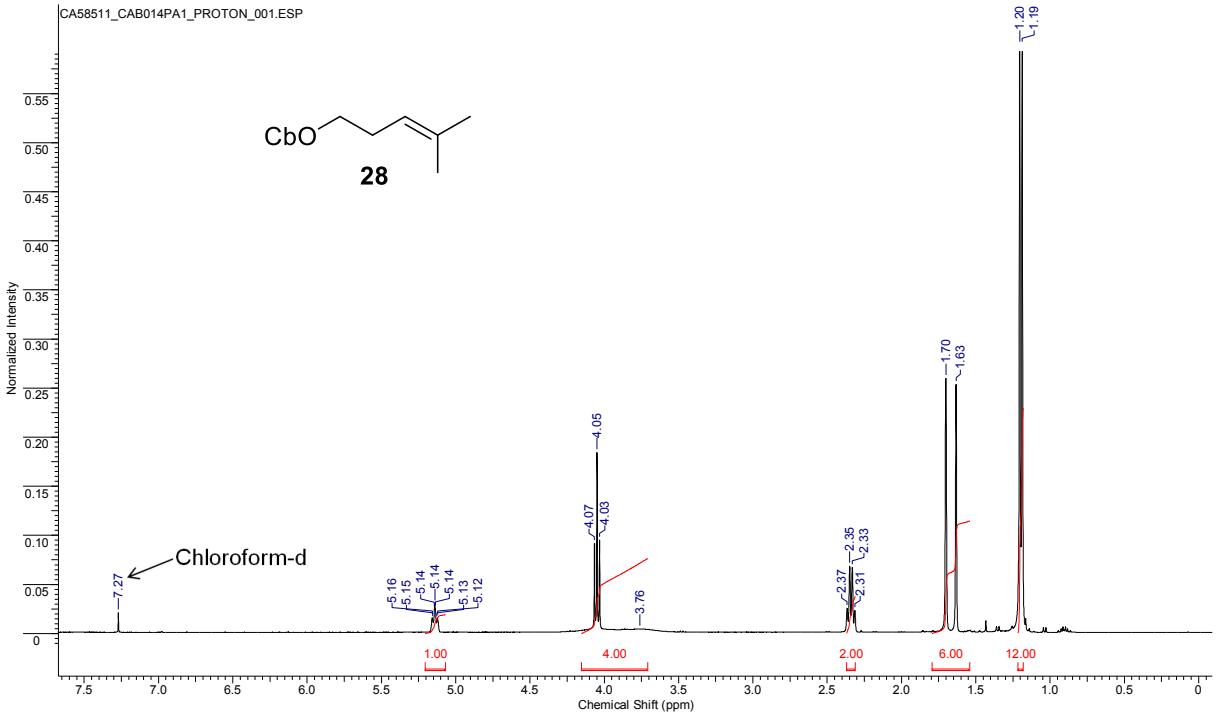
2.4 Pd-Catalyzed borylation of Allylic alcohols with $B_2(pin)_2$[17]



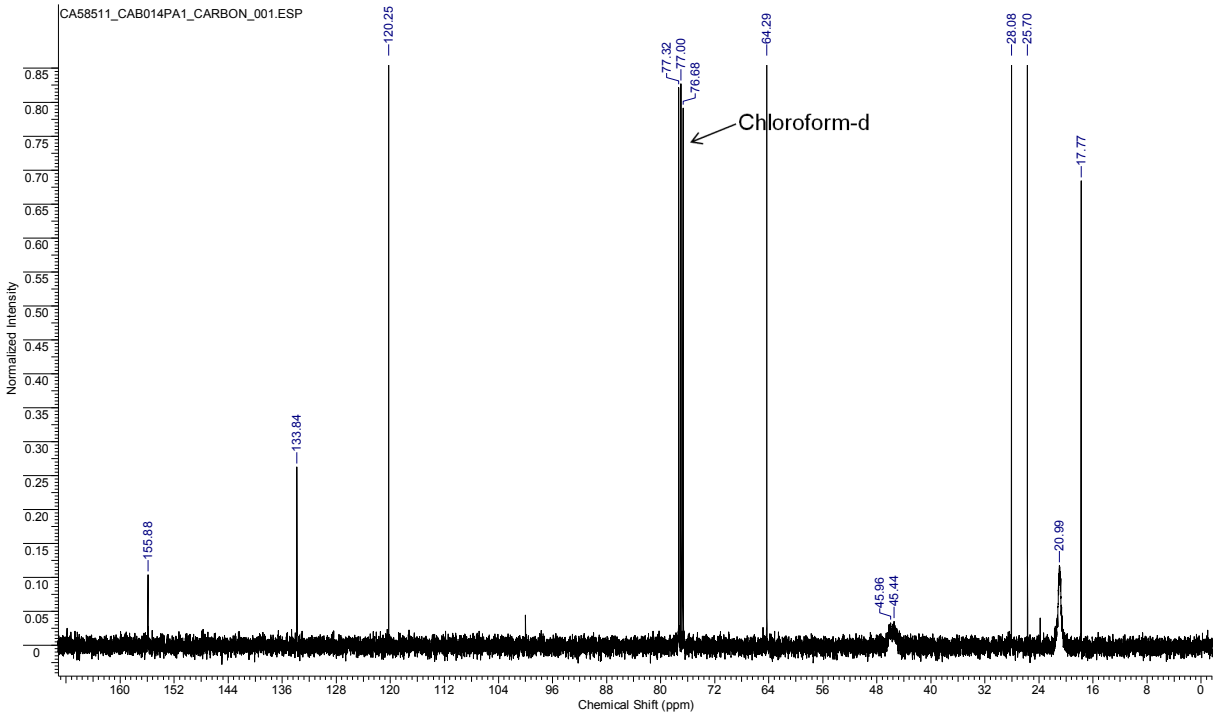
3. ^{1}H NMR and ^{13}C NMR spectra

4-Methylpent-3-en-1-yl diisopropylcarbamate (28)

^{1}H NMR (400 MHz, $CDCl_3$)

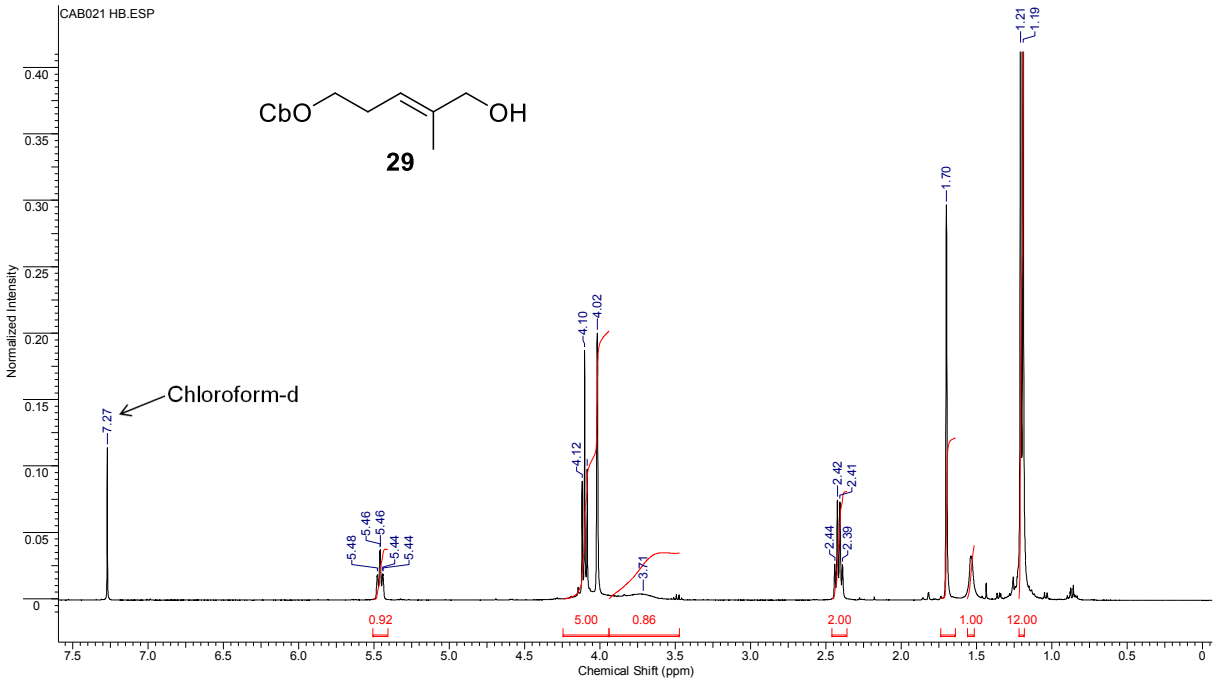


^{13}C NMR (101 MHz, $CDCl_3$)

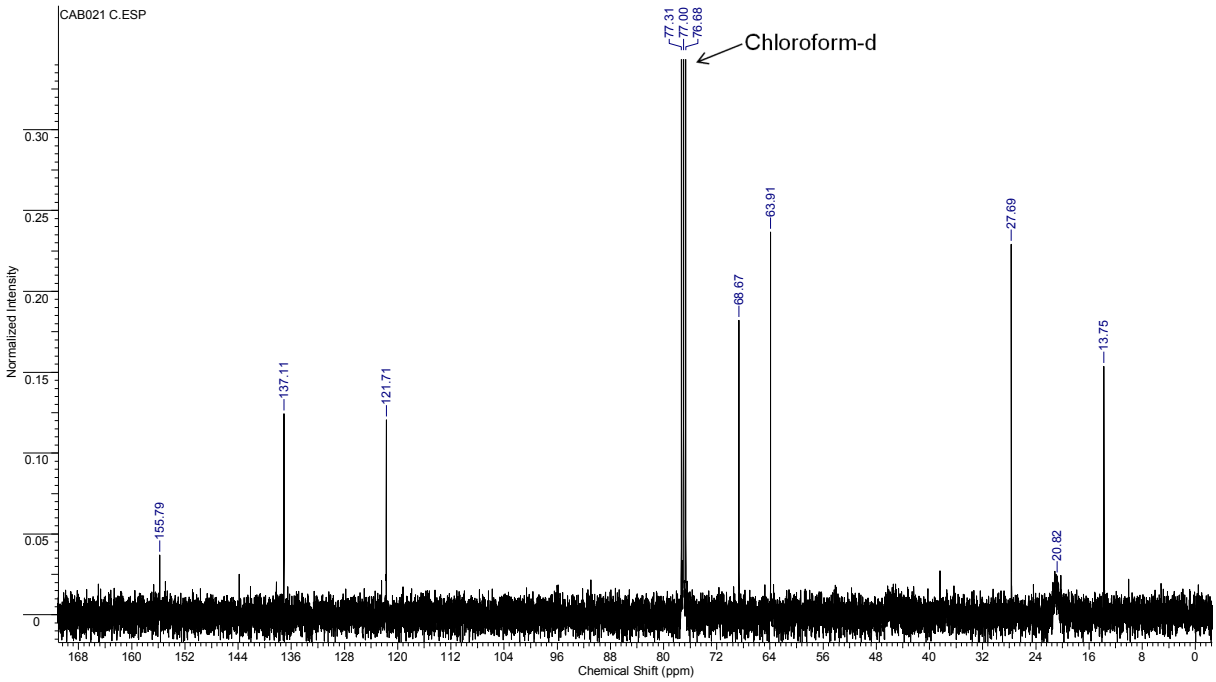


(*E*)-5-Hydroxy-4-methylpent-3-en-1-yl diisopropylcarbamate (29)

^{1}H NMR (400 MHz, $CDCl_3$)

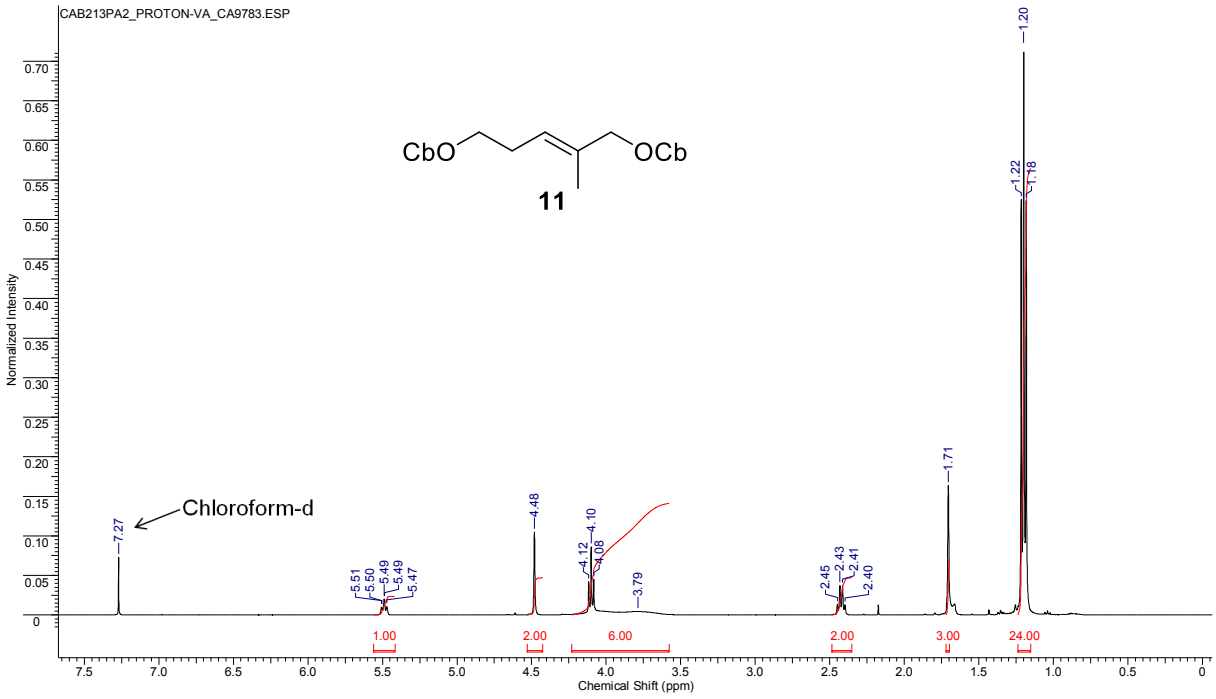


^{13}C NMR (101 MHz, $CDCl_3$)

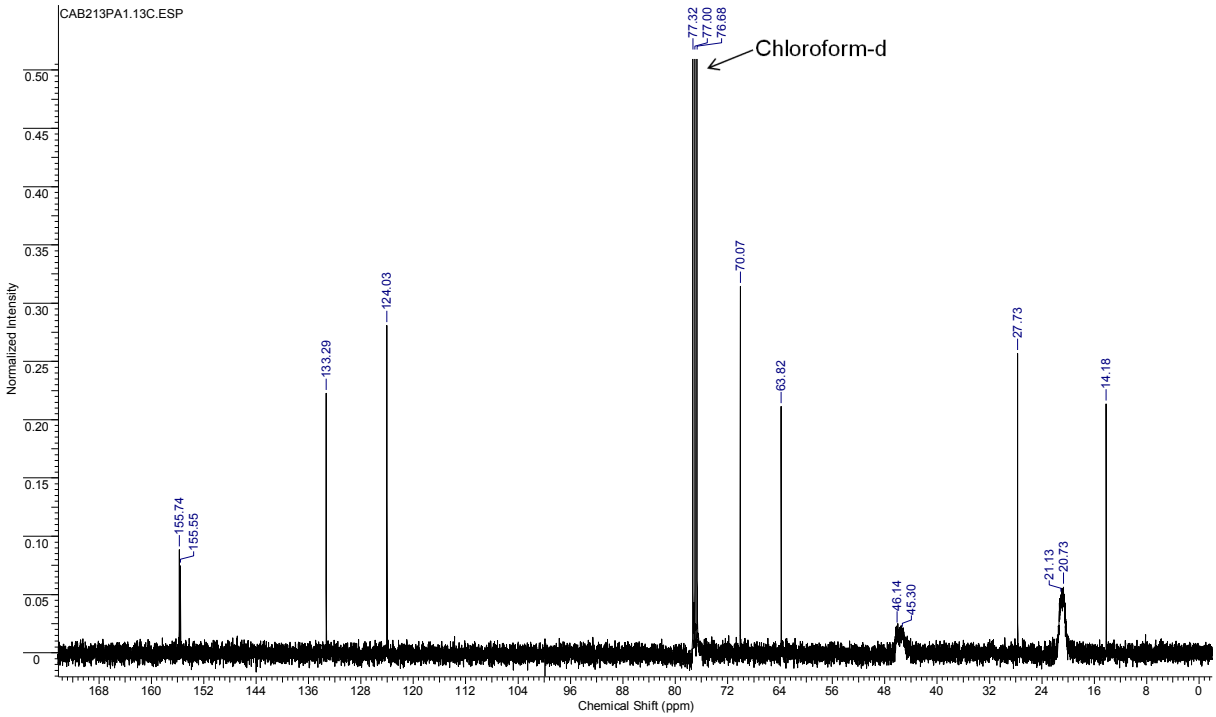


(*E*)-2-Methylpent-2-ene-1,5-diyl bis(diisopropylcarbamate) (11)

^{1}H NMR (400 MHz, $CDCl_3$)

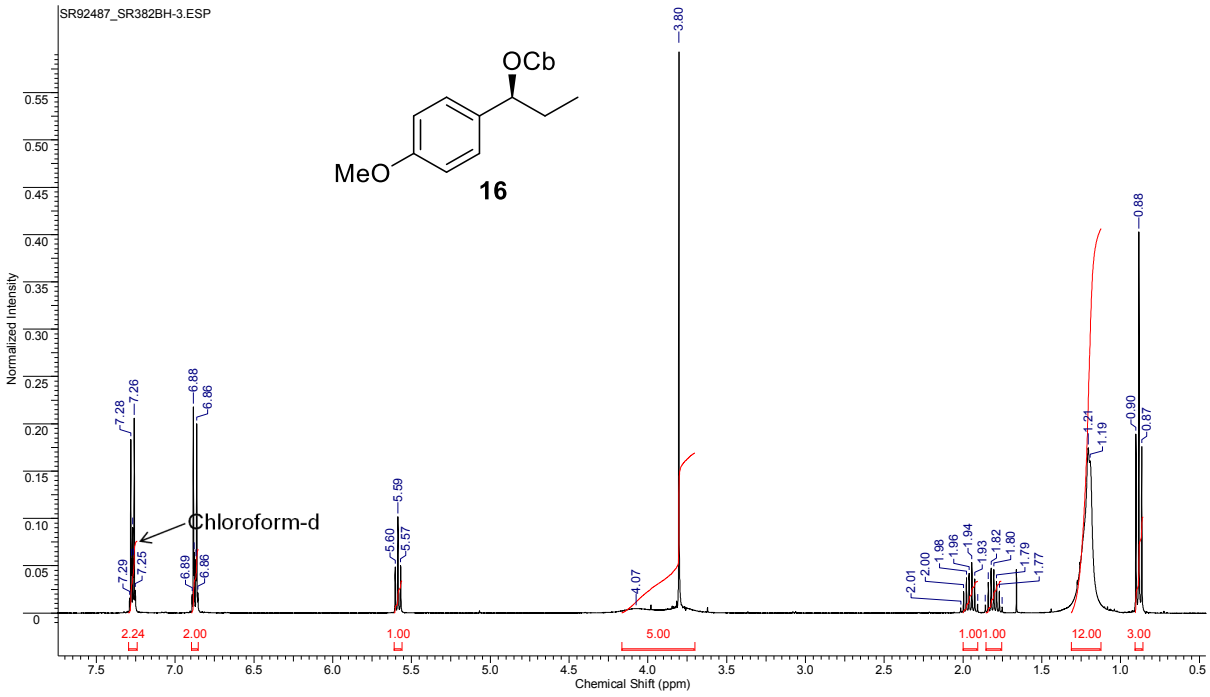


^{13}C NMR (101 MHz, $CDCl_3$)

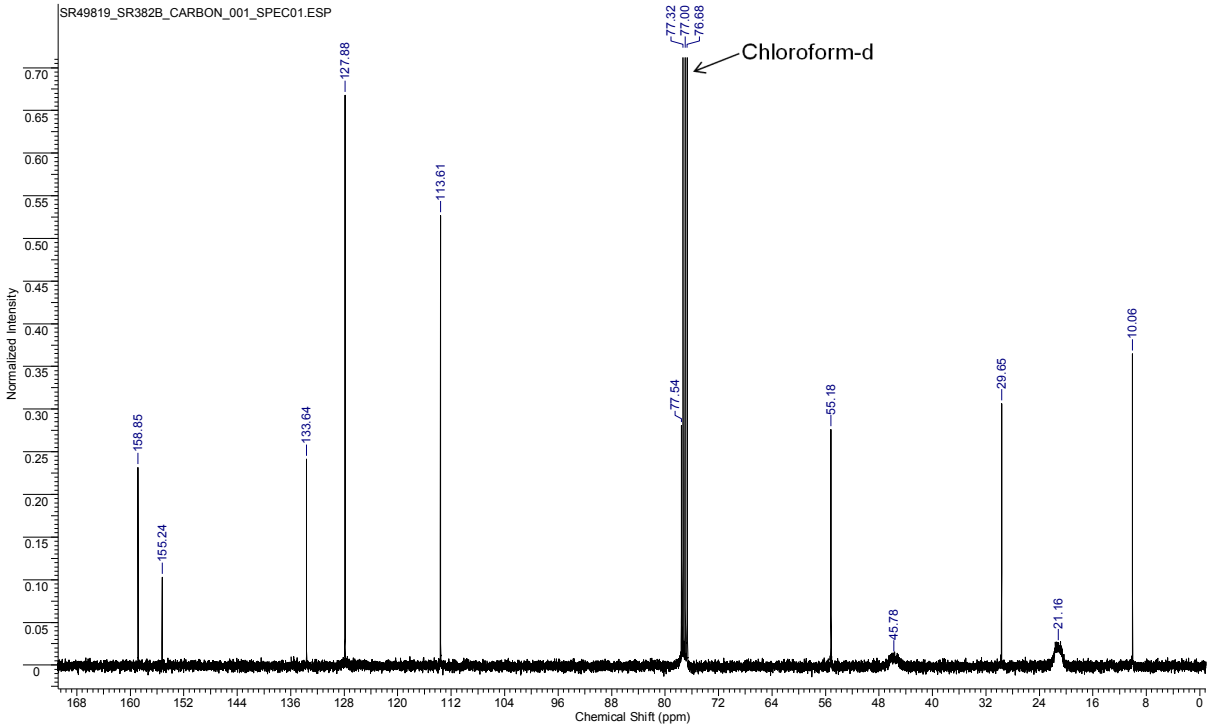


(*S*)-1-(4-Methoxyphenyl)propyl diisopropylcarbamate (16)

^{1}H NMR (400 MHz, $CDCl_3$)

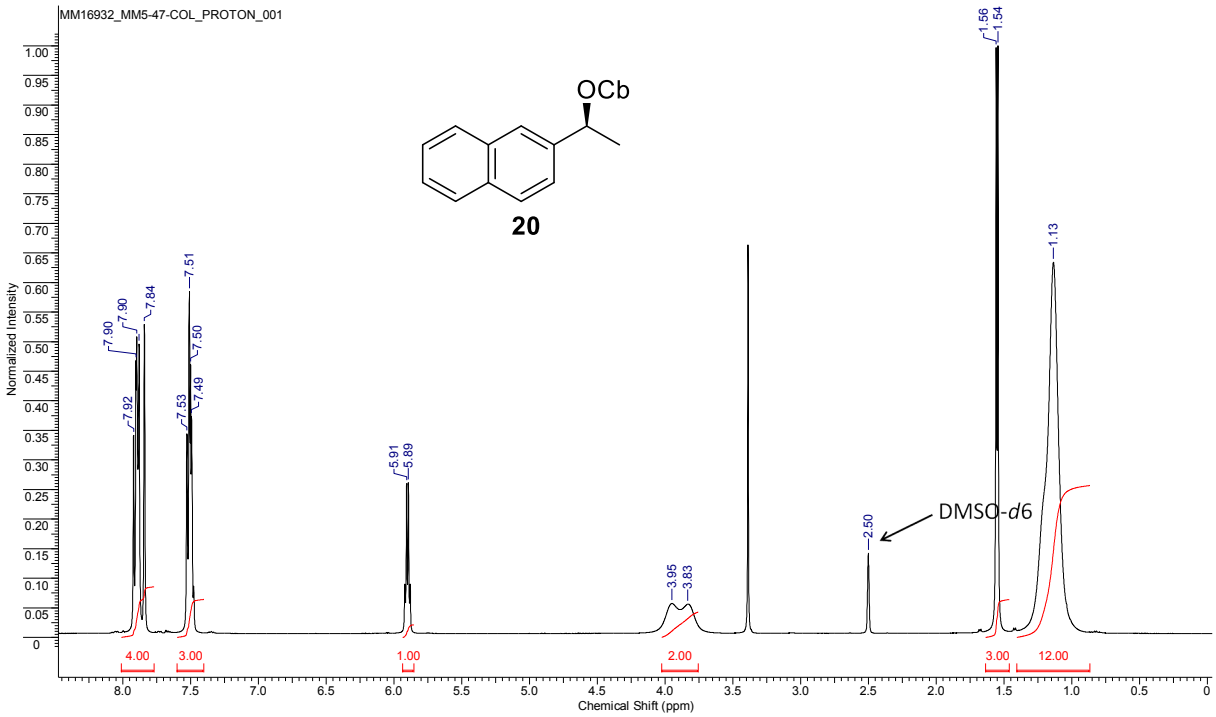


^{13}C NMR (101 MHz, $CDCl_3$)

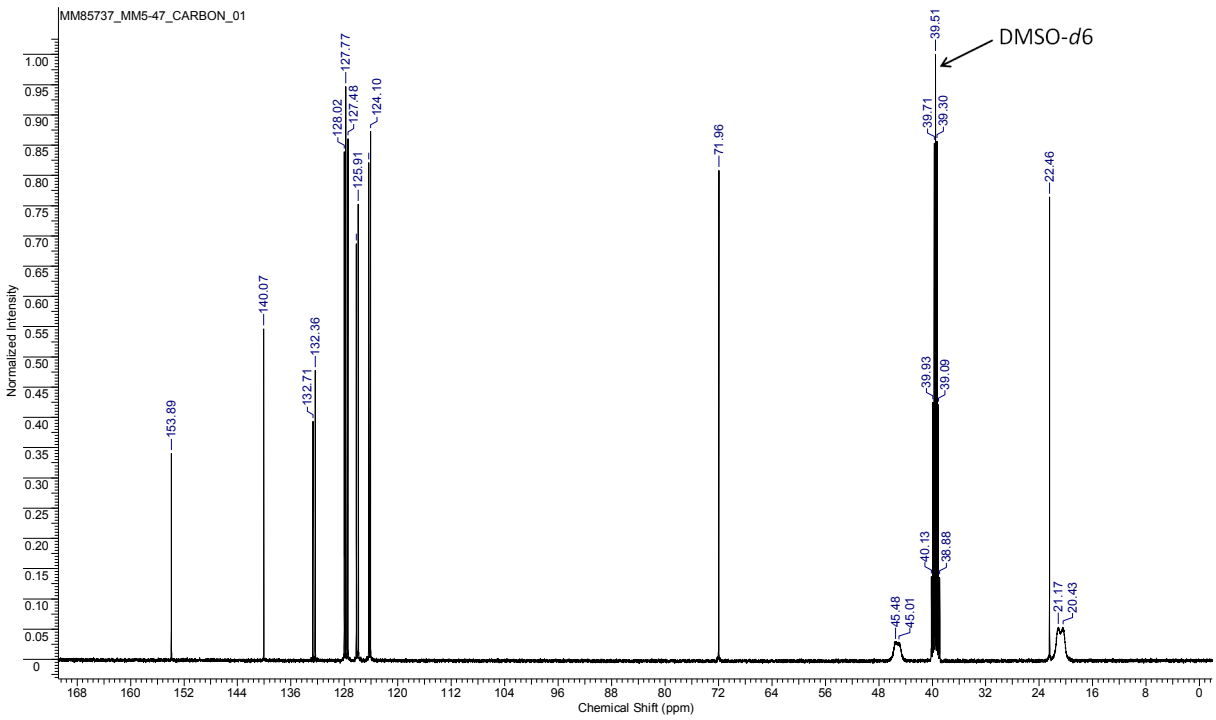


((*S*)-1-(Naphthalen-2-yl)ethyl diisopropylcarbamate (20)

^{1}H NMR (500 MHz, DMSO-*d*6)

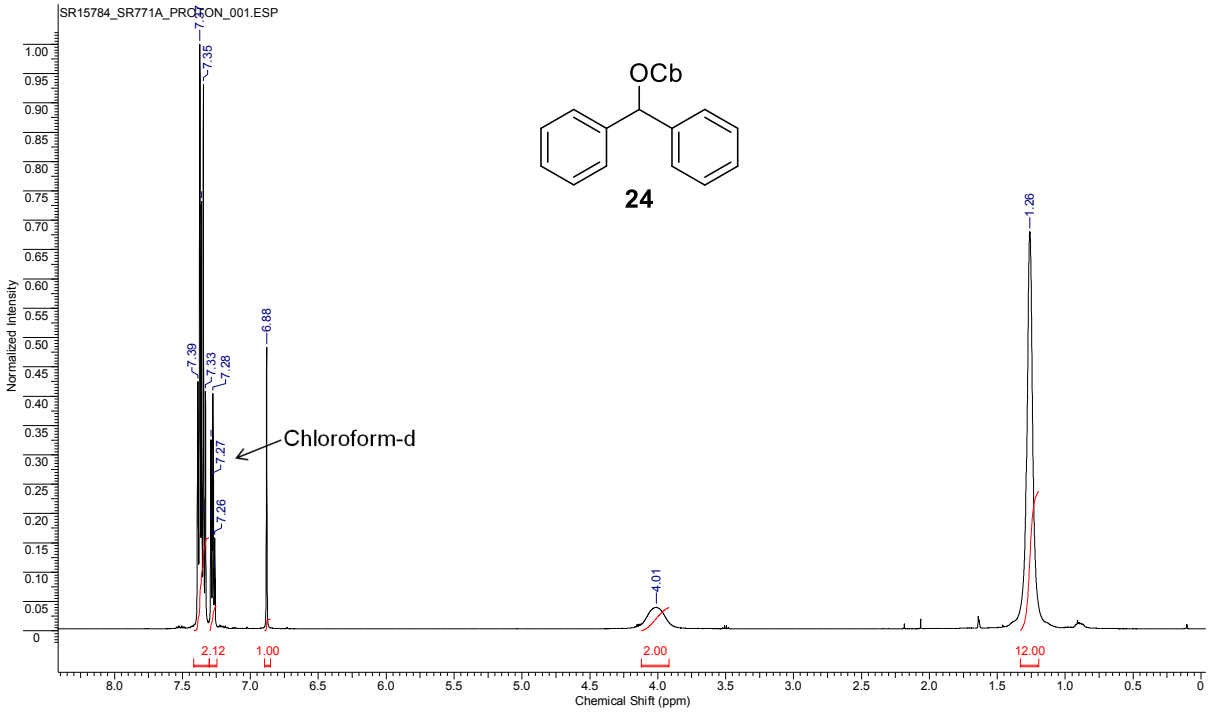


^{13}C NMR (126 MHz, DMSO-*d*6)

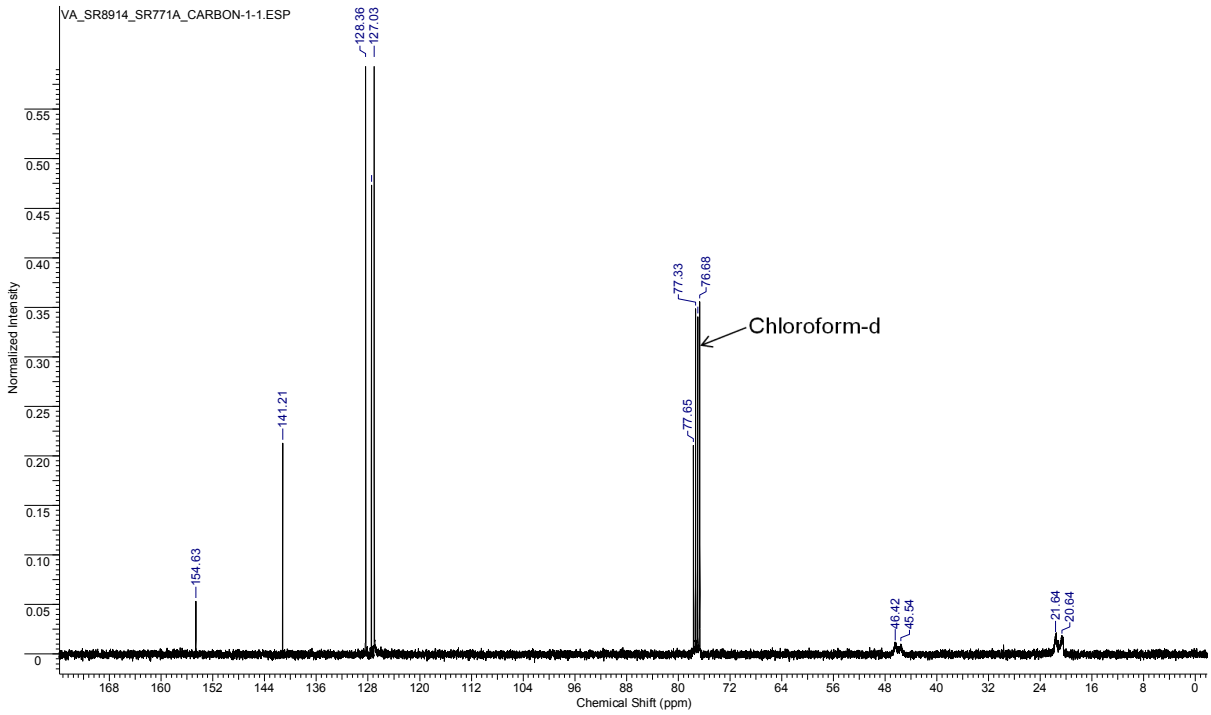


Benzhydryl diisopropylcarbamate (24)

^{1}H NMR (500 MHz, $CDCl_3$)

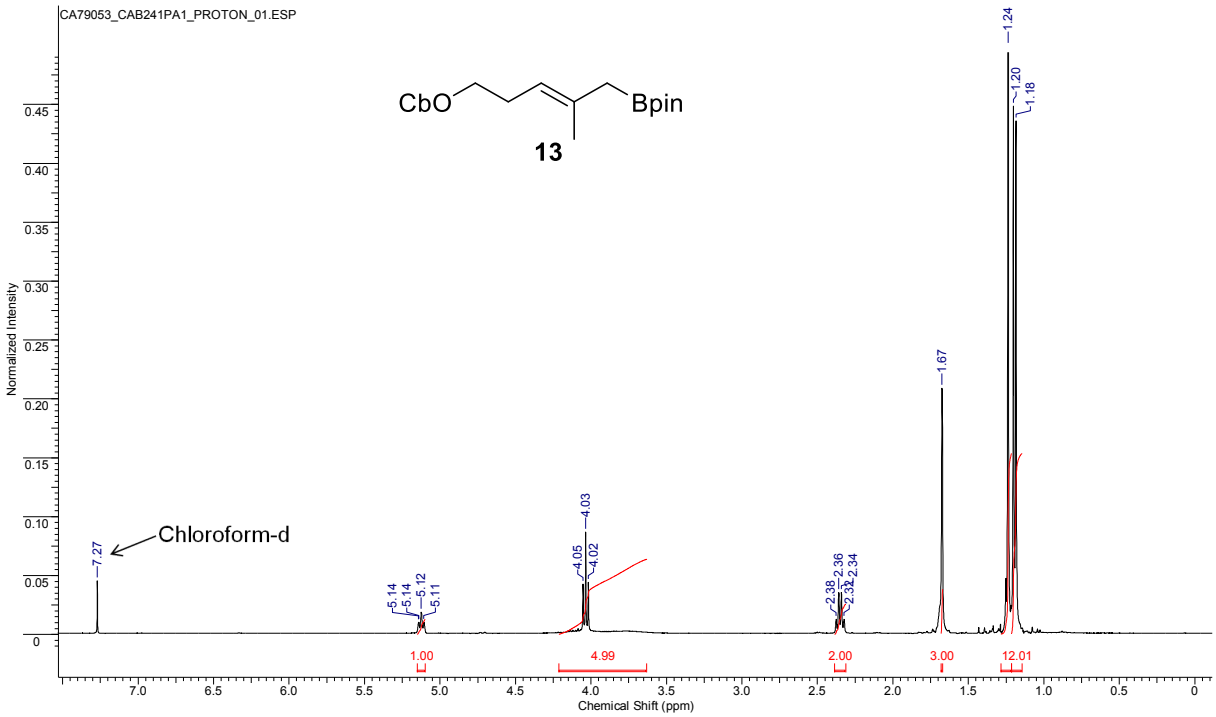


^{13}C NMR (101 MHz, $CDCl_3$)

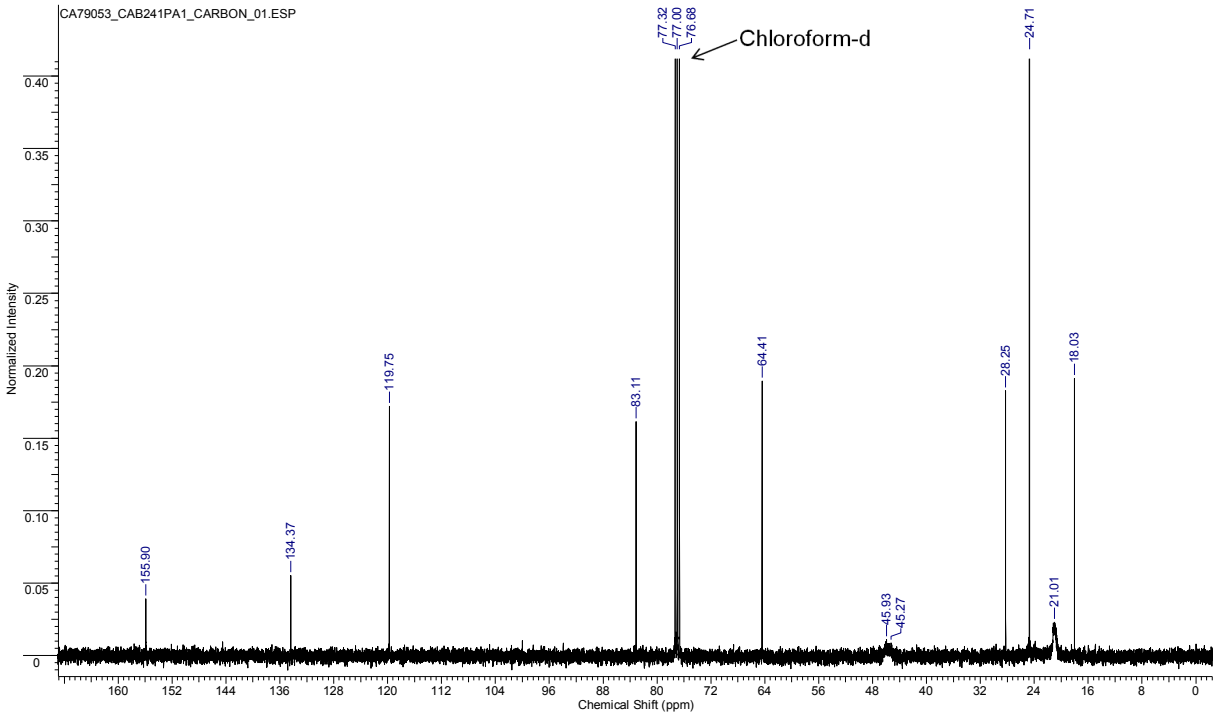


(*E*)-4-Methyl-5-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)pent-3-en-1-yl diisopropylcarbamate (13)

^{1}H NMR (400 MHz, $CDCl_3$)

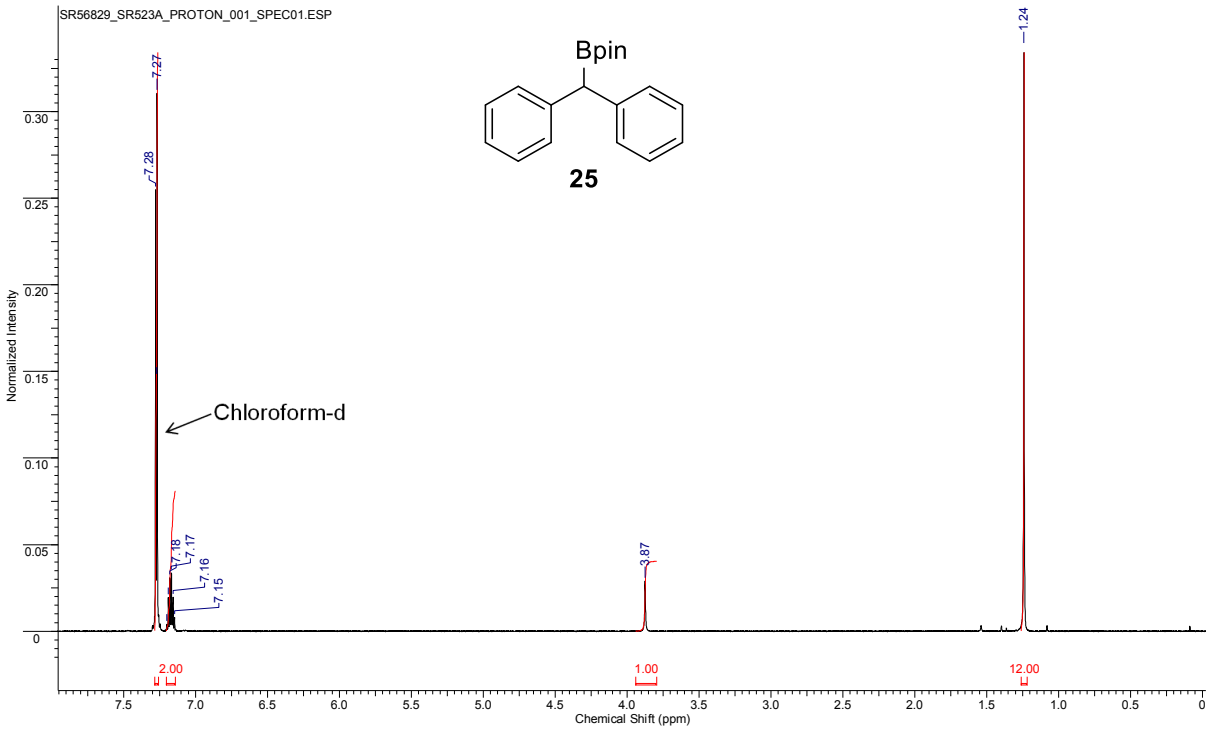


^{13}C NMR (126 MHz, $CDCl_3$)

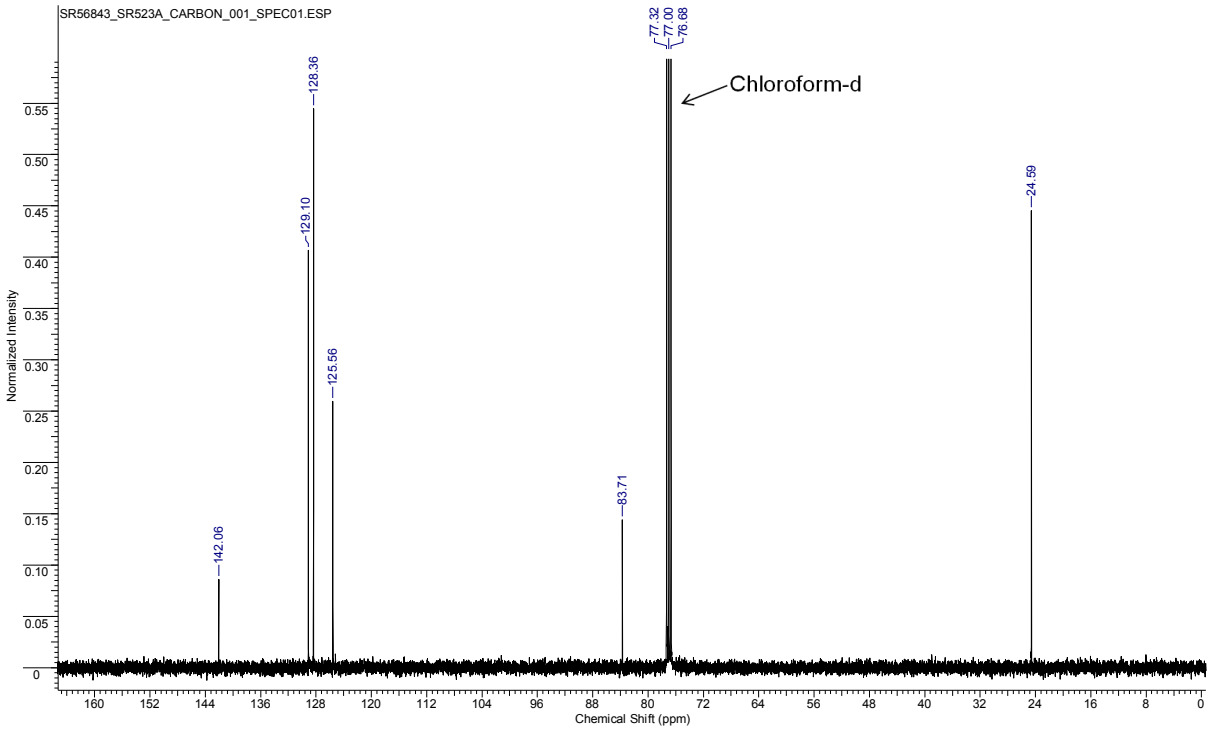


2-Benzhydryl-4,4,5,5-tetramethyl-1,3,2-dioxaborolane (25)

^{1}H NMR (400 MHz, $CDCl_3$)



^{13}C NMR (101 MHz, $CDCl_3$)



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