

## Supporting Information

For

# Synthesis and Homologation of an Azetidin-2-yl Boronic Ester with $\alpha$ -Lithioalkyl Triisopropylbenzoates

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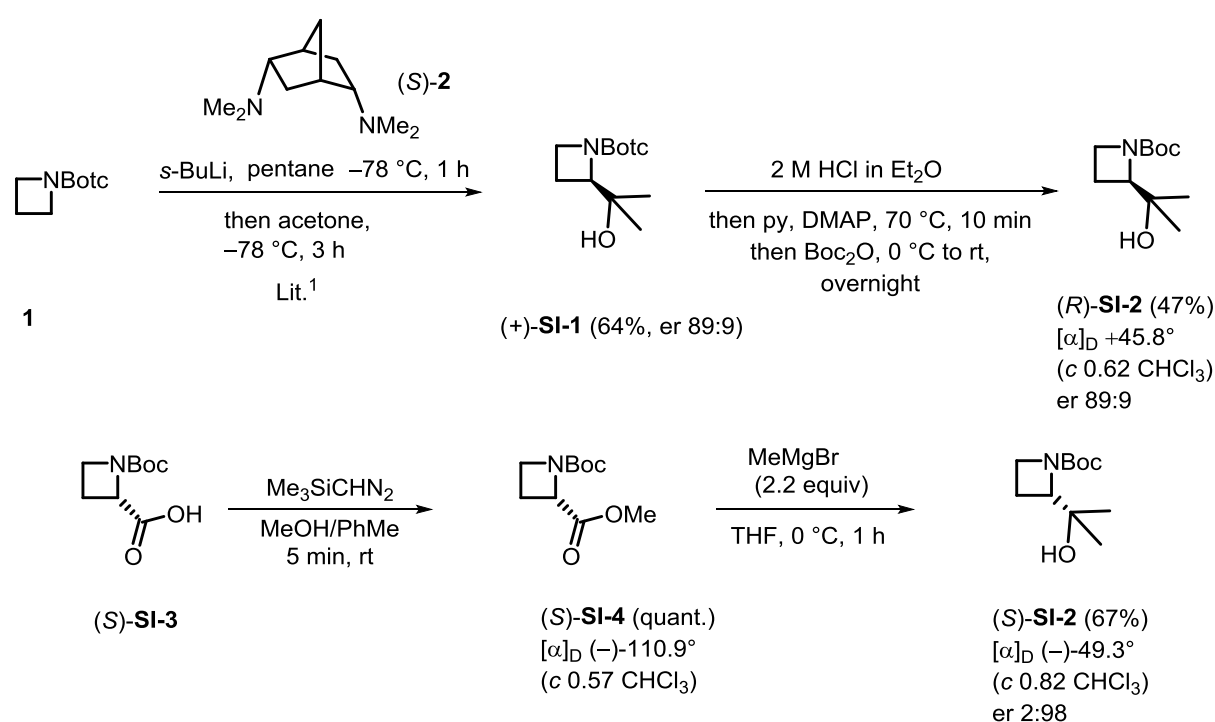
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## 1. Determinations of absolute configuration

### (a) Acetone-trapped azetidine (+)-SI-1

Tertiary alcohol (+)-SI-1 (89:11 er, Scheme S1), prepared from  $\alpha$ -lithiation of *N*-Botc azetidine **1** in the presence of DIANANE (S)-**2** and trapping with acetone,<sup>1</sup> was determined to be of *R* configuration, by *N*-protecting group interchange from Botc to Boc to give *N*-Boc alcohol (*R*)-SI-2 and specific rotation and chiral HPLC comparison with *N*-Boc alcohol (S)-SI-2. The latter was prepared from *N*-Boc (S)-azetidine-2-carboxylic acid (S)-SI-3 by esterification using Me<sub>3</sub>SiCHN<sub>2</sub><sup>2</sup> and then reaction of the resulting ester (S)-SI-4 with MeMgBr (2.2 equiv). The *R* assignment to acetone-trapped azetidine (+)-SI-1 reverses that indicated in our earlier work, which had been tentatively assigned by analogy with the sense of asymmetric induction established when MeI was used as the electrophile.<sup>1</sup>



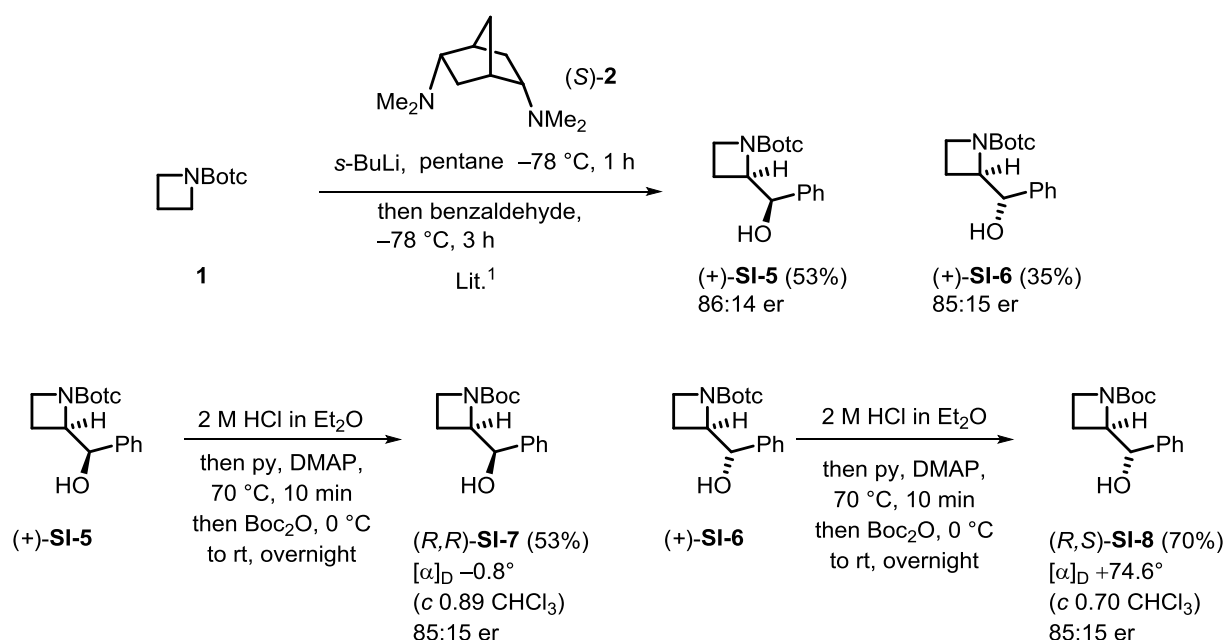
Scheme S1. Determination of absolute configuration of acetone-trapped azetidine (+)-SI-1

<sup>1</sup> Hodgson, D. M.; Mortimer, C. L.; McKenna, J. M. Amine Protection/ $\alpha$ -Activation with the *tert*-Butoxythiocarbonyl Group: Application to Azetidine Lithiation–Electrophilic Substitution. *Org. Lett.* **2015**, *17*, 330–333.

<sup>2</sup> Rayner, P. J.; Smith, J. C.; Denneval, C.; O'Brien, P.; Clarke, P. A.; Horan, R. A. J. Mechanistic Interrogation of the Asymmetric Lithiation-trapping of *N*-Thiopivaloyl Azetidine and Pyrrolidine. *Chem. Commun.* **2016**, *52*, 1354–1357.

**(b) Benzaldehyde-trapped azetidines (+)-SI-5 and (+)-SI-6**

Benzylic alcohols (+)-SI-5 (86:14 er) and (+)-SI-6 (85:15 er), previously prepared from  $\alpha$ -lithiation of *N*-Botc azetidine **1** in the presence of DIANANE (*S*)-**2** and trapping with benzaldehyde,<sup>1</sup> were determined to be *RR* and *RS* configured, by *N*-protecting group interchange from Botc to Boc (Scheme S2) and NMR, specific rotation and chiral HPLC comparison with data recently reported by O'Brien and co-workers.<sup>2</sup> These assignments for benzaldehyde-trapped azetidines reverse those indicated in our earlier work,<sup>1</sup> which were made by a now apparent erroneous correlation of the major benzylic alcohol product relative stereochemistry with crystallographically-determined benzaldehyde-derived adduct from *N*-thiopivaloyl azetidine and by analogy with the sense of asymmetric induction established when MeI was used as the electrophile.

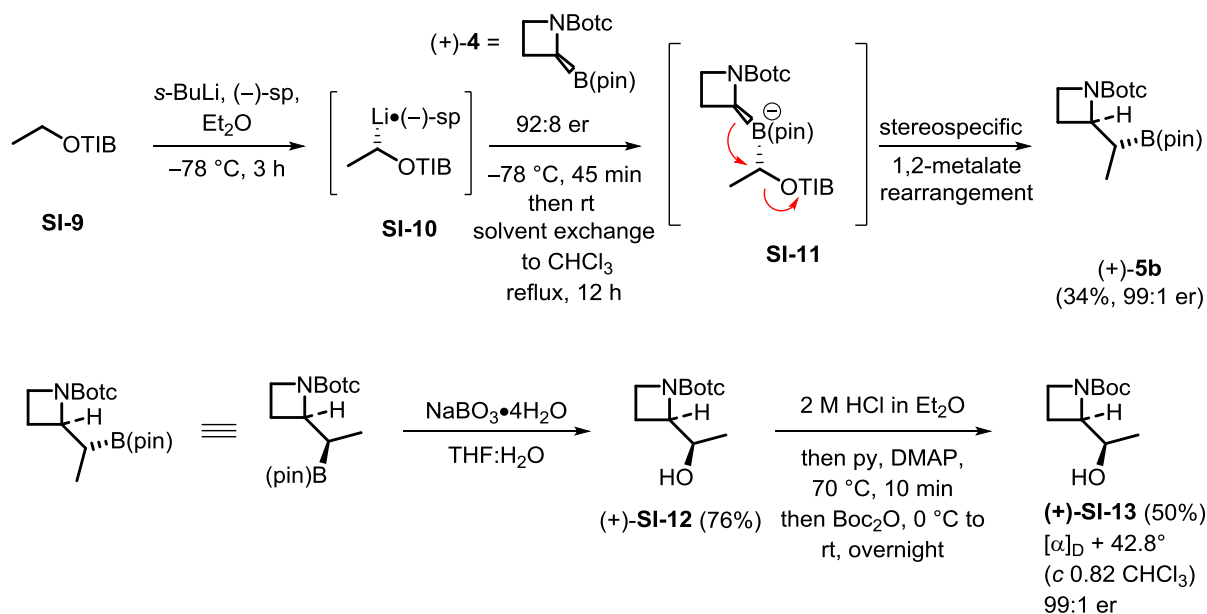


**Scheme S2. Determination of absolute configuration for benzaldehyde-trapped azetidines (+)-SI-5 and (+)-SI-6**

**(c) Boronic ester (+)-4**

The absolute configuration of boronic ester (+)-**4** was determined to be *S* by derivatisation to an alcohol (*R,R*)-SI-13 (Scheme S3) whose configuration was assigned after NMR, specific rotation and chiral HPLC comparison with alcohols (*S,S*)-SI-13 and (*S,R*)-SI-13' derived from (*S*)-azetidine-2-carboxylic acid (SI-3) (Scheme S4). For the purpose of clarity in this discussion of the assignment of

absolute configuration of boronic ester (+)-**4**, stereocentres that are enantioenriched, but of *initially* unknown absolute configuration are represented with a hollow wedge or a dashed line.<sup>3</sup>

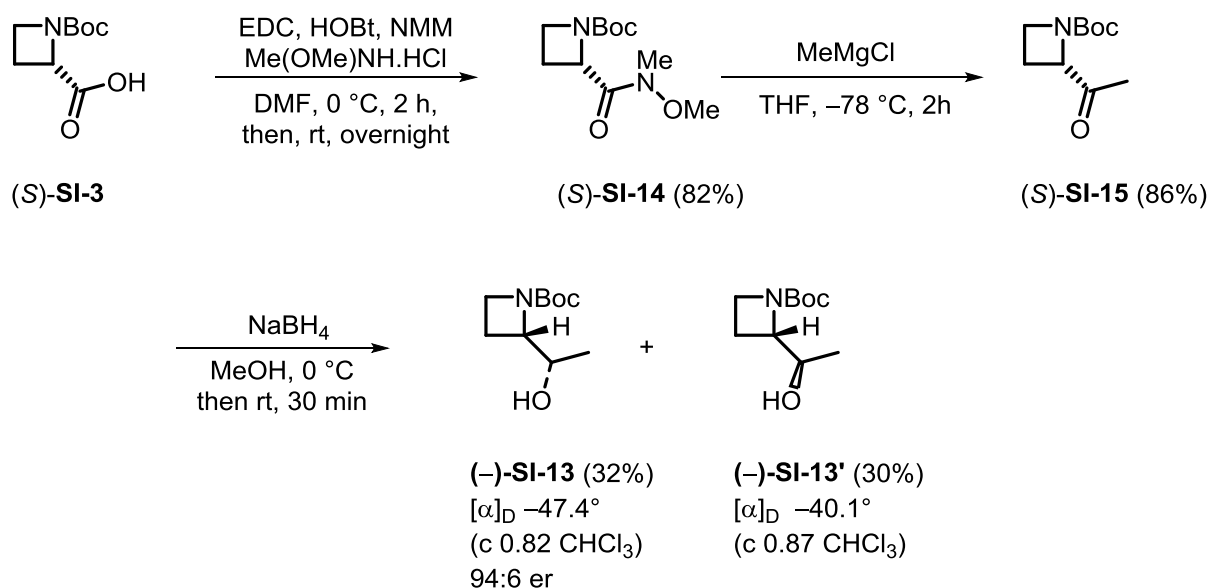


**Scheme S3. Conversion of boronic ester (+)-**4** to *N*-Boc alcohol (+)-**SI-13****

Boronic ester (+)-**4** (92:8 er) first underwent boronate homologation to (+)-**5b** (Scheme S3) via ate complex formation and subsequent 1,2-metallate rearrangement (**SI-11**→(+)-**5b**) with an  $\alpha$ -TIBO organolithium **SI-10** derived from (–)-sparteine-mediated lithiation of ethyl ester **SI-9**. As the  $\alpha$ -lithiobenzoate **SI-10** is known to be of *S*-configuration<sup>4</sup> and the 1,2-metallate rearrangement stereospecific, with retention at the migrating azetidine centre and inversion at the carbon bearing the TIBO nucleofuge, this then fixes the configuration at the homologated boron-bearing carbon in (+)-**5b** as *R*. Stereoretentive oxidation of homologated boronate (+)-**5b** to alcohol (+)-**SI-12** using sodium perborate, followed by *N*-protecting group interchange from Botc to Boc gave alcohol (+)-**SI-13**, with *R*-configuration at the hydroxyl-bearing centre and the azetidine stereocentre configuration at this stage unknown prior to the correlation below.

<sup>3</sup> Maehr, H. Graphic Representation of Configuration in Two-Dimensional Space. Current Conventions, Clarifications, and Proposed Extensions. *J. Chem. Inf. Comput. Sci.* **2002**, *42*, 894–902.

<sup>4</sup> Larouche-Gauthier, R.; Fletcher, C. J.; Couto, I.; Aggarwal, V. K. Use of Alkyl 2,4,6-Triisopropylbenzoates in the Asymmetric Homologation of Challenging Boronic Esters. *Chem. Commun.* **2011**, *47*, 12592–12594.



**Scheme S4. Derivatization of (S)-carboxylic acid SI-3 to alcohols (-)-SI-13 and (-)-SI-13'**

To obtain alcohols (-)-SI-13 and (-)-SI-13' for the correlation, a sequence similar to that developed by O'Brien and co-workers was used.<sup>2</sup> Weinreb amide (S)-SI-14, made from (S)-azetidine-2-carboxylic acid (S)-SI-3, was converted to methyl ketone (S)-SI-15 using MeMgCl. Methyl ketone (S)-SI-15 was then reduced using NaBH<sub>4</sub> to give an ≈1:1 mixture of chromatographically separable alcohols (-)-SI-13 and (-)-SI-13'. Alcohol (-)-SI-13 possessed matching NMR data to alcohol (+)-SI-13 derived from boronic ester (+)-4 but displayed opposite polarimetric and chiral HPLC data to it, indicating these alcohols are enantiomeric. As the S-carboxylic acid-derived alcohols carry unchanged azetidine stereocentre configuration and the boronic ester (+)-4-derived alcohol (+)-SI-13 (Scheme S3) is R-configured at the hydroxyl-bearing centre, this leads to the assignment of the boronic ester (+)-4-derived alcohol as (R,R)-SI-13 and boronic ester (+)-4 as S (Fig. S2) [following the stereochemical discussion in the preceding paragraph on the formation (+)-SI-13].

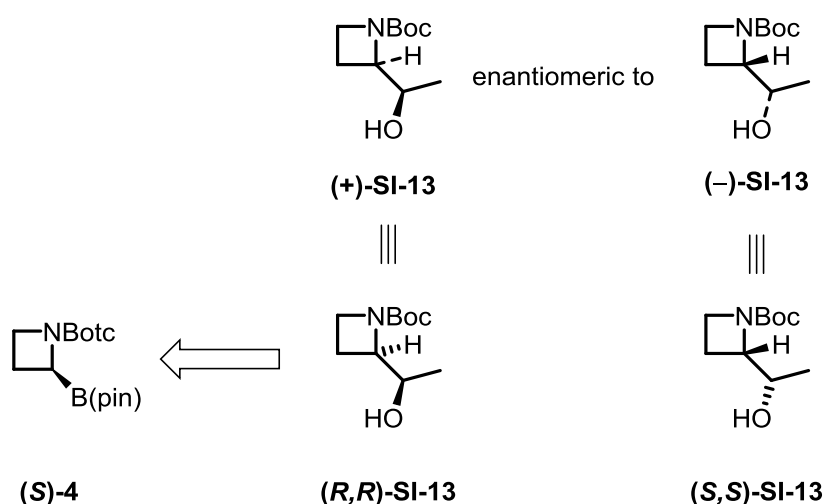


Figure S1. Correlation between and absolute configuration of alcohols (+)-SI-13 and (-)-SI-13 leading to assignment of boronic ester (+)-4 as *S*

## 2. Studies on stability of boronic ester 4 to silica

Conventional silica gel column chromatography resulted in complete loss of boronic ester **4**. So as to achieve any purification via column chromatography, deactivation of the stationary silica phase was studied. Chromatography of pure boronic ester **4** (100 mg) using boric acid-impregnated silica<sup>5</sup> or 35% wt H<sub>2</sub>O-deactivated silica led to recovery of boronic ester **4** without major losses (Table S1).

Entry	Silica	Mass of silica	Recovered boronic ester <b>4</b> (%)
1	Boric acid silica	5 g	91
2	Boric acid silica	10 g	85
3	35% wt H <sub>2</sub> O silica	10 g	69

Table S1. Comparison of boric acid silica and 35% wt H<sub>2</sub>O silica in chromatography of boronic ester **4**

Despite the above promising results with boric acid-impregnated silica and 35% wt H<sub>2</sub>O silica, separation of boronic ester **4** from impurities was still inefficient and very time consuming (caused by streaking of boronic ester). Boric acid-impregnated silica became less effective as the batch aged.

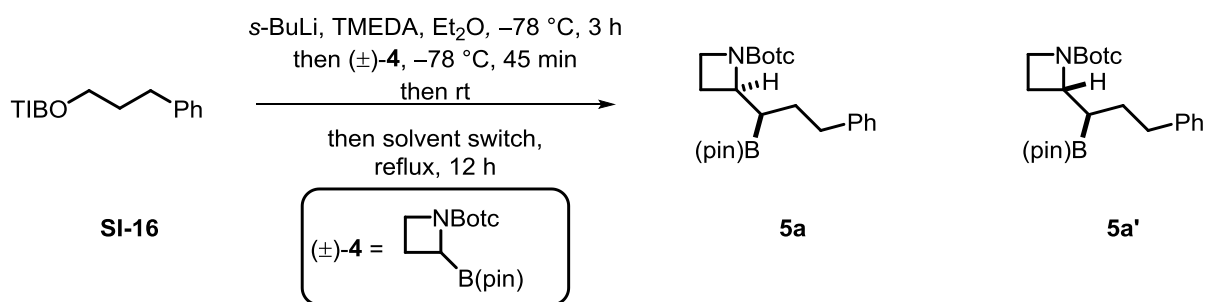
<sup>5</sup> Hitosugi, S.; Tanimoto, D.; Nakanishi, W.; Isobe, H. A Facile Chromatographic Method for Purification of Pinacol Boronic Esters. *Chem. Lett.* **2012**, *41*, 972–973.

C<sub>2</sub>-deactivated silica<sup>6</sup> was able to provide better separation; however, the efficiency of the silica varied from batch to batch and the mass recovery was similar to when using 35% wt H<sub>2</sub>O.

### 3. Studies on generation of homologated boronic ester 5a

#### (a) From 2-B(pin)-azetidine 4 and ester SI-16

##### (i) solvent and temperature variation

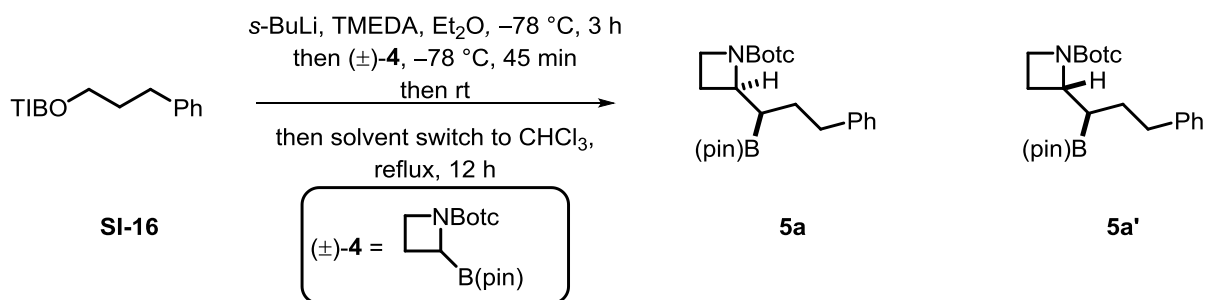


Entry	Lithiation solvent	Migration solvent	Reflux temp/ °C	Yield 5a/5a' (%)	dr (5a:5a')	Recovered SI-16 (%)
1	Et <sub>2</sub> O	Et <sub>2</sub> O	35	7	0:100	36
<b>2</b>	<b>Et<sub>2</sub>O</b>	<b>CHCl<sub>3</sub></b>	<b>63</b>	<b>45</b>	<b>74:26</b>	<b>26</b>
3	PhMe	PhMe	111	0	n/a	72
4	Et <sub>2</sub> O	PhMe	111	0	n/a	22
5	TBME	TBME	55	41	71:29	33

**Table S2. Optimisation of lithiation/1,2-rearrangement with benzoate SI-16 and boronic ester 4**

<sup>6</sup> Panne, P.; Fox, J. M. Rh-Catalyzed Intermolecular Reactions of Alkynes with  $\alpha$ -Diazoesters that Possess  $\beta$ -Hydrogens: Ligand-Based Control over Divergent Pathways. *J. Am. Chem. Soc.* **2007**, *129*, 22–23.

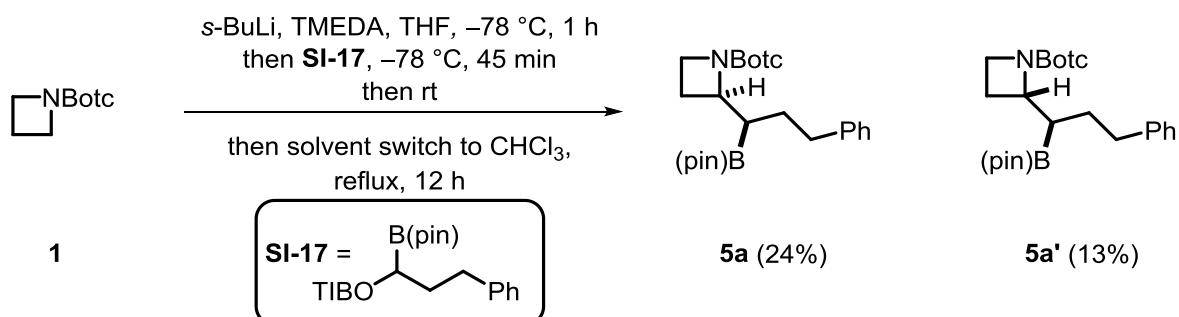
## (ii) variation in substrate equivalents



Entry	Benzoate <b>SI-16</b> (equiv)	Boronic ester <b>4</b> (equiv)	Yield <b>5a/5a'</b> (%)	dr ( <b>5a:5a'</b> )	Recovered <b>SI-16</b> (%)
1	1.3	1	45	74:26	26
2	2	1	12	59:41	50
3	1	1	37	81:19	34
<b>4</b>	<b>1</b>	<b>1.5</b>	<b>71<sup>a</sup></b>	<b>83:17</b>	<b>13</b>

<sup>a</sup> % Yield based on limiting reagent benzoate **SI-16**

**Table S3. Optimisation of conditions through variations in reagent equivalents**

(b) From *N*-Botc-azetidine **1** and boronic ester **SI-17**

**Scheme S5. Reversal of boronic ester and lithiated intermediate**



## 5. Experimental conditions

### (a) General information

Commercially available chemicals/reagents were purchased from major suppliers and unless stated otherwise were used without further purification. TMEDA, (–)-sparteine [(–)-sp] and Et<sub>3</sub>N were distilled from CaH<sub>2</sub>; DIANANE (**2**) and *i*-ProB(pin) were distilled under reduced pressure before use. All reactions were stirred using Teflon-coated magnetic stirrer bars. Where reactions are stated as under nitrogen atmosphere, glassware was flame-dried and solvents were degassed and dried using a Pure Solv-MD solvent purification system and transferred under nitrogen. The following cooling baths were used: 0 °C (ice/water) and –78 °C (dry ice/acetone). For reactions above rt, pre-heated paraffin oil baths on stirrer hotplates were used and the temperature was controlled via an external temperature probe. Reactions were monitored by TLC using Merck silica gel 60 F254 (aluminium support) TLC plates, which were developed using standard visualising agents: UV fluorescence (254 nm), potassium permanganate /Δ or vanillin /Δ. Column chromatography was carried out on silica gel (43-63 μm) in the solvent system indicated. Petroleum ether refers to the fraction boiling between 40 °C to 60 °C. Melting points were measured in open capillaries using Stuart Scientific melting point apparatus and are uncorrected. Infra-red spectra were recorded neat and the intensity of the peaks are reported as s, m, w, br, denoting strong, medium, weak, and broad, respectively. NMR spectra were recorded on Brüker DPX200 (<sup>1</sup>H = 200 MHz), Brüker AVF400 (<sup>1</sup>H = 400 MHz, <sup>13</sup>C = 101 MHz), AVC 500 (<sup>1</sup>H = 500 MHz, <sup>13</sup>C 125 MHz) or AVB400 (<sup>11</sup>B = 128 MHz) machines in commercial, deuterated, TMS free solvents at 25 °C. Chemical shifts (δ) are given in ppm relative to TMS, calibrated using residual solvent peaks. Where rotamers/diastereomers are discernible, signals due to the minor rotamer/diastereomer are given in parentheses. <sup>13</sup>C NMR spectra were recorded using the UDEFT or PENDANT pulse sequences from the Brüker standard pulse program library. <sup>13</sup>C DEPT spectra and 2D COSY, HSQC and HMBC spectra were recorded so as to assist with assignment when required. Multiplicity is denoted in <sup>1</sup>H NMR by: s (singlet), d (doublet), t (triplet), q (quartet), sext (sextet), hept (heptet) m (multiplet). Proton coupling constants *J* are reported to the nearest 0.1 Hz. NMR spectra were processed using MestReNova software. High resolution mass spectra were obtained by FI (Micromass GCT), or by ESI (LCT Premier reflectron TOF and Brüker MicroTOF) using tetraoctylammonium bromide or sodium dodecyl sulfate as lock mass; values are quoted as ratio of mass to charge in Daltons, and relative intensities of assignable peaks observed are quoted as a percentage value of the base peak. Chiral HPLC was performed on a Dionex UltiMate 3000 system comprising a Dionex LPG-3400A pump, WPS-3000SL autosampler, TCC-3000SD column compartment and DAD-3000 diode-array detector, fitted with the appropriate Daicel Chiralpak column (dimensions: 0.46 cm ø x 25 cm) and corresponding guard column (0.4 cm ø x 1 cm). Wavelengths (λ) are reported in nm, retention times (τ<sub>R</sub>) are reported in mins and solvent flow rates are reported in mL min<sup>-1</sup>.

**(b) General procedures****(i) General procedure A: *N*-Botc deprotection–*N*-Boc reprotection sequence**

To the *N*-Botc protected azetidiny alcohol (1 equiv) was added HCl (2 M in Et<sub>2</sub>O, 15 equiv) and the mixture was stirred for 1 h at rt. The reaction was concentrated under a stream of nitrogen. py (0.07 M w.r.t azetidiny alcohol) and DMAP (0.1 equiv) were added to the resulting residue, which was then heated to 70 °C (oil bath) for 10 min and then cooled to 0 °C. Boc<sub>2</sub>O (1.1 equiv) was added and the reaction mixture warmed to rt and stirred for 12 h. Aq HCl (2 M, 2 mL) was added and the reaction mixture was extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 2 mL). The combined organic layers were washed with aq HCl (2 M, 2 mL), H<sub>2</sub>O (2 mL) and brine (2 mL). The organic layer was dried (MgSO<sub>4</sub>), concentrated under reduced pressure and purified by column chromatography.

**(ii) General procedure B: stannanes from triisopropylbenzoates**

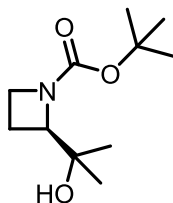
A solution of the triisopropylbenzoate (1 equiv) and TMEDA (1.3 equiv) [or (–)-sp (1.09 equiv) for asymmetric reaction] in Et<sub>2</sub>O (0.2 M) under N<sub>2</sub> was cooled to –78 °C. *s*-BuLi (1.3 equiv, 1.3 M in cyclohexane/hexane) was added dropwise and the reaction was stirred for 4 h at –78 °C. Bu<sub>3</sub>SnCl (1.3 equiv) was then added dropwise to the reaction. After 30 min at –78 °C, the reaction mixture was allowed to warm to rt, then quenched with water (10 mL) and extracted with Et<sub>2</sub>O (3 x 10 mL). The combined organic layers were washed with brine (10 mL), dried (MgSO<sub>4</sub>), concentrated under reduced pressure and purified by column chromatography.

**(iii) General procedure C: boronate homologation via tin–lithium exchange**

A solution of the stannane (1.3 equiv) in Et<sub>2</sub>O (0.1 M) under N<sub>2</sub> was cooled to –78 °C. *n*-BuLi (1.3 equiv, 2.1 M in hexanes) was added dropwise and the reaction mixture was stirred for 1 h at –78 °C. A solution of 2-B(pin)-azetidine **4** (1 equiv) in Et<sub>2</sub>O (0.4 M) was then added dropwise and the reaction mixture was stirred for 1 h at –78 °C. The solution was then warmed to rt over 15 min and the reaction mixture evaporated under vacuum (1 mbar), then CHCl<sub>3</sub> was added to give a 0.06 M solution w.r.t. starting 2-B(pin)-azetidine **4**. The solution was heated under reflux (63 °C, oil bath) overnight (12 h). The reaction mixture was then quenched with water (3 mL) and the layers separated. The organic layer was washed with brine (2 x 2 mL) and the combined aq layers extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 5 mL). The combined organic layers were dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give an orange oil.

**Compounds for determination of absolute configuration for acetone/benzaldehyde trapped azetidines**

***t*-Butyl (*R*)-2-(2-hydroxypropan-2-yl)azetidinium-1-carboxylate (*R*)-SI-2**

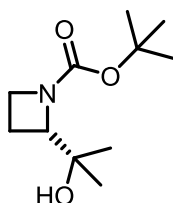


The alcohol was prepared following general procedure A, using *N*-Boc alcohol (*R*)-SI-1<sup>1</sup> (50 mg, 0.22 mmol, 89:11 er). The crude material was purified by column chromatography (10% EtOAc/petroleum ether) to give a colourless oil, alcohol (*R*)-SI-2 (22 mg, 46%) in 89:11 er (conditions for HPLC: ADH column; eluent; *n*-hexane/*i*-PrOH (95:5); flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  ((*R*) major) = 9.4 min,  $\tau_R$  ((*S*) minor) = 15.8 min.

$[\alpha]_D^{25} +45.8$  (c 0.62, CHCl<sub>3</sub>); all other data as described for racemate in Lit.<sup>7</sup>

***t*-Butyl (*S*)-2-(2-hydroxypropan-2-yl)azetidinium-1-carboxylate (*S*)-SI-2**



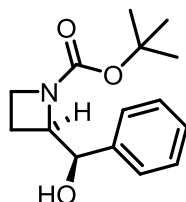
A solution of ester (*S*)-SI-4<sup>2</sup> (50 mg, 0.23 mmol) in THF (2.3 mL) was cooled to 0 °C. To the solution was added MeMgBr (3 M in Et<sub>2</sub>O, 0.17 mL, 0.51 mmol) dropwise and the reaction was stirred at 0 °C for 1 h. The reaction was quenched with sat. aq NH<sub>4</sub>Cl (5 mL) and the organic layer was concentrated under a stream of N<sub>2</sub>. The solution was extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 5 mL), combined organic layers were washed with brine (5 mL), dried (Na<sub>2</sub>SO<sub>4</sub>) and concentrated under reduced pressure to give the crude as a colourless oil. The crude was purified by column chromatography (10% EtOAc/petroleum ether) to give a colourless oil, alcohol (*S*)-SI-2 (33 mg, 67%) in 97.5:2.5 er (conditions for HPLC: ADH column; eluent; *n*-hexane/*i*-PrOH (95:5); flow rate = 1 mL min<sup>-1</sup>).

<sup>7</sup> Hodgson, D. M.; Pearson, C.; Kazmi, M. Generation and Electrophile Trapping of *N*-Boc-2-lithio-2-azetine: Synthesis of 2-Substituted 2-Azetines. *Org. Lett.* **2014**, *16*, 856-859.

$\tau_R$  ((*R*) minor) = 9.0 min,  $\tau_R$  ((*S*) major) = 15.7 min.

$[\alpha]_D^{25} -49.3$  (c 0.82, CHCl<sub>3</sub>); all other data as described for racemate in Lit.<sup>7</sup>

***t*-Butyl (*R*)-2-((*R*)-hydroxy(phenyl)methyl)azetidine-1-carboxylate (*R,R*)-SI-7**

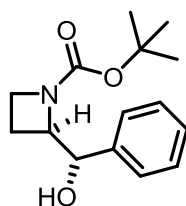


The alcohol was prepared following general procedure A, using *N*-Botc alcohol (*R,R*)-SI-5<sup>1</sup> (27 mg, 0.10 mmol, 86:14 er). The crude material was purified by column chromatography (10% EtOAc/petroleum ether) to give a colourless oil, alcohol (*R,R*)-SI-7 (14 mg, 53%) in 85:15 er (conditions for HPLC: ADH column; eluent; *n*-hexane/*i*-PrOH (95:5); flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  ((*R, R*) major) = 19.8 min,  $\tau_R$  ((*S, S*) minor) = 45.9 min.

$[\alpha]_D^{25} -0.80$  (c 0.89, CHCl<sub>3</sub>); all other data as described for in Lit.<sup>2</sup>

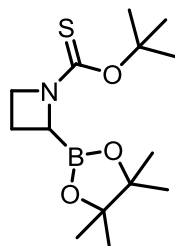
***t*-Butyl (*R*)-2-((*S*)-hydroxy(phenyl)methyl)azetidine-1-carboxylate (*R,S*)-SI-8**



The alcohol was prepared following general procedure A using *N*-Botc alcohol (*R,S*)-SI-6<sup>1</sup> (18 mg, 0.06 mmol, 85:15 er). The crude material was purified by column chromatography (10% EtOAc/petroleum ether) to give a colourless oil, alcohol (*R,S*)-SI-8 (11 mg, 70%) in 85:15 er (conditions for HPLC: ADH column; eluent; *n*-hexane/*i*-PrOH (95:5); flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  ((*R, S*) major) = 12.3 min,  $\tau_R$  ((*S, R*) minor) = 13.8 min.

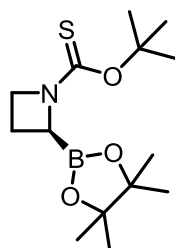
$[\alpha]_D^{25} +74.6$  (c 0.70, CHCl<sub>3</sub>); all other data as described for in Lit.<sup>2</sup>

**Boronic ester 4*****O*-(*t*-Butyl)-2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)azetidine-1-carbothioate 4**

A solution of ( $1R^*,2R^*,4R^*,5R^*$ )- $N^2,N^2,N^5,N^5$ -tetramethylbicyclo[2.2.1]heptane-2,5-diamine **2**<sup>8</sup> (850 mg, 4.68 mmol) and *O*-*t*-butyl azetidine-1-carbothioate **1** (625 mg, 3.60 mmol) in pentane (30 mL) was cooled to  $-78$  °C and *s*-BuLi (3.60 mL, 1.3 M in cyclohexane/hexane, 4.68 mmol) was added dropwise. The reaction mixture was stirred for 1 h at  $-78$  °C before addition of *i*-PrOB(pin) (0.96 mL, 4.70 mmol) dropwise. The reaction mixture was stirred for a further 2 h at  $-78$  °C, then quenched with aq HCl (1 M, 50 mL), and extracted with petroleum ether/Et<sub>2</sub>O (9:1) (4 × 30 mL). The combined organic extracts were washed with water (20 mL), then brine (20 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a pale-yellow oil which solidified under hi-vacuum (1 mbar) to give boronic ester **4** (960 mg, 89%).

mp 55–57 °C; IR (neat/cm<sup>-1</sup>) 2977 (w), 1491 (m), 1444 (m), 1416 (m), 1381 (m), 1338 (m), 1267 (m), 1226 (m), 1138 (s);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) (1.5:1 rotamer mixture, by analysis of C(CH<sub>3</sub>)<sub>3</sub> signals in the 1.63-1.57 region) 4.21 – 3.95 (3H, m, NCH & NCH<sub>2</sub>), 2.35 – 2.10 (1H, m, NCHCHH'), 2.06 – 1.94 (1H, m, NCHCHH') 1.61 (1.59) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.31 – 1.23 (12H, m, OC(CH<sub>3</sub>)<sub>2</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 184.0 (184.6) (C=S), 84.6 (84.3) (C(CH<sub>3</sub>)<sub>3</sub>), 84.2 (84.1) (OC(CH<sub>3</sub>)<sub>2</sub>), 51.9 (50.8) (NCH<sub>2</sub>), 28.6 (C(CH<sub>3</sub>)<sub>3</sub>), 25.1 (24.8) (OC(CH<sub>3</sub>)<sub>2</sub>), 16.2 (15.6) (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 32; HRMS (FTMS) calcd for [M+Na] C<sub>14</sub>H<sub>26</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>SNa 322.1619, found 322.1620.

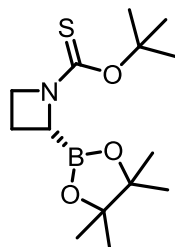
<sup>8</sup> Praz, J.; Guénée, L.; Aziz, S.; Berkessel, A.; Alexakis, A. Evaluation of the Chiral DIANANE Backbone as Ligand for Organolithium Reagents. *Adv. Synth. Catal.* **2012**, *354*, 1780–1790.

***O*-(*t*-Butyl) (*S*)-2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)azetidine-1-carbothioate (*S*)-4**

A solution of (1*S*,2*S*,4*S*,5*S*)-*N*<sup>2</sup>,*N*<sup>2</sup>,*N*<sup>5</sup>,*N*<sup>5</sup>-tetramethylbicyclo[2.2.1]heptane-2,5-diamine (*S*)-**2**<sup>8</sup> (685 mg, 3.77 mmol) and *O*-*t*-butyl azetidine-1-carbothioate **1** (500 mg, 2.88 mmol) in pentane (25 mL) was cooled to  $-78$  °C and *s*-BuLi (2.90 mL, 1.3 M in cyclohexane/hexane, 3.77 mmol) was added dropwise. The reaction mixture was stirred for 1 h at  $-78$  °C before the addition of *i*-PrOB(pin) (0.77 mL, 3.75 mmol) dropwise. The reaction mixture was stirred for a further 2 h at  $-78$  °C, then quenched with aq HCl (1 M, 50 mL), and extracted with petroleum ether/Et<sub>2</sub>O (9:1) (4 × 30 mL). The combined organic extracts were washed with water (20 mL), then brine (20 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a pale yellow oil, boronic ester (*S*)-**4** (838 mg, 92%, 5% SM) 92:8 er (conditions for HPLC: Chiralcel ADH column; eluent; *n*-hexane/*i*-PrOH (99:1); flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  ((*R*) minor) = 10.2 min,  $\tau_R$  ((*S*) major) = 13.9 min.

$[\alpha]_D^{25} +96.9$  (*c* 1.05, CHCl<sub>3</sub>); all other data as described for racemic **4**.

***O*-(*t*-Butyl) (*R*)-2-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)azetidine-1-carbothioate (*R*)-4**

A solution of (1*R*,2*R*,4*R*,5*R*)-*N*<sup>2</sup>,*N*<sup>2</sup>,*N*<sup>5</sup>,*N*<sup>5</sup>-tetramethylbicyclo[2.2.1]heptane-2,5-diamine (*R*)-**2**<sup>8</sup> (685 mg, 3.77 mmol) and *O*-*t*-butyl azetidine-1-carbothioate **1** (500 mg, 2.88 mmol) in pentane (25 mL)

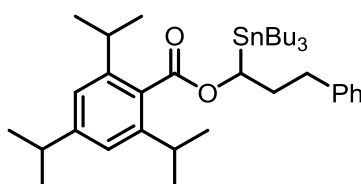
was cooled to  $-78\text{ }^{\circ}\text{C}$  and *s*-BuLi (2.90 mL, 1.3 M in cyclohexane/hexane, 3.77 mmol) was added dropwise. The reaction mixture was stirred for 1 h at  $-78\text{ }^{\circ}\text{C}$  before the addition of *i*-PrOB(pin) (0.77 mL, 3.75 mmol) dropwise. The reaction mixture was stirred for a further 2 h at  $-78\text{ }^{\circ}\text{C}$ , then quenched with sat. aq HCl (1 M, 50 mL), and extracted with Et<sub>2</sub>O (4 × 30 mL). The combined organic extracts were washed with water (20 mL), then brine (20 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure. Purification of the resulting yellow oil by column chromatography (35% wt H<sub>2</sub>O SiO<sub>2</sub>, 0-5% EtOAc/petroleum ether) gave a white solid, boronic ester (*R*)-**4** (0.541 mg, 63%) in 89:11 er (conditions for HPLC: Chiralcel ADH column, eluent: *n*-hexane/*i*-PrOH (99:1), flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  (*R*) major) = 10.2 min,  $\tau_R$  (*S*) minor) = 13.9 min.

$[\alpha]_D^{25} -87.2$  (c 0.98, CHCl<sub>3</sub>); all other data as described for racemic **4**.

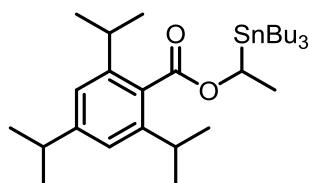
### **$\alpha$ -Stannyl triisopropylbenzoates**

#### **3-Phenyl-1-(tributylstannyl)propyl 2,4,6-triisopropylbenzoate SI-18**



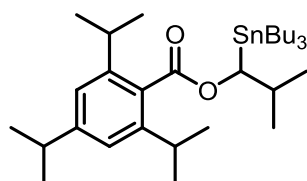
Prepared following a lit.<sup>4</sup> procedure.

#### **1-(Tributylstannyl)ethyl 2,4,6-triisopropylbenzoate SI-22**



Prepared following a lit.<sup>9</sup> procedure.

<sup>9</sup> Beak, P; Carter, L. G. Dipole-Stabilized Carbanions from Esters:  $\alpha$ -Oxo Lithiations of 2,6-Substituted Benzoates of Primary Alcohols. *J. Org. Chem.* **1981**, *46*, 2363–2373.

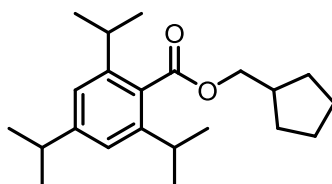
**2-Methyl-1-(tributylstannyl)propyl 2,4,6-triisopropylbenzoate SI-23**

The stannane was prepared following general procedure B, using isobutyl triisopropylbenzoate<sup>10</sup> (1.00 g, 3.30 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane **SI-23** (1.68 g, 86%).

*R<sub>f</sub>* 0.71 (5% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2958 (s), 2926 (m), 2870 (m), 1707 (m), 1607 (w), 1461 (m), 1383 (w), 1363 (w), 1325 (w), 1250 (m), 1186 (m), 1137 (w), 1064 (m); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) 6.99 (2H, s, *m*-Ar), 5.15 (1H, d, *J* = 4.2 Hz, OCH), 3.00 – 2.74 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.30 – 2.18 (1H, m, OCHCH(CH<sub>3</sub>)<sub>2</sub>), 1.58 – 1.46 (6H, m, SnCH<sub>2</sub>CH<sub>2</sub>), 1.33 (6H, sext, *J* = 7.3 Hz, CH<sub>2</sub>CH<sub>3</sub>), 1.27 – 1.21 (18H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.04 (3H, d, *J* = 6.7 Hz, OCHCH(CH<sub>3</sub>)<sub>2</sub>), 0.99 (3H, d, *J* = 6.9 Hz, OCHCH(CH<sub>3</sub>)<sub>2</sub>), 0.98 – 0.93 (6H, m, SnCH<sub>2</sub>), 0.89 (9H, t, *J* = 7.3 Hz, CH<sub>2</sub>CH<sub>3</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 171.4 (C=O), 149.8 (*p*-Ar), 145.0 (*o*-Ar), 131.2 (*i*-Ar), 120.9 (*m*-Ar), 79.4 (OCH), 34.5 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 33.0 (OCHCH(CH<sub>3</sub>)<sub>2</sub>), 31.6 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 29.3 (SnCH<sub>2</sub>CH<sub>2</sub>), 27.7 (CH<sub>2</sub>CH<sub>3</sub>), 24.8 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.4 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 21.7 (OCHCH(CH<sub>3</sub>)<sub>2</sub>), 20.2 (OCHCH(CH<sub>3</sub>)<sub>2</sub>), 13.8 (CH<sub>2</sub>CH<sub>3</sub>), 10.55 (SnCH<sub>2</sub>); HRMS (FTMS) calcd for [M+H] C<sub>32</sub>H<sub>59</sub>O<sub>2</sub><sup>120</sup>Sn 595.3536, found 595.3532.

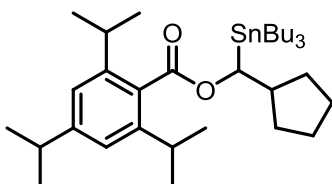
<sup>10</sup> Mykura, R. C.; Veth, S.; Varela, A.; Dewis, L.; Farndon, J. J.; Myers, E. L.; Aggarwal, V. K. Investigation of the Deprotonative Generation and Borylation of Diamine-Ligated α-Lithiated Carbamates and Benzoates by in Situ IR spectroscopy. *J. Am. Chem. Soc.* **2018**, *140*, 14677–14686.

## Cyclopentylmethyl 2,4,6-triisopropylbenzoate SI-24



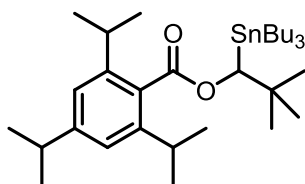
To a solution of cyclopentanemethanol (1.40 mL, 13.2 mmol) in THF (48 mL) were added Ph<sub>3</sub>P (3.50 g, 13.2 mmol) and 2,4,6-triisopropylbenzoic acid (3.00 g, 12.0 mmol). The mixture was cooled to 0 °C and DIAD (2.60 mL, 13.2 mmol) was added dropwise. The solution was stirred at 0 °C for 30 min, warmed to rt and stirred for 4 h. The reaction was then quenched with sat. aq NH<sub>4</sub>Cl (10 mL) and the layers separated. The organic layer was washed with brine (2 x 10 mL) and the combined aq layers were extracted with Et<sub>2</sub>O (3x 10 mL). The combined organic extracts were dried (MgSO<sub>4</sub>) and concentrated under reduced pressure. The crude residue was triturated with pentane to remove Ph<sub>3</sub>P=O and concentrated under reduced pressure to give a pale yellow oil. This crude material was purified by column chromatography (2% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, benzoate **SI-24** (3.51 g, 88%).

*R<sub>f</sub>* 0.50 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2959 (s), 2870 (w), 1725 (s), 1607 (w), 1461 (w), 1283 (w), 1250 (s), 1137 (m), 1103 (w), 1075 (m); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) 7.02 (2H, s, *m*-Ar), 4.21 (2H, d, *J* = 7.2 Hz, OCH<sub>2</sub>), 2.95 – 2.81 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.32 (1H, hept, *J* = 7.2 Hz, OCH<sub>2</sub>CH), 1.89 – 1.75 (2H, m, CHCHH'), 1.70 – 1.52 (4H, m, CHCH<sub>2</sub>CH<sub>2</sub>), 1.38 – 1.29 (2H, m, CHCHH'), 1.26 (12H, d, *J* = 6.7 Hz, *o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.26 (6H, d, *J* = 6.9 Hz, *p*-ArCH(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 171.3 (C=O), 150.1 (*p*-Ar), 144.8 (*o*-Ar), 121 (*i*-Ar & *m*-Ar), 69.3 (OCH<sub>2</sub>), 38.6 (OCH<sub>2</sub>CH), 34.6 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 31.7 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 29.7 (OCH<sub>2</sub>CHCH<sub>2</sub>), 25.6 (CHCH<sub>2</sub>CH<sub>2</sub>), 24.3 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>); HRMS (FTMS) calcd for [M+H] C<sub>22</sub>H<sub>35</sub>O<sub>2</sub> 331.2632, found 331.2633.

**Cyclopentyl(tributylstannyl)methyl 2,4,6-triisopropylbenzoate SI-25**

The stannane was prepared following general procedure B, using cyclopentylmethyl triisopropylbenzoate **SI-24** (897 mg, 2.71 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, cyclopentylmethyl stannane **SI-25** (1.28 g, 77%).

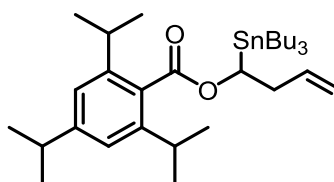
*R<sub>f</sub>* 0.71 (5% EtOAc/petroleum ether); IR (neat/cm<sup>-1</sup>) 2957 (s), 2927 (m), 2869 (w), 1706 (m), 1461 (w), 1068 (m); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) 6.99 (2H, s, *m*-Ar), 5.18 – 5.11 (1H, m, OCH), 2.92 – 2.80 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.49 – 2.34 (1H, m, OCHCH), 1.82 – 1.69 (2H, m, CHCHH'), 1.68 – 1.41 (10H, m, CH<sub>2</sub>CH<sub>2</sub> & SnCH<sub>2</sub>), 1.40 – 1.18 (26H, m, SnCH<sub>2</sub>CH<sub>2</sub>, ArCH(CH<sub>3</sub>)<sub>2</sub> & CHCHH'), 1.00 – 0.82 (15H, m, CH<sub>2</sub>CH<sub>3</sub> & CH<sub>2</sub>CH<sub>3</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 171.3 (C=O) 149.7 (*p*-Ar), 144.9 (*o*-Ar), 131.2 (*i*-Ar), 120.8 (*m*-Ar), 75.9 (OCHSn), 44.5 (OCHCH), 34.4 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 31.5 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 30.9 (CHCH<sub>2</sub>), 29.2 (SnCH<sub>2</sub>), 27.6 (SnCH<sub>2</sub>CH<sub>2</sub>), 25.8 (CHCH<sub>2</sub>CH<sub>2</sub>), 24.6 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.3 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 13.7 (CH<sub>2</sub>CH<sub>3</sub>), 10.3 (CH<sub>2</sub>CH<sub>3</sub>); HRMS (FTMS) calcd for [M+H] C<sub>35</sub>H<sub>61</sub>O<sub>2</sub><sup>120</sup>Sn 621.3688, found 621.3689.

**2,2-Dimethyl-1-(tributylstannyl)propyl 2,4,6-triisopropylbenzoate SI-26**

The stannane was prepared following general procedure B, using neopentyl triisopropylbenzoate<sup>10</sup> (884 mg, 2.78 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane **SI-26** (1.41 g, 84%).

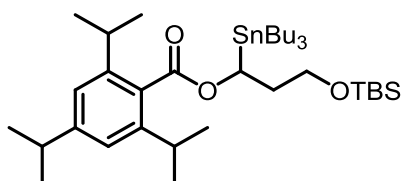
$R_f$  0.71 (5% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2957 (s), 2927 (s), 2870 (w), 1710 (s), 1461 (m), 1363 (w) 1251 (s), 1135 (w), 1103 (w), 1028 (s);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 7.00 (2H, s, *m*-Ar), 5.24 – 5.06 (1H, m, OCH), 3.02 – 2.73 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.61 – 1.42 (6H, m, SnCH<sub>2</sub>), 1.38 – 1.30 (6H, m, CH<sub>2</sub>CH<sub>3</sub>), 1.29 – 1.22 (18H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.07 – 0.94 (15H, m, C(CH<sub>3</sub>)<sub>3</sub> & SnCH<sub>2</sub>CH<sub>2</sub>), 0.92 – 0.85 (9H, m, CH<sub>2</sub>CH<sub>3</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) 170.9 (C=O), 149.8 (*p*-Ar), 145.3 (*o*-Ar), 131.0 (*i*-Ar), 121.1 (*m*-Ar), 83.9 (OCH), 34.5 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 36.4 (C(CH<sub>3</sub>)<sub>3</sub>), 31.5 (*m*-CH(CH<sub>3</sub>)<sub>2</sub>), 29.3 (SnCH<sub>2</sub>), 28.5 (C(CH<sub>3</sub>)<sub>3</sub>), 27.7 (CH<sub>2</sub>CH<sub>3</sub>), 24.7 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.6 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 13.8 (CH<sub>2</sub>CH<sub>3</sub>), 11.3 (SnCH<sub>2</sub>); HRMS (FTMS) calcd for [M+H] C<sub>33</sub>H<sub>61</sub>O<sub>2</sub><sup>120</sup>Sn 609.3688, found 609.3690.

### 1-(Tributylstannyl)but-3-en-1-yl 2,4,6-triisopropylbenzoate SI-27



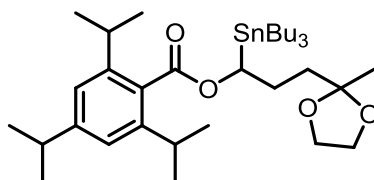
The stannane was prepared following general procedure B, using but-3-enyl triisopropyl benzoate<sup>10</sup> (1.30 g, 4.40 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane **SI-27** (1.37 g, 52%).

$R_f$  0.88 (5% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2958 (s), 2925 (s), 2870 (m), 1711 (s), 1461 (m), 1250 (s), 1136 (m), 1103 (m), 1066 (s), 876 (m);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 6.99 (2H, s, *m*-Ar), 5.84 (1H, ddt,  $J = 17.1, 10.1, 6.8$  Hz, CH<sub>2</sub>=CH), 5.27 (1H, dd,  $J = 7.3, 6.3$  Hz, OCH), 5.12 (1H, ddt,  $J = 17.1, 2.1, 1.5$  Hz, CH<sub>trans</sub>H=CH), 5.06 (1H, ddt,  $J = 10.1, 2.1, 1.1$  Hz, CH<sub>cis</sub>H=CH), 2.92 – 2.80 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.71 – 2.65 (2H, m, OCHCH<sub>2</sub>), 1.61 – 1.43 (6H, m, SnCH<sub>2</sub>CH<sub>2</sub>), 1.32 (6H, sext,  $J = 7.3$  Hz, CH<sub>2</sub>CH<sub>3</sub>), 1.26 – 1.20 (18H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.00 – 0.93 (6H, m, SnCH<sub>2</sub>), 0.89 (9H, t,  $J = 7.3$  Hz, CH<sub>2</sub>CH<sub>3</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) 171.3 (C=O), 149.9 (*p*-Ar), 145.0 (*o*-Ar), 136.4 (CH<sub>2</sub>=CH), 131.1 (*i*-Ar), 120.9 (*m*-Ar), 117.0 (CH<sub>2</sub>=CH), 70.9 (OCH), 38.9 (OCHCH<sub>2</sub>), 34.5 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 31.5 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 29.3 (SnCH<sub>2</sub>CH<sub>2</sub>), 27.7 (CH<sub>2</sub>CH<sub>3</sub>), 24.7 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.3 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 13.8 (CH<sub>2</sub>CH<sub>3</sub>), 10.0 (SnCH<sub>2</sub>); HRMS (FTMS) calcd for [M+H] C<sub>32</sub>H<sub>57</sub>O<sub>2</sub><sup>120</sup>Sn 593.3380, found 593.3378.

**3-((*t*-Butyldimethylsilyl)oxy)-1-(tributylstannyl)propyl 2,4,6-triisopropylbenzoate SI-28**


The stannane was prepared following general procedure B, using 3-((*t*-butyldimethylsilyl)oxy)propyl triisopropylbenzoate<sup>11</sup> (460 mg, 1.09 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane **SI-28** (232 mg, 30%).

*R<sub>f</sub>* 0.67 (3% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2958 (s), 2927 (s), 1709 (m), 1462 (m), 1251 (m), 1101 (m), 1071 (m); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) 6.99 (2H, s, *m*-Ar), 5.21 (1H, dd, *J* = 10.0, 3.6 Hz, OCH), 3.73 – 3.63 (2H, m, OCH<sub>2</sub>), 2.94 – 2.74 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.17 (1H, dddd, *J* = 14.8, 10.0, 6.5, 5.0 Hz, OCHCHH'), 2.03 (1H, dtd, *J* = 14.8, 7.4, 3.6 Hz, OCHCHH'), 1.62 – 1.46 (6H, m, SnCH<sub>2</sub>CH<sub>2</sub>), 1.32 (6H, sext, *J* = 7.3 Hz, CH<sub>2</sub>CH<sub>3</sub>), 1.25 – 1.20 (18H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.01 – 0.93 (6H, m, SnCH<sub>2</sub>), 0.92 – 0.86 (18H, m, CH<sub>2</sub>CH<sub>3</sub> & C(CH<sub>3</sub>)<sub>3</sub>), 0.04 (6H, s, Si(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 171.2 (C=O), 149.9 (*p*-Ar), 145.0 (*o*-Ar), 131.1 (*i*-Ar), 120.9 (*m*-Ar), 68.3 (OCH), 61.4 (OCH<sub>2</sub>), 37.7 (OCHCH<sub>2</sub>), 34.5 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 31.6 (*m*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 29.3 (SnCH<sub>2</sub>CH<sub>2</sub>), 27.7 (CH<sub>2</sub>CH<sub>3</sub>), 26.1 (C(CH<sub>3</sub>)<sub>3</sub>), 24.6 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.4 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.10 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 18.5 (C(CH<sub>3</sub>)<sub>3</sub>), 13.8 (CH<sub>2</sub>CH<sub>3</sub>), 10.00 (SnCH<sub>2</sub>), -5.10 (Si(CH<sub>3</sub>)<sub>2</sub>); HRMS (FTMS) calcd for [M+H] C<sub>37</sub>H<sub>71</sub>O<sub>3</sub><sup>28</sup>Si<sup>120</sup>Sn 711.4195, found 711.4192.

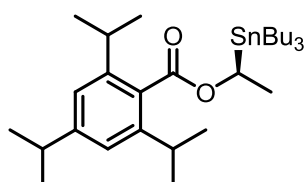
**3-(2-Methyl-1,3-dioxolan-2-yl)-1-(tributylstannyl)propyl 2,4,6-triisopropylbenzoate SI-29**


<sup>11</sup> Fawcett, A.; Nitsch, D.; Ali, M.; Bateman, J. M.; Myers, E. L.; Aggarwal, V. K. Regio- and Stereoselective Homologation of 1,2-Bis(Boronic Esters): Stereocontrolled Synthesis of 1,3-Diols and Sch 725674. *Angew. Chem., Int. Ed.* **2016**, *55*, 14663–14667.

The stannane was prepared following general procedure B, using 3-(2-methyl-1,3-dioxolan-2-yl)propyl triisopropylbenzoate<sup>12</sup> (1.00 g, 2.66 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane **SI-29** (1.14 g, 64%).

$R_f$  0.59 (10% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2958 (s), 2925 (s), 2871 (m), 1707 (m), 1461 (m), 1376 (w), 1286 (w), 1250 (s), 1137 (m), 1103 (m), 1066 (s), 1052 (s);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 6.99 (2H, s, *m*-Ar), 5.15 (1H, dd,  $J = 7.0, 5.9$  Hz, OCH), 3.98 – 3.87 (4H, m, OCH<sub>2</sub>), 2.94 – 2.77 (3H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.02 (2H, dt,  $J = 8.2, 6.9$  Hz, OCHCH<sub>2</sub>), 1.87 – 1.67 (2H, m, CH<sub>2</sub>CO<sub>2</sub>), 1.60 – 1.47 (6H, m, SnCH<sub>2</sub>CH<sub>2</sub>), 1.39 – 1.27 (9H, m, CH<sub>2</sub>CH<sub>3</sub> & CO<sub>2</sub>CH<sub>3</sub>), 1.24 (12H, d,  $J = 6.9$  Hz, *o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.24 (6H, d,  $J = 6.8$  Hz, *p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.02 – 0.94 (6H, m, SnCH<sub>2</sub>), 0.89 (9H, t,  $J = 7.3$  Hz, CH<sub>2</sub>CH<sub>3</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) 171.3 (C=O), 149.9 (*p*-Ar), 145.0 (*o*-Ar), 131.1 (*i*-Ar), 120.9 (*m*-Ar), 109.9 (CO<sub>2</sub>), 72.2 (OCH), 64.9 (OCH<sub>2</sub>), 38.1 (CH<sub>2</sub>CO<sub>2</sub>), 34.5 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 31.6 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 29.3 (SnCH<sub>2</sub>CH<sub>2</sub>), 29.0 (OCHCH<sub>2</sub>), 27.7 (CH<sub>2</sub>CH<sub>3</sub>), 24.7 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.3 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub> & CO<sub>2</sub>CH<sub>3</sub>), 13.8 (CH<sub>2</sub>CH<sub>3</sub>), 10.0 (SnCH<sub>2</sub>); HRMS (FTMS) calcd for [M+H] C<sub>35</sub>H<sub>63</sub>O<sub>4</sub><sup>120</sup>Sn 667.3749, found 667.3749.

#### (*S*)-1-(Tributylstannyl)ethyl 2,4,6-triisopropylbenzoate (*S*)-SI-22

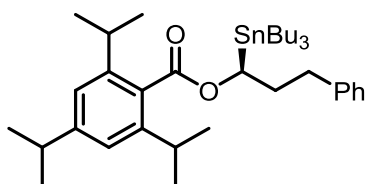


The stannane was prepared following general procedure B, using ethyl triisopropylbenzoate **SI-9**<sup>4</sup> (975 mg, 3.53 mmol) and (–)- sparteine (0.88 mL, 3.84 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane (*S*)-**SI-22** (1.39 g, 70%) in 92:8 er (conditions for HPLC: ODH column; eluent; *n*-hexane; flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  ((*S*) major) = 3.6 min,  $\tau_R$  ((*R*) minor) = 4.2 min.

$[\alpha]_D^{25} +19.3$  (c 1.01, CHCl<sub>3</sub>); all other data as described for racemate in Lit.<sup>9</sup>

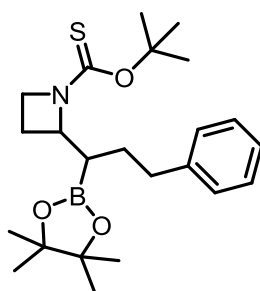
<sup>12</sup> Casoni, G.; Kucukdisli, M.; Fordham, J. M.; Burns, M.; Myers, E. L.; Aggarwal, V. K.  $\alpha$ -Sulfinyl Benzoates as Precursors to Li and Mg Carbenoids for the Stereoselective Iterative Homologation of Boronic Esters. *J. Am. Chem. Soc.* **2017**, *139*, 11877–11886.

**(S)-3-Phenyl-1-(tributylstannyl)propyl 2,4,6-triisopropylbenzoate (S)-SI-18**

The stannane was prepared following general procedure B, using 3-phenylpropyl triisopropylbenzoate **SI-16**<sup>4</sup> (1.37 g, 3.74 mmol) and (–)- sparteine (0.94 mL, 4.08 mmol). The crude material was purified by column chromatography (1% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, stannane (S)-**SI-18** (431 g, 82%) in 94:6 er (conditions for HPLC: ODH column; eluent; *n*-hexane; flow rate = 1 mL min<sup>-1</sup>).

$\tau_R$  ((S) major) = 4.1 min,  $\tau_R$  ((R) minor) = 4.7 min.

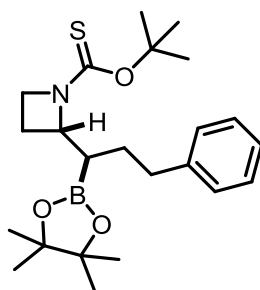
$[\alpha]_D^{25} +20.8$  (c 1.01, CHCl<sub>3</sub>); all other data as described for racemate in Lit.<sup>4</sup>

**Homologated boronic esters****Direct lithiation*****O*-*t*-Butyl 2-(3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5a and (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5a'**

A solution of triisopropyl benzoate **SI-16** (155 mg, 0.42 mmol) and TMEDA (70  $\mu$ L, 0.46 mmol) in Et<sub>2</sub>O (5.5 mL) under N<sub>2</sub> was cooled to –78 °C. *s*-BuLi (0.41 mL, 1.3 M in hexanes, 0.53 mmol) was added dropwise and the reaction mixture was stirred for 3 h at –78 °C. A solution of azetidine boronic ester **4** (190 mg, 0.63 mmol) in Et<sub>2</sub>O (1 mL) was added dropwise and the reaction mixture was stirred for 45 min at –78 °C. The solution was then warmed to rt, Et<sub>2</sub>O was removed under vacuum and CHCl<sub>3</sub> (6.5 mL) was added. The solution was heated under reflux (63 °C) overnight (12 h). The reaction mixture was then quenched with water (3 mL) and the layers separated. The organic layer was

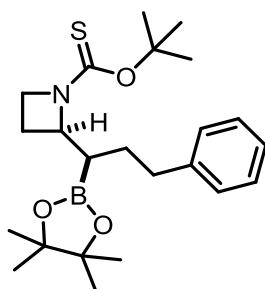
washed with brine (2 x 2 mL) and the combined aq layers extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 5 mL). The combined organic layers were dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give an orange oil. This residue was purified by chromatography (3% EtOAc/petroleum ether). First eluted, a colourless oil, benzoate **SI-16** (20 mg, 13%). Second eluted a colourless oil, which solidified on standing, minor diastereomer (*R\*,S\**)-**5a'** (22 mg, 12%). Thirdly eluted a colourless oil, which solidified on standing, major diastereomer (*R\*,R\**)-**5a** (104 mg, 59%).

***O*-*t*-Butyl (*R\**)-2-((*S\**)-3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R\*,S\**)-**5a'****



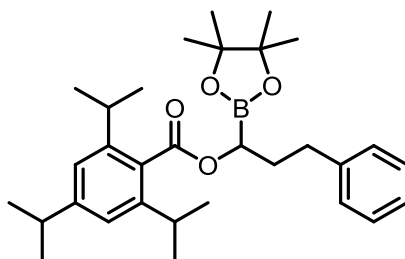
*R<sub>f</sub>* 0.38 (10% EtOAc/petroleum ether); mp 63–64 °C; IR (neat/cm<sup>-1</sup>) 2978 (w), 2927 (w), 1477 (m), 1437 (m), 1390 (m), 1366 (m), 1330 (m), 1280 (m), 1241 (w), 1141 (s); δ<sub>H</sub> (500 MHz, CDCl<sub>3</sub>) (7.4:1 rotamer mixture by analysis of the NCH signals in the 4.67 – 4.37 region) 7.35 – 7.11 (5H, m, Ph), 4.41 (4.64) (1H, q, *J* = 6.7 Hz, (*J* = 6.0 Hz), NCH), 3.99 (3.91 – 3.83) (2H, t, *J* = 7.7 Hz, (m), NCH<sub>2</sub>), 2.74 – 2.52 (2.42 – 2.35) (2H, m, PhCH<sub>2</sub>), 2.27 – 2.07 (2H, m, NCHCH<sub>2</sub>), 1.96 (1H, dt, *J* = 9.8, 6.3 Hz, BCH), 1.74 (1H, dtd, *J* = 13.1, 9.8, 5.6 Hz, PhCH<sub>2</sub>CHH'), 1.61 (1.63) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.59 – 1.54 (1H, m, PhCH<sub>2</sub>CHH'), 1.28 (1.27) (12H, s, C(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (125 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 185.5 (185.3) (C=S), 142.3 (*i*-Ph), 128.49 (*o*-Ph), 128.46 (*m*-Ph), 126.0 (*p*-Ph), 85.0 (84.2) (C(CH<sub>3</sub>)<sub>3</sub>), 83.4 (83.2) (OC(CH<sub>3</sub>)<sub>2</sub>), 65.3 (66.1) (NCH), 49.7 (49.6) (NCH<sub>2</sub>), 35.6 (35.8) (PhCH<sub>2</sub>), 29.4 (29.9) (PhCH<sub>2</sub>CH<sub>2</sub>), 28.5 (28.7) (C(CH<sub>3</sub>)<sub>3</sub>), 25.22 (25.15) (OC(CH<sub>3</sub>)<sub>2</sub>), 25.1 (25.0) (OC(CH<sub>3</sub>)<sub>2</sub>), 18.8 (19.7) (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+Na] C<sub>23</sub>H<sub>37</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>SNa 440.2401, found 440.2403.

***O*-*t*-Butyl (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5a**



*R<sub>f</sub>* 0.29 (10% EtOAc/petroleum ether); mp 75-76 °C; IR (neat/cm<sup>-1</sup>) 2978 (w), 1479 (m), 1439 (m), 1367 (m), 1323 (m), 1275 (m), 1242 (m), 1140 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (4.9:1 rotamer mixture by analysis of the NCH signals in the 4.70 – 4.44 region) 7.36 – 7.09 (m, 5H, Ph), 4.55 (4.73) (1H, dt, *J* = 9.7, 5.5 Hz, (*J* = 9.7, 5.2 Hz), NCH), 3.99 – 3.78 (2H, m, NCH<sub>2</sub>), 2.80 (1H, ddt, *J* = 15.0, 10.3, 4.9 Hz, PhCHH'), 2.64 – 2.43 (2.44) (1H, m, (dt, *J* = 9.8, 4.5 Hz), PhCHH'), 2.25 – 1.64 (5H, m, NCHCH<sub>2</sub>, BCH and PhCH<sub>2</sub>CH<sub>2</sub>), 1.55 (1.61) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.17 (12H, m, C(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 185.5 (C=S), 142.6 (*i*-Ph), 128.7 (128.6) (*o*-Ph), 128.5 (128.3) (*m*-Ph), 125.9 (*p*-Ph), 84.8 (84.3) (C(CH<sub>3</sub>)<sub>3</sub>), 83.5 (83.3) (OC(CH<sub>3</sub>)<sub>2</sub>), 65.5 (66.4) (NCH), 49.6 (49.9) (NCH<sub>2</sub>), 35.8 (35.9) (PhCH<sub>2</sub>), 28.6 (28.7) (C(CH<sub>3</sub>)<sub>3</sub>), 26.6 (26.8) (PhCH<sub>2</sub>CH<sub>2</sub>), 25.08 (25.11) (OC(CH<sub>3</sub>)<sub>2</sub>), 24.8 (24.9) (OC(CH<sub>3</sub>)<sub>2</sub>), 18.3 (19.1) (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+H] C<sub>23</sub>H<sub>37</sub>O<sub>3</sub>N<sup>10</sup>B<sup>32</sup>S 417.2624, found 417.2627.

**3-Phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl 2,4,6-triisopropylbenzoate SI-17**



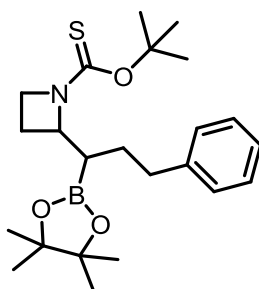
A solution of triisopropyl benzoate **SI-16** (215 mg, 0.59 mmol) and TMEDA (0.11 mL, 0.71 mmol) in Et<sub>2</sub>O (1.2 mL) under N<sub>2</sub> was cooled to –78 °C. *s*-BuLi (0.55 mL, 1.3 M in hexanes, 0.71 mmol) was

added dropwise and the reaction mixture was stirred for 4 h at  $-78\text{ }^{\circ}\text{C}$ . *i*-PrOB(pin) (0.15 mL, 0.71 mmol) was then added dropwise, the reaction was stirred at  $-78\text{ }^{\circ}\text{C}$  for 1 h and then warmed to rt. After 10 min, the reaction was quenched with sat. aq  $\text{NH}_4\text{Cl}$  (1 mL) and extracted with EtOAc (3 x 2 mL). The combined organic extracts were dried ( $\text{Na}_2\text{SO}_4$ ) and concentrated under reduced pressure to give a crude residue as a colourless oil. The residue was purified by column chromatography (5%  $\text{Et}_2\text{O}$ /petroleum ether) to give a colourless oil which solidified on standing to give a white solid, boronic ester **SI-17** (244 mg, 84%).

$R_f$  0.35 (25%  $\text{Et}_2\text{O}$ /petroleum ether); mp  $83\text{--}84\text{ }^{\circ}\text{C}$ ; IR (neat/ $\text{cm}^{-1}$ ) 2961 (m), 2929 (m), 1709 (s), 1460 (m), 1383 (s), 1343 (s), 1288 (m), 1246 (s), 1139 (s), 1105 (m), 1076 (s), 968 (m), 876 (m), 850 (m), 748 (m), 700 (s);  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 7.31 – 7.24 (2H, m, *m*-Ph), 7.21 – 7.15 (3H, m, *o*- & *p*-Ph), 7.02 (2H, s, *m*-Ar), 4.20 (1H, dd,  $J = 9.3, 4.7$  Hz, BCH), 3.08 (2H, hept,  $J = 6.8$  Hz, 2 x *o*-Ar $\text{CH}(\text{CH}_3)_2$ ), 2.95 – 2.79 (2H, m, *p*-Ar $\text{CH}(\text{CH}_3)_2$  & PhCHH'), 2.71 (1H, ddd,  $J = 13.7, 10.2, 6.4$  Hz, PhCHH'), 2.19 – 1.96 (2H, m,  $\text{PhCH}_2\text{CH}_2$ ), 1.32 – 1.22 (30H, m, 10 x Me);  $\delta_{\text{C}}$  (100 MHz,  $\text{CDCl}_3$ ) 172.5 (C=O), 150.2 (*p*-Ar), 145.4 (*o*-Ar), 141.8 (*i*-Ph), 130.1 (*i*-Ar), 128.6 (*o*-Ph), 128.5 (*m*-Ph), 126.0 (*p*-Ph), 121.0 (*m*-Ar), 84.0 ( $\text{OC}(\text{CH}_3)_2$ ), 34.6 (*p*-Ar $\text{CH}(\text{CH}_3)_2$ ), 33.3 ( $\text{PhCH}_2$ ), 32.3 ( $\text{PhCH}_2\text{CH}_2$ ), 31.1 (*o*-Ar $\text{CH}(\text{CH}_3)_2$ ), 25.0 ( $\text{OC}(\text{CH}_3)_2$ ), 24.8 ( $\text{OC}(\text{CH}_3)_2$ ), 24.5 (*o*-Ar $\text{CH}(\text{CH}_3)_2$ ), 24.1 (*p*-Ar $\text{CH}(\text{CH}_3)_2$ ). BCH carbon not observed due to quadrupolar relaxation.  $\delta_{\text{B}}$  (128 MHz,  $\text{CDCl}_3$ ) 32; HRMS (FTMS) calcd for  $[\text{M}+\text{H}]^+ \text{C}_{31}\text{H}_{46}^{10}\text{BO}_4$  492.3520, found 492.3527.

### Reversal of boronic ester and lithiated intermediate

#### *O*-*t*-Butyl 2-(3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*\*,*R*\*)-5a and (*R*\*,*S*\*)-5a'

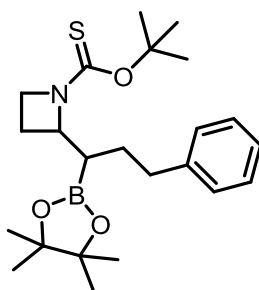


To a solution of *N*-Botc azetidine **1** (26 mg, 0.15 mmol) and TMEDA (50  $\mu\text{L}$ , 0.34 mmol) in THF (0.75 mL) under  $\text{N}_2$  was cooled to  $-78\text{ }^{\circ}\text{C}$ . *s*-BuLi (0.15 mL, 1.3 M in cyclohexane/hexanes, 0.20 mmol) was added dropwise and the reaction mixture was stirred for 1 h at  $-78\text{ }^{\circ}\text{C}$ . A solution of boronic ester **SI-17** (0.45 mL, 0.5 M in THF, 0.22 mmol) was added dropwise and the reaction was stirred at  $-78\text{ }^{\circ}\text{C}$  for 45 min. The mixture was warmed to rt, solvents removed under vacuum, then  $\text{CHCl}_3$  (1.2 mL) was

added. The solution was heated under reflux (63 °C) overnight (12 h). The reaction mixture was then quenched with water (3 mL) and the layers separated. The organic layer was washed with brine (2 x 2 mL) and the combined aq layers extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 5 mL). The combined organic layers were dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a colourless oil. This residue was purified by column chromatography (3% EtOAc/petroleum ether). First eluted a colourless oil, minor diastereomer (*R\*,S\**)-**5a'** (8 mg, 13%). Second eluted a colourless oil, major diastereomer (*R\*,R\**)-**5a** (15 mg, 24%).

All data matched those described previously (pp. S25 – 26).

**O- t-Butyl 2-(3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R\*,R\**)-5a and (*R\*,S\**)-5a'**

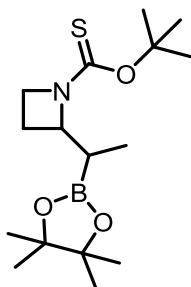


In a flame dried Schlenk flask, a solution of stannane **SI-18** (852 mg, 1.30 mmol) in Et<sub>2</sub>O (13 mL) under N<sub>2</sub> was cooled to –78 °C. *n*-BuLi (0.52 mL, 2.5 M in hexanes, 1.30 mmol) was added dropwise and the reaction mixture was stirred for 1 h at –78 °C. A solution of 2-B(pin)-azetidine **4** (300 mg, 1.00 mmol) in Et<sub>2</sub>O (2.5 mL) was added dropwise and the reaction mixture was stirred for 1 h at –78 °C. The solution was warmed to rt over 15 min and the reaction mixture evaporated under vacuum (1 mbar), then CHCl<sub>3</sub> (16.6 mL) was added. The solution was heated under reflux (63 °C) overnight (12 h). The reaction mixture was then quenched with water (10 mL) and the layers separated. The organic layer was washed with brine (2 x 5 mL) and the combined aq layers extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 10 mL). The combined organic layers were dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give an orange oil. The residue was purified by column chromatography (2% EtOAc/petroleum ether). First eluted a colourless oil, minor diastereomer (*R\*,S\**)-**5a'** (88 mg, 21%). Second eluted a pale yellow oil, major diastereomer (*R\*,R\**)-**5a** (197 mg, 47%).

All data matched those described previously (pp. S25 – 26).

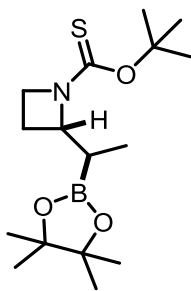
(A 0.42 mmol scale reaction gave (*R\*,S\**)-**5a'** (33 mg, 19%) and (*R\*,R\**)-**5a** (87 mg, 50%) respectively)

***O*-(*t*-Butyl) 2-(1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5b and (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5b'**



Following general procedure C, using stannane **SI-22** (311 mg, 0.55 mmol) and azetidine boronic ester **4** (125 mg, 0.42 mmol) with heating (63 °C) in CHCl<sub>3</sub> for 3 h. The residue was purified by column chromatography (2% EtOAc/petroleum ether). First eluted a colourless oil, minor diastereomer (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-**5b'** (41 mg, 30%). Second eluted a pale yellow oil, major diastereomer (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**5b** (52 mg, 38%)

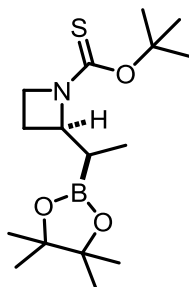
***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*S*<sup>\*</sup>)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5b'**



*R*<sub>f</sub> 0.25 (10% Et<sub>2</sub>O/petroleum ether); 2976 (m), 2918 (m), 1735 (w), 1479 (m), 1465 (m), 1438 (m), 1391 (m), 1380 (m), 1366 (m), 1330 (m), 1281 (m), 1266 (s), 1220 (w), 1144 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (5.4:1 rotamer mixture by analysis of the NCH signals in the 4.58 – 4.25 region) 4.29 (4.58 – 4.49) (1H, pseudo q, *J* = 7.2 Hz, (m), NCH), 4.06 – 3.79 (2H, m, NCH<sub>2</sub>), 2.40 – 1.96 (2H, m, NCHCH<sub>2</sub>), 1.88 (1H, pseudo p, *J* = 7.5 Hz, BCH), 1.64 (1.61) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.23 (1.25) (12H, s, C(CH<sub>3</sub>)<sub>2</sub>), 0.93 (0.96) (3H, d, *J* = 7.5 Hz, BCHCH<sub>3</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 185.4 (C=S), 84.9 (C(CH<sub>3</sub>)<sub>3</sub>), 83.3 (OC(CH<sub>3</sub>)<sub>2</sub>), 66.8 (NCH), 49.8 (NCH<sub>2</sub>), 28.6 (28.7) (C(CH<sub>3</sub>)<sub>3</sub>), 25.1 (25.0) (OC(CH<sub>3</sub>)<sub>2</sub>), 24.8

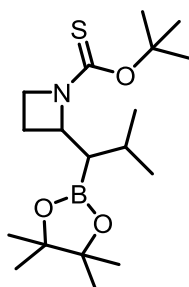
(OC(CH<sub>3</sub>)<sub>2</sub>), 19.5 (NCHCH<sub>2</sub>), 11.7 (BCHCH<sub>3</sub>). BCH not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+Na] C<sub>16</sub>H<sub>30</sub><sup>11</sup>BNO<sub>3</sub><sup>32</sup>SNa 350.1932, found 350.1931.

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5b**



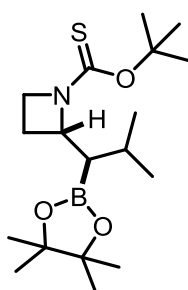
*R<sub>f</sub>* 0.16 (10% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2976 (m), 2929 (w), 2880 (w), 1481 (m), 1452 (m), 1440 (m), 1390 (m), 1363 (s), 1322 (m), 1277 (s), 1268 (s), 1235 (m), 1224 (m), 1143 (s), 1102 (m), 1022 (w);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) (3.7:1 rotamer mixture by analysis of the NCH signals in the 4.80 – 4.54 region) 4.64 – 4.54 (4.80 – 4.72) (1H, m, NCH), 4.05 – 3.72 (2H, m, NCH<sub>2</sub>), 2.28 – 2.09 (1H, m, NCHCHH'), 1.98 – 1.82 (2.48) (2H, m, (qd, *J* = 7.5, 4.6 Hz), NCHCH'H and BCH), 1.62 (1.61) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.22 – 1.19 (12H, m, OC(CH<sub>3</sub>)<sub>2</sub>), 1.00 (1.01) (2H, d, *J* = 7.5 Hz, (*J* = 7.5 Hz), BCHCH<sub>3</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 185.2 (184.8) (C=S), 84.8 (84.3) (C(CH<sub>3</sub>)<sub>3</sub>), 83.5 (83.2) (OC(CH<sub>3</sub>)<sub>2</sub>), 65.8 (66.5) (NCH), 49.7 (49.9) (NCH<sub>2</sub>), 28.7 (C(CH<sub>3</sub>)<sub>3</sub>), 25.0 (OC(CH<sub>3</sub>)<sub>2</sub>), 24.7 (OC(CH<sub>3</sub>)<sub>2</sub>), 17.7 (18.4) (NCHCH<sub>2</sub>), 8.1 (7.7) (BCHCH<sub>3</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+Na] C<sub>16</sub>H<sub>30</sub><sup>11</sup>BNO<sub>3</sub><sup>32</sup>SNa 350.1932, found 350.1933.

***O*-(*t*-Butyl) 2-(2-methyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5c and (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5c'**



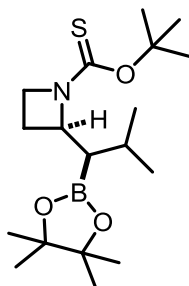
Following general procedure C, using stannane **SI-23** (326 mg, 0.55 mmol) and azetidine boronic ester **4** (125 mg, 0.42 mmol). The residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether). First eluted a colourless oil, minor diastereomer (*R\*,S\**)-**5c'** (13 mg, 9%). Second eluted a colourless oil, major diastereomer (*R\*,R\**)-**5c** (83 mg, 56%)

***O*-(*t*-Butyl) (*R\**)-2-((*S\**)-2-methyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R\*,S\**)-**5c'****



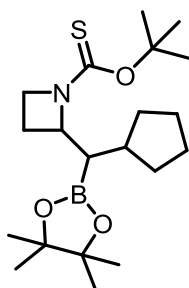
*R<sub>f</sub>* 0.50 (25% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2961 (w), 2928 (w), 1466 (m), 1436 (m), 1387 (m), 1365 (w), 1326 (w), 1279 (m), 1142 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (5.7:1 rotamer mixture by analysis of the NCH signals in the 4.72 – 4.46 region) 4.50 (4.74 – 4.63) (1H, dt, *J* = 8.5, 6.4 Hz, (m), NCH), 3.99 – 3.90 (2H, m, NCH<sub>2</sub>), 2.27 (1H, ddt, *J* = 11.0, 8.5, 6.4 Hz, NCHCHH'), 2.15 – 2.04 (1H, m, NCHCHH'), 1.84 – 1.70 (1H, m, CH(CH<sub>3</sub>)<sub>2</sub>), 1.64 (1.63) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.62 – 1.59 (1H, m, BCH), 1.24 (6H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 1.23 (6H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 0.93 (3H, d, *J* = 6.7 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 0.87 (3H, d, *J* = 6.5 Hz, CH(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 185.7 (C=S), 84.9 (C(CH<sub>3</sub>)<sub>3</sub>), 83.3 (OC(CH<sub>3</sub>)<sub>2</sub>), 64.6 (NCH), 49.9 (NCH<sub>2</sub>), 28.6 (C(CH<sub>3</sub>)<sub>3</sub>), 26.6 (CH(CH<sub>3</sub>)<sub>2</sub>), 25.4 (OCH(CH<sub>3</sub>)<sub>2</sub>), 25.1 (OCH(CH<sub>3</sub>)<sub>2</sub>), 23.2 (CH(CH<sub>3</sub>)<sub>2</sub>), 22.6 (CH(CH<sub>3</sub>)<sub>2</sub>), 18.7 (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+Na] C<sub>18</sub>H<sub>34</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>SNa 377.2245, found 377.2244.

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-2-methyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5c**



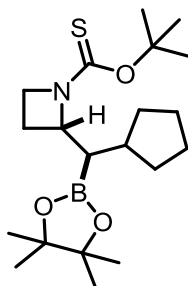
*R<sub>f</sub>* 0.48 (25% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2975 (w), 1465 (m), 1434 (m), 1379 (m), 1322 (w), 1276 (m), 1141 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (5.7:1 rotamer mixture by analysis of the NCH signals in the 4.73 – 4.52 region) 4.60 – 4.52 (4.73 – 4.66) (1H, m, NCH), 4.01 – 3.83 (2H, m, NCH<sub>2</sub>), 2.32 – 2.00 (3H, m, NCHCH<sub>2</sub> & CH(CH<sub>3</sub>)<sub>2</sub>), 1.65 (1.60) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.36 (1H, dd, *J* = 7.8, 3.2 Hz, BCH), 1.23 (12H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 0.99 (3H, d, *J* = 3.4 Hz, CH(CH<sub>3</sub>)<sub>2</sub>), 0.98 (3H, d, *J* = 3.4 Hz, CH(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 186.0 (C=S), 85.2 (C(CH<sub>3</sub>)<sub>3</sub>), 83.3 (OC(CH<sub>3</sub>)<sub>2</sub>), 65.2 (NCH), 49.9 (NCH<sub>2</sub>), 28.7 (28.6) (C(CH<sub>3</sub>)<sub>3</sub>), 26.2 (CH(CH<sub>3</sub>)<sub>2</sub>), 25.2 (OC(CH<sub>3</sub>)<sub>2</sub>), 25.1 (OC(CH<sub>3</sub>)<sub>2</sub>), 23.6 (CH(CH<sub>3</sub>)<sub>2</sub>), 23.5 (CH(CH<sub>3</sub>)<sub>2</sub>), 20.4 (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 33; HRMS (FTMS) calcd for [M+Na] C<sub>18</sub>H<sub>34</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>SNa 378.2245, found 378.2247.

***O*-(*t*-Butyl)-2-(cyclopentyl(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5d and (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5d'**



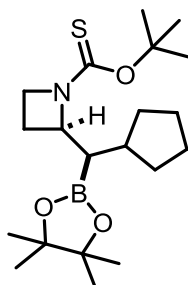
Following general procedure C, using stannane **SI-25** (340 mg, 0.55 mmol) and azetidine boronic ester **4** (125 mg, 0.42 mmol). The residue was purified by column chromatography (2% EtOAc/petroleum ether). First eluted a colourless oil, minor diastereomer (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-**5d'** (24 mg, 15%). Second eluted a pale yellow oil, major diastereomer (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**5d** (64 mg, 40%).

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*S*<sup>\*</sup>)-cyclopentyl(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5d'**



*R<sub>f</sub>* 0.68 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2975 (w), 2953 (w), 1477 (m), 1437 (m), 1388 (m), 1366 (m), 1329 (m), 1278 (s), 1244 (w), 1142 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (6.7:1 rotamer mixture by analysis of the NCH signals in the 4.66 – 4.39 region) 4.49 – 4.39 (4.66 – 4.58) (1H, m, NCH), 3.96 – 3.90 (2H, m, NCH<sub>2</sub>), 2.39 – 2.26 (1H, m, NCHCHH'), 2.11 – 2.00 (1H, m, NCHCHH'), 1.80 – 1.66 (4H, m, BCH, BCHCH & CHCHH'), 1.65 – 1.54 (11H, m, C(CH<sub>3</sub>)<sub>3</sub> & CH<sub>2</sub>CH<sub>2</sub>), 1.53 – 1.40 (2H, m, CH<sub>2</sub>CH<sub>2</sub>), 1.23 (6H, s, C(CH<sub>3</sub>)<sub>2</sub>), 1.22 (6H, s, C(CH<sub>3</sub>)<sub>2</sub>), 1.18 – 1.10 (1H, m, CHCHH'), 1.08 – 0.97 (1H, m, CHCHH'); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 185.3 (C=S), 84.8 (C(CH<sub>3</sub>)<sub>3</sub>), 83.2 (C(CH<sub>3</sub>)<sub>2</sub>), 65.0 (65.9) (NCH), 49.6 (NCH<sub>2</sub>), 38.0 (BCHCH), 32.9 (CHCH<sub>2</sub>), 32.6 (CHCH<sub>2</sub>), 28.5 (28.7) (C(CH<sub>3</sub>)<sub>3</sub>), 25.3 (C(CH<sub>3</sub>)<sub>2</sub>), 24.98 (C(CH<sub>3</sub>)<sub>2</sub>), 24.96 (CH<sub>2</sub>CH<sub>2</sub>), 24.7 (CH<sub>2</sub>CH<sub>2</sub>), 18.2 (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+H] C<sub>20</sub>H<sub>37</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>S 382.2582, found 382.2579.

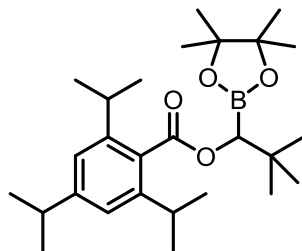
***O*-(*t*-Butyl)-(*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-cyclopentyl(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)methyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5d**



*R<sub>f</sub>* 0.63 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2975 (w), 2867 (w), 1465 (m), 1434 (m), 1379 (m), 1365 (m), 1323 (m), 1274 (s), 1139 (s), 966 (w); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (6.7:1 rotamer mixture by analysis of the NCH signals in the 4.66 – 4.37 region) 4.53 – 4.37 (4.66 – 4.57) (1H, m, NCH), 3.95 –

3.74 (2H, m, NCH<sub>2</sub>), 2.21 – 1.97 (3H, m, NCHCH<sub>2</sub> & BCHCH), 1.89 – 1.76 (2H, m, CHCHH'), 1.58 (1.54) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.56 – 1.36 (5H, m, BCH & CH<sub>2</sub>CH<sub>2</sub>), 1.16 (6H, s, C(CH<sub>3</sub>)<sub>2</sub>), 1.15 (6H, s, C(CH<sub>3</sub>)<sub>2</sub>), 1.11 – 0.96 (2H, m, CHCHH');  $\delta_c$  (100 MHz, CDCl<sub>3</sub>) 185.6 (185.4) (C=S), 85.0 (84.1) (C(CH<sub>3</sub>)<sub>3</sub>), 83.2 (83.0) (C(CH<sub>3</sub>)<sub>2</sub>), 65.8 (66.8) (NCH), 49.8 (NCH<sub>2</sub>), 37.8 (37.6) (BCHCH), 33.4 (CHCH<sub>2</sub>), 33.2 (CHCH<sub>2</sub>), 28.66 (28.71) (C(CH<sub>3</sub>)<sub>3</sub>), 25.2 (CH<sub>2</sub>CH<sub>2</sub>), 25.0 (C(CH<sub>3</sub>)<sub>2</sub>), 24.9 (C(CH<sub>3</sub>)<sub>2</sub>), 19.7 (19.8) (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 33; HRMS (FTMS) calcd for [M+H] C<sub>20</sub>H<sub>37</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>S 382.2582, found 382.2578.

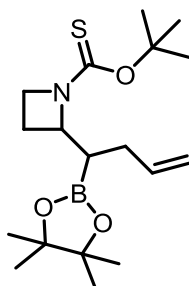
**2,2-Dimethyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl 2,4,6-triisopropylbenzoate SI-30**



Following general procedure C, using stannane **SI-26** (340 mg, 0.55 mmol) and azetidine boronic ester **4** (125 mg, 0.42 mmol). The crude material was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether) to give a white solid, boronic ester **SI-30** (132 mg, 71%).

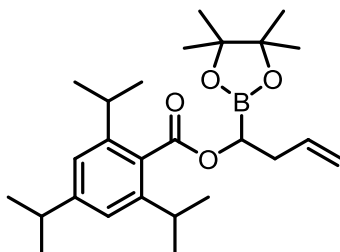
$R_f$  0.59 (15% Et<sub>2</sub>O/petroleum ether); mp 76–77 °C; IR (neat/cm<sup>-1</sup>) 2960 (m), 2870 (s), 2360 (w), 1708 (s), 1462 (w), 1371 (s), 1339 (s), 1285 (m), 1271 (m), 1238 (s), 1140 (s), 1079 (m);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 7.00 (2H, s, *m*-Ar), 3.83 (1H, s, OCH), 3.06 (2H, hept,  $J = 6.7$  Hz, *o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.89 (1H, hept,  $J = 6.9$  Hz, *p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.31 (6H, s, C(CH<sub>3</sub>)<sub>2</sub>), 1.28 (6H, s, C(CH<sub>3</sub>)<sub>2</sub>), 1.27 – 1.20 (18H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>), 1.03 (9H, s, C(CH<sub>3</sub>)<sub>3</sub>);  $\delta_c$  (100 MHz, CDCl<sub>3</sub>) 172.6 (C=O), 149.9 (*p*-Ar), 145.4 (*o*-Ar), 130.6 (*i*-Ar), 120.9 (*m*-Ar), 83.9 (OC(CH<sub>3</sub>)<sub>2</sub>), 34.5 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 32.8 (C(CH<sub>3</sub>)<sub>3</sub>), 30.9 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 27.5 (C(CH<sub>3</sub>)<sub>3</sub>), 25.09 (C(CH<sub>3</sub>)<sub>2</sub>), 25.04 (C(CH<sub>3</sub>)<sub>2</sub>), 24.6 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.3 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 32; HRMS (FTMS) calcd for [M+H] C<sub>27</sub>H<sub>46</sub>O<sub>4</sub><sup>11</sup>B 445.3484, found 445.3485.

***O*-(*t*-Butyl) 2-(1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-en-1-yl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5f and (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5f'**



Following general procedure C using stannane **SI-27** (325 mg, 0.55 mmol) and azetidine boronic ester **4** (125 mg, 0.42 mmol). The crude material was purified by column chromatography (2% EtOAc/petroleum ether). First eluted a colourless oil, boronic benzoate **SI-31** (8 mg, 4%). second eluted a colourless oil, minor diastereomer (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-**5f'** (21 mg, 14%). Third eluted a pale yellow oil, major diastereomer (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**5f** (53 mg, 36%).

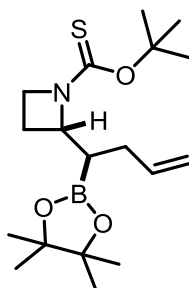
**1-(4,4,5,5-Tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-en-1-yl 2,4,6-triisopropylbenzoate SI-31**



$R_f$  0.45 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2961 (s), 2929 (m), 2870 (w), 1711 (s), 1461 (w), 1428 (w), 1384 (s), 1347 (m), 1252 (m), 1142 (s), 1104 (w), 1078 (m);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 6.99 (2H, s, *m*-Ar), 5.87 (1H, ddt,  $J = 17.0, 10.2, 6.7$  Hz, CH<sub>2</sub>=CH), 5.13 (1H, dq,  $J = 17.0, 1.4$  Hz, CH<sub>trans</sub>H=CH), 5.04 (1H, dq,  $J = 10.2, 1.4$  Hz, CHH<sub>cis</sub>=CH), 4.27 (1H, dd,  $J = 8.0, 6.1$  Hz, BCH), 3.03 (2H, hept,  $J = 6.7$  Hz, *o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.88 (1H, hept,  $J = 6.9$  Hz, *p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 2.63 – 2.46 (2H, m, BCHCH<sub>2</sub>), 1.29 (6H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 1.27 (6H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 1.26 – 1.20 (18H, m, ArCH(CH<sub>3</sub>)<sub>2</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) 172.3 (C=O), 150.2 (*p*-Ar), 145.5 (*o*-Ar), 135.1 (CH<sub>2</sub>=CH), 130.0 (*i*-Ar), 120.9 (*m*-Ar), 117.0 (CH<sub>2</sub>=CH), 84.1 (OC(CH<sub>3</sub>)<sub>2</sub>), 34.8 (BCHCH<sub>2</sub>), 34.6 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 31.0 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 25.1 (OC(CH<sub>3</sub>)<sub>2</sub>), 24.9 (OC(CH<sub>3</sub>)<sub>2</sub>),

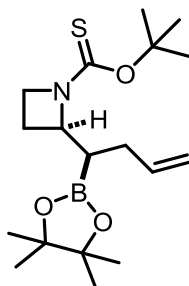
24.44 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.42 (*o*-ArCH(CH<sub>3</sub>)<sub>2</sub>), 24.1 (*p*-ArCH(CH<sub>3</sub>)<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 31; HRMS (FTMS) calcd for [M+H] C<sub>26</sub>H<sub>42</sub>O<sub>4</sub><sup>11</sup>B 429.3172, found 429.3172.

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*S*<sup>\*</sup>)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-en-1-yl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5f'**



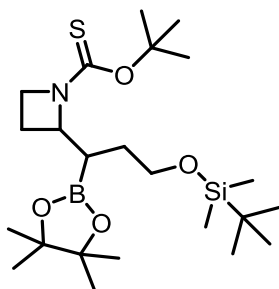
*R<sub>f</sub>* 0.36 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2976 (w), 1476 (m), 1437 (m), 1390 (m), 1365 (m), 1332 (w) 1279 (m), 1141 (s);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) (5.6:1 rotamer mixture by analysis of the NCH signals in the 4.61 – 4.34 region) 5.77 (1H, ddt, *J* = 17.0, 10.1, 6.6 Hz, CH<sub>2</sub>=CH), 5.03 (1H, dt, *J* = 17.0, 1.6 Hz, CH<sub>trans</sub>H=CH), 4.98 – 4.92 (1H, m, CHH<sub>cis</sub>=CH), 4.44 – 4.33 (4.61 – 4.53) (1H, m, NCH), 4.00 – 3.92 (2H, m, NCH<sub>2</sub>), 2.23 – 1.93 (5H, m, NCHCH<sub>2</sub>, BCH & BCHCH<sub>2</sub>), 1.65 (1.63) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.22 (12H, s, C(CH<sub>3</sub>)<sub>2</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) (rotamer mixture) 185.5 (C=S), 137.5 (CH<sub>2</sub>=CH), 115.5 (CH<sub>2</sub>=CH), 85.0 (C(CH<sub>3</sub>)<sub>3</sub>), 83.4 (OC(CH<sub>3</sub>)<sub>2</sub>), 65.1 (NCH), 49.7 (50.8) (NCH<sub>2</sub>), 31.6 (BCHCH<sub>2</sub>), 28.61 (28.58) (C(CH<sub>3</sub>)<sub>3</sub>), 25.2 (OC(CH<sub>3</sub>)<sub>2</sub>), 25.0 (OC(CH<sub>3</sub>)<sub>2</sub>), 19.0 (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+H] C<sub>18</sub>H<sub>33</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>S 354.2269, found 354.2271.

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)but-3-en-1-yl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5f**



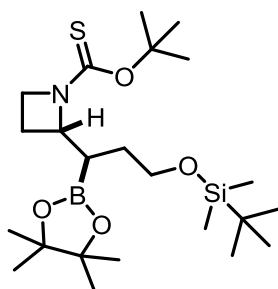
*R<sub>f</sub>* 0.24 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2976 (w), 1479 (m), 1439 (m), 1365 (m), 1329 (m), 1275 (m), 1140 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (4.9:1 rotamer mixture by analysis of the NCH signals in the 4.72 – 4.50 region) 5.85 (1H, ddt, *J* = 17.0, 10.1, 6.8 Hz, CH<sub>2</sub>=CH), 5.08 – 4.98 (1H, m, CH<sub>trans</sub>H=CH), 4.96 – 4.86 (1H, m, CHH<sub>cis</sub>=CH), 4.54 (4.69) (1H, dtd, *J* = 8.3, 4.6, 2.5 Hz, (dt, *J* = 9.4, 5.1 Hz), NCH), 3.99 – 3.75 (2H, m, NCH<sub>2</sub>), 2.53 – 1.96 (4H, m, NCHCH<sub>2</sub> & BCHCH<sub>2</sub>), 1.85 (1H, dt, *J* = 10.4, 4.6 Hz, BCH), 1.62 (1.59) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.19 (12H, s, OC(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (rotamer mixture) 185.4 (185.1) (C=S), 138.2 (138.9) (CH<sub>2</sub>=CH), 115.0 (114.5) (CH<sub>2</sub>=CH), 84.9 (84.2) (C(CH<sub>3</sub>)<sub>3</sub>), 83.5 (83.3) (OC(CH<sub>3</sub>)<sub>2</sub>), 65.2 (66.1) (NCH), 49.6 (49.8) (NCH<sub>2</sub>), 29.2 (29.3) (BCHCH<sub>2</sub>), 28.70 (28.67) (C(CH<sub>3</sub>)<sub>3</sub>), 24.97 (25.00) (OC(CH<sub>3</sub>)<sub>2</sub>), 24.8 (24.9) (OC(CH<sub>3</sub>)<sub>2</sub>), 18.3 (19.0) (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 33; HRMS (FTMS) calcd for [M+H] C<sub>18</sub>H<sub>33</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>S 354.2269, found 353.2272.

***O*-(*t*-Butyl) 2-(3-((*t*-butyldimethylsilyl)oxy)propyl)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5g and (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5g'**



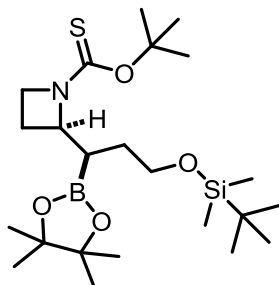
Following general procedure C, using stannane **SI-28** (200 mg, 0.28 mmol) and azetidine boronic ester **4** (63 mg, 0.21 mmol). The residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether). First eluted a colourless oil, minor diastereomer (*R*\*,*S*\*)-**5g'** (28 mg, 28%). Second eluted a colourless oil, major diastereomer (*R*\*,*R*\*)-**5g** (37 mg, 37%).

***O*-(*t*-Butyl) (*R*\*)-2-((*S*\*)-3-((*t*-butyldimethylsilyl)oxy)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*\*,*S*\*)-**5g'****



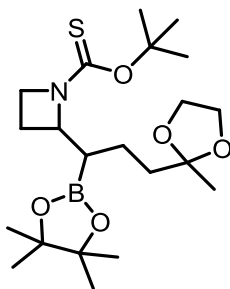
*R<sub>f</sub>* 0.31 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2928 (w), 1471 (m), 1438 (m), 1389 (m), 1365 (m), 1329 (w), 1279 (s), 1249 (m), 1142 (s), 1096 (m); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (3.6:1 rotamer mixture by analysis of the NCH signals in the 4.63 – 4.36 region) 4.41 (4.63 – 4.54) (1H, q, *J* = 6.8 Hz, (m), NCH), 3.95 (2H, t, *J* = 7.6 Hz, NCH<sub>2</sub>), 3.69 – 3.50 (2H, m, OCH<sub>2</sub>), 2.27 – 2.04 (2H, m, NCHCH<sub>2</sub>), 1.98 (1H, dt, *J* = 9.2, 6.8 Hz, BCH), 1.65 (1.60) (9H, s, OC(CH<sub>3</sub>)<sub>3</sub>), 1.57 – 1.44 (2H, m, OCH<sub>2</sub>CH<sub>2</sub>), 1.23 (12H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 0.89 (0.88) (9H, s, SiC(CH<sub>3</sub>)<sub>3</sub>), 0.04 (0.03) (6H, s, Si(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (125 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 185.5 (C=S), 85.0 (OC(CH<sub>3</sub>)<sub>3</sub>), 83.3 (OC(CH<sub>3</sub>)<sub>2</sub>), 65.3 (66.0) (NCH), 62.8 (OCH<sub>2</sub>), 49.6 (NCH<sub>2</sub>), 30.5 (OCH<sub>2</sub>CH<sub>2</sub>), 28.6 (28.7) (OC(CH<sub>3</sub>)<sub>3</sub>), 26.1 (26.2) (SiC(CH<sub>3</sub>)<sub>3</sub>), 25.2 (OC(CH<sub>3</sub>)<sub>2</sub>), 25.0 (OC(CH<sub>3</sub>)<sub>2</sub>), 18.9 (NCHCH<sub>2</sub>), 18.5 (SiC(CH<sub>3</sub>)<sub>3</sub>), -5.2 (Si(CH<sub>3</sub>)<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 33; HRMS (FTMS) calcd for [M+Na] C<sub>23</sub>H<sub>46</sub>O<sub>4</sub>N<sup>11</sup>B<sup>32</sup>S<sup>28</sup>SiNa 494.2905, found 494.2900.

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-3-((*t*-butyldimethylsilyl)oxy)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5g**



$R_f$  0.25 (20% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2928 (w), 1471 (m), 1438 (m), 1366 (m), 1277 (m), 1250 (m), 1143 (s), 1097 (m);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) (3.8:1 rotamer mixture by analysis of the NCH signals in the 4.74 – 4.51 region) 4.60 – 4.51 (4.70) (1H, m, (dt,  $J = 9.6, 5.2$  Hz), NCH), 4.01 – 3.81 (2H, m, NCH<sub>2</sub>), 3.79 – 3.57 (2H, m, OCH<sub>2</sub>), 2.33 – 2.08 (1H, m, NCHCHH), 1.98 (1H, ddt,  $J = 11.8, 9.3, 6.3$  Hz, NCHCHH), 1.87 – 1.68 (3H, m, OCH<sub>2</sub>CH<sub>2</sub> & BCH), 1.64 (1.61) (9H, s, OC(CH<sub>3</sub>)<sub>3</sub>), 1.23 – 1.19 (12H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 0.90 (0.89) (9H, s, Si(CH<sub>3</sub>)<sub>3</sub>), 0.05 (0.06) (6H, s, Si(CH<sub>3</sub>)<sub>2</sub>);  $\delta_C$  (125 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 185.7 (185.3) (C=S), 85.0 (84.3) (OC(CH<sub>3</sub>)<sub>3</sub>), 83.5 (83.3) (OC(CH<sub>3</sub>)<sub>2</sub>), 65.5 (66.3) (NCH), 63.2 (63.7) (OCH<sub>2</sub>), 49.7 (49.9) (NCH<sub>2</sub>), 28.74 (28.71) (OC(CH<sub>3</sub>)<sub>3</sub>), 28.1 (27.8) (OCH<sub>2</sub>CH<sub>2</sub>), 26.27 (26.25) (Si(CH<sub>3</sub>)<sub>3</sub>), 25.1 (OC(CH<sub>3</sub>)<sub>2</sub>), 24.8 (OC(CH<sub>3</sub>)<sub>2</sub>), 18.6 (Si(CH<sub>3</sub>)<sub>3</sub>), 18.5 (NCHCH<sub>2</sub>), –5.0 (Si(CH<sub>3</sub>)<sub>2</sub>), –5.1 (Si(CH<sub>3</sub>)<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 33; HRMS (FTMS) calcd for [M+Na] C<sub>23</sub>H<sub>46</sub>O<sub>4</sub>N<sup>11</sup>B<sup>32</sup>C<sup>28</sup>SiNa 494.2905, found 493.2902.

***O*-(*t*-Butyl) 2-(3-(2-methyl-1,3-dioxolan-2-yl)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate 5h**

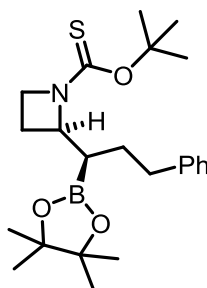


Following general procedure C, using stannane **SI-29** (366 mg, 0.55 mmol) and azetidine boronic ester **4** (125 mg, 0.42 mmol). The crude material was purified by column chromatography (5-20% EtOAc/petroleum ether) and eluted a colourless oil, 2:1 inseparable mixture of diastereomers **5h** (100 mg, 56%).

$R_f$  0.50 (50% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>3</sup>) 2976 (w), 1479 (m), 1439 (m), 1367 (m), 1328 (w), 1277 (m), 1142 (s);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) (2:1 mixture diastereomers by analysis of C(CH<sub>3</sub>)<sub>2</sub> signals in the 1.24 – 1.17 region and rotamers) 4.75 – 4.29 (1H, m, NCH), 4.03 – 3.82 (6H, m, NCH<sub>2</sub> & OCH<sub>2</sub>CH<sub>2</sub>O), 2.34 – 1.93 (2H, m, NCHCH<sub>2</sub>), 1.86 – 1.75 (1H, m, C(OCH<sub>2</sub>)<sub>2</sub>CHH'), 1.74 – 1.66 (1H, m, BCH), 1.64 (1.63 & 1.60) (10H, s, (m), C(CH<sub>3</sub>)<sub>3</sub> & BCHCHH'), 1.56 – 1.42 (2H, m, C(OCH<sub>2</sub>)<sub>2</sub>CHH' & BCHCHH'), 1.33 (1.35, 1.32 & 1.29) (3H, s, CH<sub>3</sub>), 1.20 (1.22, 1.21 & 1.19) (12H, s, C(CH<sub>3</sub>)<sub>2</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) (diastereomer mixture) 185.6 (185.4) (C=S), 110.2 (C(OCH<sub>2</sub>)<sub>2</sub>), 84.9 (85.0) (C(CH<sub>3</sub>)<sub>3</sub>), 83.5 (83.3) (C(CH<sub>3</sub>)<sub>2</sub>), 65.8 (65.5) (NCH), 64.7 (64.58) (OCH<sub>2</sub>), 64.62 (64.5) (OCH<sub>2</sub>), 49.7 (50.0) (NCH<sub>2</sub>), 38.9 (38.2) (C(OCH<sub>2</sub>)<sub>2</sub>CH<sub>2</sub>), 28.7 (28.6) (C(CH<sub>3</sub>)<sub>3</sub>), 25.1 (26.2) (C(CH<sub>3</sub>)<sub>2</sub>), 24.8 (24.9) (C(CH<sub>3</sub>)<sub>2</sub>), 23.8 (23.6) (CH<sub>3</sub>), 19.3 (19.1) (BCHCH<sub>2</sub>), 18.5 (18.8) (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation.  $\delta_B$  (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+Na] C<sub>21</sub>H<sub>38</sub>O<sub>5</sub>N<sup>11</sup>B<sup>32</sup>SNa 450.2458, found 450.2451.

### Asymmetric homologation

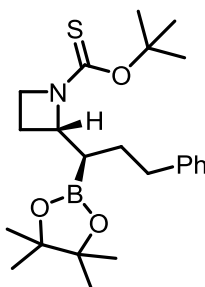
**O-(*t*-Butyl) (*R*)-2-((*R*)-3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*R,R*)-5a**



Following general procedure C, using stannane (*S*)-**SI-18** (360 mg, 0.55 mmol) and azetidine boronic ester (*S*)-**4** (125 mg, 0.42 mmol). The residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether). First eluted a colourless oil, minor diastereomer (*S,R*)-**5a'** (6 mg, 3%, 71:29 er). Second eluted a colourless oil, major diastereomer (*R,R*)-**5a** (80 mg, 46%, 98.5:1.5 er) (by HPLC: ODH column; eluent; *n*-hexane/*i*-PrOH (99.8:0.2); flow rate = 1 mL min<sup>-1</sup>);  $\tau_R$  ((*S,S*) minor) = 10.4 min,

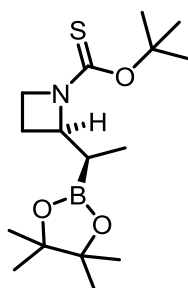
$\tau_R$  ((*R,R*) major) = 12.7 min;  $[\alpha]_D^{25} +73.9$  (c 1.01,  $\text{CHCl}_3$ ); all other data as described for racemic (*R\*,R\**)-**5a** (pp. S26).

***O*-(*t*-Butyl) (*S*)-2-((*R*)-3-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidine-1-carbothioate (*S,R*)-**5a'****



Following general procedure C, using stannane (*S*)-**SI-18** (360 mg, 0.55 mmol) and azetidine boronic ester (*R*)-**4** (125 mg, 0.42 mmol). The residue was purified by column chromatography (5%  $\text{Et}_2\text{O}$ /petroleum ether). First eluted a colourless oil, major diastereomer (*S,R*)-**5a'** (77 mg, 44%, 99:1 er) (by HPLC: ODH column; eluent; *n*-hexane/*i*-PrOH (99.9:0.1); flow rate = 1 mL  $\text{min}^{-1}$ );  $\tau_R$  ((*R,S*) minor) = 15.3 min,  $\tau_R$  ((*S,R*) major) = 18.4 min;  $[\alpha]_D^{25} -24.5$  (c 0.82,  $\text{CHCl}_3$ ); all other data as described for racemic (*R\*,S\**)-**5a'** (pp. S25). Second eluted a colourless oil, minor diastereomer (*R,R*)-**5a** (12 mg, 7%, 72:28 er).

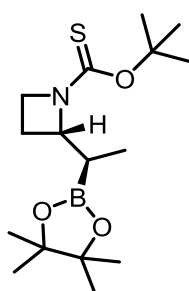
***O*-(*t*-Butyl) (*R*)-2-((*R*)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethyl)azetidine-1-carbothioate (*R,R*)-**5b****



Following general procedure C, using stannane (*S*)-**SI-22** (311 mg, 0.55 mmol) and azetidine boronic ester (*S*)-**4** (125 mg, 0.42 mmol). The residue was purified by column chromatography (5%

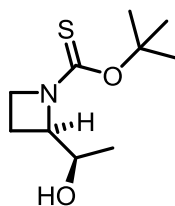
Et<sub>2</sub>O/petroleum ether). First eluted a colourless oil, minor diastereomer (*S,R*)-**5b'** (11 mg, 8%, 55:45 er). Second eluted a colourless oil, major diastereomer (*R,R*)-**5b** (61 mg, 44%, 99:1 er) (by HPLC: ODH column; eluent; *n*-hexane/*i*-PrOH (99.9:0.1); flow rate = 1 mL min<sup>-1</sup>;  $\tau_R$  ((*S,S*) minor) = 8.1 min,  $\tau_R$  ((*R,R*) major) = 9.3 min);  $[\alpha]_D^{25} +60.5$  (c 0.93, CHCl<sub>3</sub>); all other data as described for racemic **5b**. (pp. S30).

***O*-(*t*-Butyl) (*S*)-2-((*R*)-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)ethyl)azetidine-1-carbothioate (*S,R*)-**5b'****



Following general procedure C, using stannane (*S*)-**SI-22** (311 mg, 0.55 mmol) and azetidine boronic ester (*R*)-**4** (125 mg, 0.42 mmol). The residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether). First eluted a colourless oil, major diastereomer (*S,R*)-**5b'** (43 mg, 31% 97.5:2.5 er) (by HPLC: ODH column; eluent; *n*-hexane/*i*-PrOH (99.9:0.1); flow rate = 1 mL min<sup>-1</sup>;  $\tau_R$  ((*S,R*) major) = 7.8 min,  $\tau_R$  ((*R,S*) minor) = 8.9 min);  $[\alpha]_D^{25} -36.9$  (c 0.91, CHCl<sub>3</sub>); all other data as described for racemic (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-**5b'** (pp. S29). Second eluted a colourless oil, minor diastereomer (*R,R*)-**5b** (20 mg, 15%, 75:25 er).

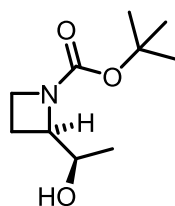
**Compounds for determination of absolute configuration of boronic ester (*S*)-**4****  
***O*-(*t*-Butyl) (*R*)-2-((*R*)-1-hydroxyethyl)azetidine-1-carbothioate (*R,R*)-**SI-12****



To a solution of boronic ester (*R,R*)-**5b** (46 mg, 0.14 mmol) in THF (1.2 mL) and water (1.2 mL) was added sodium perborate tetrahydrate (108 mg, 0.70 mmol). The reaction mixture was stirred vigorously for 1 h at rt. The reaction was diluted with water (5 mL) and extracted with EtOAc (3 x 5 mL). The combined organic layers were washed with brine (5 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a pale yellow oil. This residue was purified by column chromatography (10% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, alcohol (*R,R*)-**SI-12** (16 mg, 52%, 99:1 er) (by HPLC: Chiralcel ODH column, eluent; *n*-hexane/*i*-PrOH (97:3); flow rate = 1 mL min<sup>-1</sup>);  $\tau_R$  ((*S,S*) minor) = 13.5 min,  $\tau_R$  ((*R,R*) major) = 14.8 min.

$[\alpha]_D^{25} +58.2$  (c 1.05, CHCl<sub>3</sub>);  $R_f$  0.22 (25% EtOAc/petroleum ether); IR (neat/cm<sup>-1</sup>) 3333 (br), 2975 (m), 2929 (w), 1477 (s), 1438 (s), 1392 (m), 1366 (m), 1279 (s), 1142 (s), 1107 (m), 1022 (w);  $\delta_H$  (500 MHz, CDCl<sub>3</sub>) (1.7:1 rotamer mixture by analysis of the NCH signals in the 4.46 – 4.20 region) 5.33 (3.08) (1H, s, OH), 4.43 (4.24) (1H, td,  $J = 8.6, 6.0$  Hz, (pseudo q,  $J = 7.5$  Hz), NCH), 4.15 – 3.84 (3H, m, NCH<sub>2</sub> and CHOH), 2.33 – 2.21 (1H, m, NCHCHH'), 1.93 – 1.77 (1H, m, NCHCHH'), 1.63 (1.69) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.12 (1.13) (3H, d,  $J = 6.4$  Hz, (d,  $J = 6.4$  Hz), CHCH<sub>3</sub>);  $\delta_C$  (125 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 187.3 (C=S), 86.2 (87.2) (C(CH<sub>3</sub>)<sub>3</sub>), 72.3 (70.9) (CHOH), 71.8 (70.6) (NCH), 49.1 (50.1) (NCH<sub>2</sub>), 28.6 (28.5) (C(CH<sub>3</sub>)<sub>3</sub>), 18.7 (17.7) (NCHCH<sub>2</sub>), 18.2 (17.8) (CHCH<sub>3</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>10</sub>H<sub>19</sub>NO<sub>2</sub><sup>32</sup>SNa 240.1029, found 240.1030.

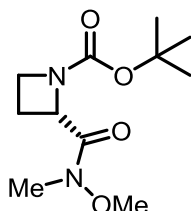
***t*-Butyl (*R*)-2-((*R*)-1-hydroxyethyl)azetidone-1-carboxylate (*R,R*)-**SI-13****



The alcohol was prepared following general procedure A, using *N*-Botc alcohol (*R,R*)-**SI-12** (14 mg, 0.06 mmol). The crude material was purified by column chromatography (10% EtOAc/petroleum ether) to give a colourless oil, alcohol (*R,R*)-**SI-13** (6 mg, 50%, 99:1 er) (by HPLC: Chiralcel ADH column; eluent; *n*-hexane/*i*-PrOH (95:5), flow rate = 1 mL min<sup>-1</sup>);  $\tau_R$  ((*R,R*) major) = 9.1 min,  $\tau_R$  ((*S,S*) minor) = 16.2 min.

$[\alpha]_D^{25} +42.8$  (c 0.41,  $\text{CHCl}_3$ );  $R_f$  0.48 (EtOAc/petroleum ether); IR (neat/ $\text{cm}^{-1}$ ) 3395 (br), 2974 (w), 1699 (m), 1665 (s), 1405 (s), 1366 (s), 1258 (m), 1157 (s), 1138 (s), 1077 (m), 976 (m);  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 5.14 (1H, br, OH), 4.07 (1H, pseudo q,  $J = 8.0$  Hz, NCH), 3.93 – 3.79 (2H, m, CHOH & NCHH'), 3.73 (1H, td,  $J = 8.9, 4.5$  Hz, NCHH'), 2.20 – 2.08 (1H, m, NCHCHH'), 1.91 – 1.79 (1H, m, NCHCHH'), 1.44 (9H, s,  $\text{OC}(\text{CH}_3)_3$ ), 1.04 (3H, d,  $J = 6.3$  Hz,  $\text{CHCH}_3$ );  $\delta_{\text{C}}$  (100 MHz,  $\text{CDCl}_3$ ) 157.9 (C=O), 80.7 ( $\text{OC}(\text{CH}_3)_3$ ), 72.3 (CHOH), 68.5 (NCH), 46.6 ( $\text{NCH}_2$ ), 28.5 ( $\text{OC}(\text{CH}_3)_3$ ), 19.1 ( $\text{NCHCH}_2$ ), 17.4 ( $\text{CHCH}_3$ ); HRMS (FTMS) calcd for  $[\text{M}+\text{Na}] \text{C}_{10}\text{H}_{19}\text{O}_3\text{NNa}$  224.1257, found 224.1257.

***t*-Butyl (*S*)-2-(methoxy(methyl)carbamoyl)azetidine-1-carboxylate (*S*)-SI-14**

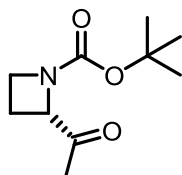


Prepared following a lit.<sup>2</sup> procedure. To a stirred solution of (*S*)-1-(*t*-butoxycarbonyl) azetidine-2-carboxylic acid (*S*)-SI-3 (210 mg, 1.04 mmol) and *N,O*-dimethylhydroxylamine.HCl (120 mg, 1.25 mmol) in DMF (2.3 mL) at 0 °C was added sequentially *N*-Me morpholine (0.14 mL, 1.25 mmol), HOBT (170 mg, 1.25 mmol) and EDC (240 mg, 1.25 mmol). The reaction mixture was stirred at 0 °C for 2 h, warmed to rt and stirred at rt for 16 h. The reaction was diluted with EtOAc (8 mL) and the solution was washed with aq HCl (1 M, 5 mL), aq NaOH (2 M, 2 x 5 mL) and brine (3 x 5 mL), dried ( $\text{MgSO}_4$ ) and concentrated under reduced pressure to give a white crystalline solid Weinreb amide (*S*)-SI-14 (209 mg, 82%).

mp 58–59 °C;  $[\alpha]_D^{25} -87.6$  (c 1.10,  $\text{CHCl}_3$ ) IR (neat/ $\text{cm}^{-1}$ ) 2974 (w), 2893 (w), 1703 (s), 1390 (s), 1366 (m), 1144 (m), 1060 (m);  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) 5.03 (1H, dd,  $J = 9.0, 5.6$  Hz, NCH), 4.04 (1H, td,  $J = 9.0, 6.2$  Hz, NCHH'), 3.86 (1H, td,  $J = 9.0, 5.6$  Hz, NCHH'), 3.70 (3H, s,  $\text{OCH}_3$ ), 3.21 (3H, s,  $\text{NCH}_3$ ), 2.46 (1H, dtd,  $J = 11.2, 9.0, 6.2$  Hz, NCHCHH'), 2.12 (1H, ddt,  $J = 11.1, 9.0, 5.6$  Hz, NCHCHH'), 1.42 (9H, s,  $\text{OC}(\text{CH}_3)_3$ );  $\delta_{\text{C}}$  (100 MHz,  $\text{CDCl}_3$ ) 171.5 (CHC=O), 155.7 (OC=O), 79.6 ( $\text{OC}(\text{CH}_3)_3$ ), 61.5 ( $\text{OCH}_3$ ), 58.4

(NCH), 47.8 (NCH<sub>2</sub>), 32.3 (NCH<sub>3</sub>), 28.3 (OC(CH<sub>3</sub>)<sub>3</sub>), 20.4 (NCHCH<sub>2</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>11</sub>H<sub>20</sub>O<sub>4</sub>N<sub>2</sub>Na 267.1315, found 267.1314.

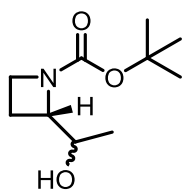
***t*-Butyl (S)-2-acetylazetidone-1-carboxylate (S)-SI-15**



A solution of Weinreb amide (S)-SI-14 (100 mg, 0.41 mmol) in THF (1.8 mL) was cooled to –78 °C. MeMgCl (3 M in THF, 0.21 mL, 0.62 mmol) was added dropwise, at the resulting solution was stirred at –78 °C for 2 h. The reaction was quenched with sat. aq NH<sub>4</sub>Cl (3 mL) and extracted with EtOAc (3 x 3 mL). The combined organic layers were washed with brine (3 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a colourless oil. This residue was purified by column chromatography (10% EtOAc/petroleum ether) to give a colourless oil, ketone (S)-SI-15 (71 mg, 86%).

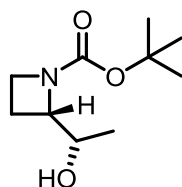
$R_f$  0.13 (25% EtOAc/petroleum ether);  $[\alpha]_D^{25}$  –173.6 ( $c$  1.02, CHCl<sub>3</sub>); IR (neat/cm<sup>-1</sup>) 2976 (w), 1699 (s), 1391 (s), 1366 (s), 1250 (m), 1135 (s);  $\delta_H$  (400 MHz, CDCl<sub>3</sub>) 4.59 (1H, dd,  $J$  = 9.7, 6.3 Hz, NCH), 3.97 – 3.84 (2H, m, NCH<sub>2</sub>), 2.52 – 2.38 (1H, m, NCHCH'), 2.26 (3H, s, CH<sub>3</sub>C=O), 2.12 (1H, ddt,  $J$  = 12.0, 8.7, 6.3 Hz, NCHCH'), 1.43 (9H, s, OC(CH<sub>3</sub>)<sub>3</sub>);  $\delta_C$  (100 MHz, CDCl<sub>3</sub>) 207.5 (C=O), 155.9 (NC=O), 80.2 (OC(CH<sub>3</sub>)<sub>3</sub>), 66.7 (NCH), 46.9 (NCH<sub>2</sub>), 28.2 (OC(CH<sub>3</sub>)<sub>3</sub>), 25.9 (CH<sub>3</sub>C=O), 19.6 (NCHCH<sub>2</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>10</sub>H<sub>17</sub>NO<sub>3</sub>Na 222.1101, found 222.1101.

***t*-Butyl (S)-2-(-1-hydroxyethyl)azetidone-1-carboxylate (S,S)-SI-13 and (S,R)-SI-13'**



A stirred solution of ketone (*S*)-**SI-15** (60 mg, 0.30 mmol) in MeOH (1 mL) was cooled to 0 °C. NaBH<sub>4</sub> (14 mg, 0.36 mmol) was added and the reaction mixture was stirred at rt for 30 min. The solution was then cooled to 0 °C, quenched with sat. aq NH<sub>4</sub>Cl (1 mL) dropwise and extracted with EtOAc (3 x 3 mL). The combined organic layers were washed with brine (3 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a pale yellow oil. This residue was purified by column chromatography (10% EtOAc/petroleum ether). First eluted a colourless oil, alcohol (*S,S*)-**SI-13** (20 mg, 32%). Second eluted a colourless oil, alcohol (*S,R*)-**SI-13'** (18 mg, 30%).

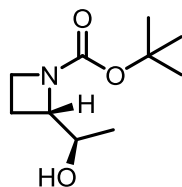
***t*-Butyl (*S*)-2-((*S*)-1-hydroxyethyl)azetidine-1-carboxylate (*S,S*)-**SI-13****



96:4 er (by HPLC: Chiralcel ADH column; eluent; *n*-hexane/*i*-PrOH (95:5), flow rate = 1 mL min<sup>-1</sup>);  $\tau_R$  ((*R,R*) minor) = 9.0 min,  $\tau_R$  ((*S,S*) major) = 16.0 min.

$[\alpha]_D^{25}$  -47.4 (*c* 0.82, CHCl<sub>3</sub>); all other data as described for (*R,R*)-**SI-13** (pp. S43 – 44).

***t*-Butyl (*S*)-2-((*R*)-1-hydroxyethyl)azetidine-1-carboxylate (*S,R*)-**SI-13'****

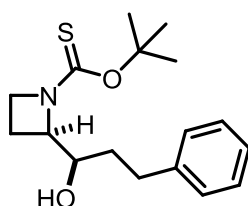


$[\alpha]_D^{25}$  -40.1 (*c* 0.82, CHCl<sub>3</sub>);  $R_f$  0.28 (EtOAc/petroleum ether); IR (neat/cm<sup>-1</sup>) 3424 (br), 2973 (m), 2930 (m), 2893 (m), 1698 (s), 1677 (s), 1393 (s), 1367 (s), 1256 (m), 1155 (s), 1136 (s);  $\delta_H$  (500 MHz, CDCl<sub>3</sub>) 4.34 (1H, br s, NCH), 3.95 (1H, br s, CHOH), 3.84 (1H, q,  $J$  = 8.2, NCH'H), 3.72 (1H, q,  $J$  = 7.8 Hz, NCHH'), 2.09 (2H, d,  $J$  = 8.7 Hz, NCHCH<sub>2</sub>), 1.44 (9H, s, OC(CH<sub>3</sub>)<sub>3</sub>), 1.15 (3H, d,  $J$  = 6.5 Hz, CHCH<sub>3</sub>);  $\delta_C$

(125 MHz, CDCl<sub>3</sub>) 157.3 (C=O), 80.2 (OC(CH<sub>3</sub>)<sub>3</sub>), 67.6 (CHOH), 67.2 (NCH), 47.0 (NCH<sub>2</sub>), 28.5 (OC(CH<sub>3</sub>)<sub>3</sub>), 16.6 (NCHCH<sub>2</sub> and CHCH<sub>3</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>10</sub>H<sub>20</sub>O<sub>3</sub>N 202.1438, found 202.1439.

### Transformations of homologated boronic ester (*R\*,R\**)-5a and (*R\*,S\**)-5a'

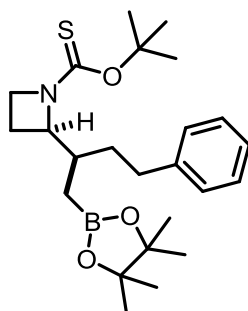
#### *O-t*-Butyl (*R\**)-2-((*R\**)-1-hydroxy-3-phenylpropyl)azetidone-1-carbothioate (*R\*,R\**)-7



To a solution of boronic ester (*R\*,R\**)-5a (160 mg, 0.38 mmol) in THF (3.20 mL) and water (3.20 mL) was added sodium perborate tetrahydrate (290 mg, 1.90 mmol). The reaction mixture was stirred vigorously for 1 h at rt. The reaction was then diluted with water (15 mL) and extracted with EtOAc (3 x 10 mL). The combined organic layers were washed with brine (10 mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a pale-yellow oil. This residue was purified by column chromatography (10% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, alcohol (*R\*,R\**)-7 (77 mg, 66%).

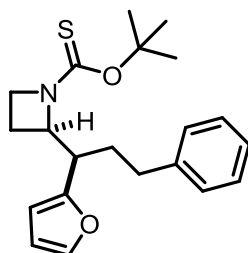
*R<sub>f</sub>* 0.13 (25% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 3325 (br), 2926 (w), 2361 (m), 2342 (m) 1476 (m), 1438 (s), 1392 (m), 1366 (m), 1274 (s), 1143 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (1.15:1 rotamer mixture by analysis of the NCH signals in the 4.57 – 4.25 region) 7.33 – 7.15 (5H, m, Ph), 5.42 (3.04) (1H, br s, OH), 4.52 (4.30) (1H, q, *J* = 8.6 Hz, (*J* = 7.5 Hz), NCH), 3.98 – 3.76 (4.07 – 3.99) (3H, m, NCH<sub>2</sub> and CHOH), 2.96 – 2.84 (1H, m, PhCHH'), 2.80 – 2.66 (1H, m, PhCHH'), 2.31 – 2.15 (1H, m, NCHH'), 1.92 – 1.74 (1H, m, NCHH'), 1.73 – 1.63 (2H, m, PhCH<sub>2</sub>CH<sub>2</sub>), 1.63 (1.67) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers) 187.4 (186.1) (C=S), 142.3 (141.7) (*i*-Ph), 128.6 (128.52) (*m*-Ph), 128.46 (128.4) (*o*-Ph), 125.8 (126.0) (*p*-Ph), 86.1 (87.0) (C(CH<sub>3</sub>)<sub>3</sub>), 74.9 (73.4) (CHOH), 70.8 (69.5) (NCH), 49.2 (50.1) (NCH<sub>2</sub>), 34.3 (33.7) (PhCH<sub>2</sub>CH<sub>2</sub>), 31.2 (31.5) (PhCH<sub>2</sub>), 28.4 (28.5) (C(CH<sub>3</sub>)<sub>3</sub>), 18.5 (17.6) (NCHCH<sub>2</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>17</sub>H<sub>25</sub>O<sub>2</sub>N<sup>32</sup>SNa 330.1498, found 330.1496.

***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-4-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)butan-2-yl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-8**



A solution of boronic ester (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5a (34 mg, 0.08 mmol) and CH<sub>2</sub>Br<sub>2</sub> (20 μL, 0.20 mmol) in THF (0.8 ml) under N<sub>2</sub> was cooled to –78 °C. *n*-BuLi (90 μL, 2.1 M in hexanes, 0.19 mmol) was added slowly dropwise (10 seconds per drop). The reaction was then stirred at –78 °C for 30 min then before being warmed to rt. After 12 h the reaction was diluted with Et<sub>2</sub>O (1 mL) and water (1 mL) and the layers separated. The aq layer was extracted with Et<sub>2</sub>O (3 x 1 mL), the combined organic layers washed with brine (1 x 2mL), dried (MgSO<sub>4</sub>) and concentrated under reduced pressure to give a pale-yellow oil. This residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, boronic ester (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-8 (27 mg, 79%).

*R*<sub>f</sub> 0.35 (25% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>-1</sup>) 2975 (w), 2927 (w), 1479 (m), 1440 (m), 1365 (m), 1325 (m), 1278 (m), 1143 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (6.2:1 rotamer mixture by analysis of the NCH signals in the 4.65 – 4.37 region) 7.32 – 7.13 (5H, m, Ph), 4.46 – 4.37 (4.65 – 4.57) (1H, m, NCH), 3.99 (1H, ddd, *J* = 9.9, 9.5, 6.1 Hz, NCHH'), 3.87 (1H, dddd, *J* = 10.6, 9.5, 6.0, 1.3 Hz, NCHH'), 2.76 (2.93 – 2.82) (1H, ddd, *J* = 13.6, 10.6, 5.0 Hz, (m), PhCHH'), 2.54 (2.69 – 2.60) (1H, ddd, *J* = 13.6, 10.4, 6.5 Hz, (m), PhCHH'), 2.42 – 2.31 (1H, m, NCHCH), 2.09 (2.23 – 2.14) (1H, dtd, *J* = 11.5, 9.9, 6.0 Hz, (m), NCHCHH'), 1.97 – 1.89 (1H, m, NCHCHH'), 1.82 (1H, dddd, *J* = 14.1, 10.6, 6.5, 3.6 Hz, PhCH<sub>2</sub>CHH'), 1.59 (1.62) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.53 – 1.39 (1H, m, PhCH<sub>2</sub>CHH'), 1.25 (12H, s, OC(CH<sub>3</sub>)<sub>2</sub>), 0.96 (1H, dd, *J* = 15.8, 5.2 Hz, BCHH'), 0.57 (1H, dd, *J* = 15.8, 9.3 Hz, BCHH'); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) 185.9 (C=S), 142.5 (*i*-Ph), 128.6 (*m*-Ph), 128.5 (*o*-Ph), 125.9 (*p*-Ph), 84.9 (C(CH<sub>3</sub>)<sub>3</sub>), 83.3 (OC(CH<sub>3</sub>)<sub>2</sub>), 68.5 (NCH), 49.7 (NCH<sub>2</sub>), 35.6 (NCHCH), 34.0 (PhCH<sub>2</sub>), 32.4 (PhCH<sub>2</sub>CH<sub>2</sub>), 28.7 (C(CH<sub>3</sub>)<sub>3</sub>), 25.1 (OC(CH<sub>3</sub>)<sub>2</sub>), 25.0 (OC(CH<sub>3</sub>)<sub>2</sub>), 16.4 (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+Na] C<sub>24</sub>H<sub>38</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>SNa 454.2560, found 454.2557.

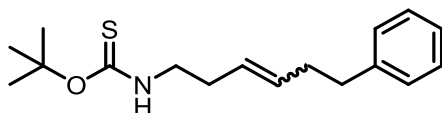
***O*-(*t*-Butyl) (*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-1-(furan-2-yl)-3-phenylpropyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-9**

A solution of furan (18  $\mu$ L, 0.23 mmol) in THF (0.76 mL) under  $N_2$  was cooled to  $-78$   $^{\circ}C$ . *n*-BuLi (0.11 mL, 2.1 M in hexanes, 0.23 mmol) was added dropwise and the reaction mixture was then warmed to rt. The mixture was stirred at rt for 1 h, then cooled to  $-78$   $^{\circ}C$ . A solution of boronic ester (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**5a** (0.38 mL, 0.5 M in THF, 0.19 mmol) was added dropwise and the reaction was stirred at  $-78$   $^{\circ}C$  for 1 h. DDQ (0.96 mL, 0.3 M in THF, 0.29 mmol) was then added dropwise and the reaction mixture was stirred at  $-78$   $^{\circ}C$  for 1 h. The reaction was then quenched with sat. aq  $Na_2S_2O_3$  (2 mL) at  $-78$   $^{\circ}C$ , and the mixture was warmed to rt. To the mixture was added  $Et_2O$  (2 mL) and  $H_2O$  (2 mL), the layers were separated and the aq layer was extracted with  $Et_2O$  (3 x 2 mL). The combined organic layers were washed with brine (1 x 3 mL), dried ( $MgSO_4$ ) and concentrated under reduced pressure to give a brown oil. This residue was purified by column chromatography (5%  $Et_2O$ /petroleum ether). First eluted a colourless oil, furan (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**9** (38 mg, 55%). Second eluted a colourless oil, alkene **10** (16 mg, 28%).

$R_f$  0.55 (25%  $Et_2O$ /petroleum ether); IR (neat/ $cm^{-1}$ ) 3025 (w), 2927 (w), 1476 (m), 1437 (s), 1390 (w), 1364 (w), 1279 (s), 1141 (s);  $\delta_H$  (400 MHz,  $CDCl_3$ ) (3.9:1 rotamer mixture by analysis of the NCH signals in the 4.76 – 4.46 region) 7.38 (1H, d,  $J$  = 1.9 Hz, OCH=), 7.32 – 7.24 (2H, m, *m*-Ph), 7.22 – 7.09 (3H, m, *o*-Ph & *p*-Ph), 6.35 (1H, dd,  $J$  = 3.2, 1.9 Hz, OCH=CH), 6.12 (1H, d,  $J$  = 3.2 Hz, OCq=CH), 4.50 (4.76 – 4.64) (1H, dt,  $J$  = 9.6, 4.2 Hz, (m), NCH), 3.98 (1H, td,  $J$  = 9.7, 6.1 Hz, NCHH'), 3.88 (1H, td,  $J$  = 9.7, 6.1 Hz, NCHH'), 3.42 (4.21 – 4.07) (1H, dt,  $J$  = 11.9, 4.2 Hz, (m), NCHCH), 2.70 (2.63 – 2.54) (1H, ddd,  $J$  = 13.6, 8.7, 4.8 Hz, (m), PhCHH'), 2.44 (1H, dt,  $J$  = 13.6, 8.4 Hz, PHCHH'), 2.29 – 1.92 (4H, m, NCHCH<sub>2</sub> & PhCH<sub>2</sub>CH<sub>2</sub>), 1.53 (1.64) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>);  $\delta_C$  (100 MHz,  $CDCl_3$ ) (rotamer mixture) 186.0 (C=S), 154.4 (OCq=), 142.0 (OCH=), 141.7 (*i*-Ph), 128.7 (*o*-Ph), 128.6 (128.5) (*m*-Ph), 126.1 (125.9) (*p*-Ph), 110.3 (OCH=CH), 107.0 (OCq=CH), 85.3 (C(CH<sub>3</sub>)<sub>3</sub>), 66.4 (NCH), 49.88 (49.93) (NCH<sub>2</sub>), 40.0 (NCHCH),

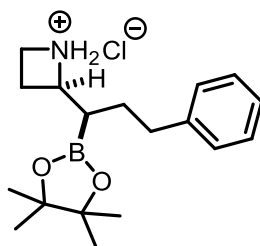
33.6 (PhCH<sub>2</sub>), 28.5 (28.6) (C(CH<sub>3</sub>)<sub>3</sub> & PhCH<sub>2</sub>CH<sub>2</sub>), 17.1 (NCH<sub>2</sub>CH<sub>2</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>21</sub>H<sub>27</sub>O<sub>2</sub>N<sup>32</sup>SNa 380.1655, found 380.1654.

**O-(*t*-Butyl) (6-phenylhex-3-en-1-yl)carbamothioate 10**



*R<sub>f</sub>* 0.50 (25% Et<sub>2</sub>O/ petroleum ether); IR (neat/cm<sup>-1</sup>) 3236 (br), 2977 (w), 2927 (w), 1497 (w), 1453 (m), 1391 (m), 1365 (m), 1336 (m), 1251 (m), 1194 (w), 1140 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (mixture of rotamers and *E/Z* isomers) 7.32 – 7.24 (2H, m, *m*-Ph), 7.21 – 7.18 (3H, m, *p*-Ph & *o*-Ph), 6.06 (6.39) (1H, br s, NH), 5.62 – 5.49 (1H, m, PhCH<sub>2</sub>CH<sub>2</sub>CH), 5.40 – 5.26 (1H, m, NCH<sub>2</sub>CH<sub>2</sub>CH), 3.54 – 3.37 (3.17 (E)) (3.07) (2H, m, (td, *J* = 6.8, 5.7 Hz, (td, *J* = 7.0, 5.8 Hz), NCH<sub>2</sub>), 2.73 – 2.64 (2H, m, PhCH<sub>2</sub>), 2.43 – 2.30 (2H, m, PhCH<sub>2</sub>CH<sub>2</sub>), 2.29 – 2.21 (2.20 – 2.11) (2H, m, NCH<sub>2</sub>CH<sub>2</sub>), 1.65 (1.68) (9H, s, C(CH<sub>3</sub>)<sub>3</sub> (E)), 1.62 (1.67) (9H, s, C(CH<sub>3</sub>)<sub>3</sub> (Z)); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (mixture of rotamers and *E/Z* isomers) 188.34 (188.08) (C=S) (Z), 188.28 (188.04) (C=S) (E), 141.89 (141.87) (*i*-Ph) (E), 141.84 (141.78) (*i*-Ph) (Z), 132.7 (133.1) (PhCH<sub>2</sub>CH<sub>2</sub>CH) (E), 132.1 (132.2) (PhCH<sub>2</sub>CH<sub>2</sub>CH) (Z), 128.63 (*o*-Ph) (Z), 128.61 (*o*-Ph) (E), 128.4 (*m*-Ph) (E & Z), 127.4 (126.7) (NCH<sub>2</sub>CH<sub>2</sub>CH) (E), 126.4 (NCH<sub>2</sub>CH<sub>2</sub>CH) (Z), 126.04 (125.92) (*p*-Ph) (Z), 125.97 (*p*-Ph) (E), 84.97 (86.36) (OC(CH<sub>3</sub>)<sub>3</sub>) (Z), 84.94 (86.31) (OC(CH<sub>3</sub>)<sub>3</sub>) (E), 44.0 (43.1) (NCH<sub>2</sub>) (Z), 43.2 (E), 35.94 (35.86) (PhCH<sub>2</sub>) (Z), 35.91 (PhCH<sub>2</sub>) (E), 34.47 (34.54) (PhCH<sub>2</sub>CH<sub>2</sub>) (E), 31.6 (32.2) (NCH<sub>2</sub>CH<sub>2</sub>) (E), 29.37 (29.39) (PhCH<sub>2</sub>CH<sub>2</sub>) (Z), 28.68 (28.46) (C(CH<sub>3</sub>)<sub>3</sub>) (E), 28.65 (28.44) (C(CH<sub>3</sub>)<sub>3</sub>) (Z), 26.4 (27.1) (NCH<sub>2</sub>CH<sub>2</sub>) (Z); HRMS (FTMS) calcd for [M+Na] C<sub>17</sub>H<sub>25</sub>ON<sup>32</sup>SNa 314.1549, found 314.1551.

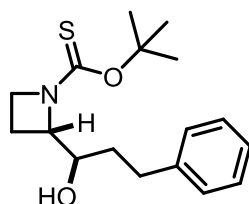
**(*R*<sup>\*</sup>)-2-((*R*<sup>\*</sup>)-3-Phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)propyl)azetidinium-1-ium  
(*R*<sup>\*</sup>,*R*<sup>\*</sup>)-11**



HCl (0.20 mL, 2 M in Et<sub>2</sub>O, 0.40 mmol) was added to boronic ester (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**5a** (20 mg, 0.05 mmol) at rt. The reaction was stirred for 1 h at rt, then concentrated under reduced pressure to give a white solid, azetidinium chloride (*R*<sup>\*</sup>,*R*<sup>\*</sup>)-**11** (16 mg, quant).

mp 131–132 °C; IR (neat/cm<sup>-1</sup>) 3394 (br), 2924 (w), 2858 (w), 1453 (w), 1372 (m), 1328 (m), 1141 (s); δ<sub>H</sub> (400 MHz, CD<sub>3</sub>OD) 7.36 – 7.11 (5H, m, Ph), 4.53 (1H, q, *J* = 9.2 Hz, NCH), 4.03 (1H, q, *J* = 9.6 Hz, NCHH'), 3.76 (1H, td, *J* = 10.0, 4.0 Hz, NCHH'), 2.79 (1H, ddd, *J* = 14.3, 8.8, 5.8 Hz, PhCHH'), 2.70 – 2.51 (2H, m, PhCHH' & NCHCHH'), 2.38 – 2.25 (1H, m, NCHCHH'), 1.79 – 1.59 (3H, m, BCH & PhCH<sub>2</sub>CH<sub>2</sub>), 1.35 (12H, s, C(CH<sub>3</sub>)<sub>2</sub>); δ<sub>C</sub> (100 MHz, CD<sub>3</sub>OD) 143.0 (*i*-Ph), 129.5 (*m*-Ph), 129.4 (*o*-Ph), 127.1 (*p*-Ph), 85.6 (OC(CH<sub>3</sub>)<sub>2</sub>), 63.5 (NCH), 43.5 (NCH<sub>2</sub>), 35.3 (PhCH<sub>2</sub>), 29.0 (PhCH<sub>2</sub>CH<sub>2</sub>), 27.3 (NCHCH<sub>2</sub>), 25.3 (OC(CH<sub>3</sub>)<sub>2</sub>), 25.1 (OC(CH<sub>3</sub>)<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CD<sub>3</sub>OD) 33; HRMS (FTMS) calcd for [M-Cl] C<sub>18</sub>H<sub>29</sub>O<sub>2</sub>N<sup>11</sup>B 302.2286, found 302.2288.

***O*-*t*-Butyl (*R*<sup>\*</sup>)-2-((*S*<sup>\*</sup>)-1-hydroxy-3-phenylpropyl)azetidine-1-carbothioate (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-SI-19**

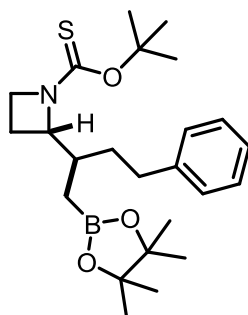


To a solution of boronic ester (*R*<sup>\*</sup>,*S*<sup>\*</sup>)-**5a'** (14 mg, 0.03 mmol) in THF (0.26 mL) and water (0.26 mL) was added sodium perborate tetrahydrate (25 mg, 0.16 mmol). The reaction mixture was stirred vigorously for 1 h at rt. The reaction was diluted with water (5 mL) and extracted with EtOAc (3 x 2

mL). The combined organic layers were washed with brine (2 mL), dried ( $\text{MgSO}_4$ ) and concentrated under reduced pressure to give pale yellow oil. This residue was purified by column chromatography (10%  $\text{Et}_2\text{O}$ /petroleum ether) to give a colourless oil, alcohol ( $R^*,S^*$ )-**SI-19** (6 mg, 64%).

$R_f$  0.29 (25%  $\text{Et}_2\text{O}$ /petroleum ether); IR (neat/ $\text{cm}^{-1}$ ) 3418 (br), 2926 (m), 2361 (m), 2343 (m), 1482 (s), 1437 (s), 1391 (m), 1366 (m), 1281 (s), 1144 (s);  $\delta_{\text{H}}$  (400 MHz,  $\text{CDCl}_3$ ) (1.15:1 rotamer mixture by analysis of the NCH signals in the 4.71 – 4.27 region) 7.32 – 7.16 (5H, m, Ar), 4.69 (4.29) (1H, t,  $J = 7.7$  Hz, ( $J = 7.2$  Hz), NCH), 4.10 (4.06 – 4.01) (1H, br d,  $J = 6.7$  Hz, (m), CHOH), 4.00 – 3.79 (2H, m,  $\text{NCH}_2$ ), 3.53 (1H, br d,  $J = 7.5$  Hz, OH), 3.03 – 2.94 (2.90 – 2.82) (1H, m,  $\text{PhCHH}'$ ), 2.74 – 2.66 (1H, m,  $\text{PhCHH}'$ ), 2.28 – 2.12 (1H, m,  $\text{NCHCHH}'$ ), 2.10 – 1.94 (1H, m,  $\text{NCHCHH}'$ ), 1.84 – 1.66 (1.61 – 1.58) (2H, m,  $\text{PhCH}_2\text{CH}_2$ ), 1.62 (1.57) (9H, s,  $\text{C}(\text{CH}_3)_3$ );  $\delta_{\text{C}}$  (100 MHz,  $\text{CDCl}_3$ ) (mixture of rotamers) 186.5 (186.6) ( $\text{C}=\text{S}$ ), 142.4 (*i*-Ph), 128.7 (128.62) (*m*-Ph), 128.55 (128.59) (*o*-Ph), 126.0 (126.2) (*p*-Ph), 85.7 (85.8) ( $\text{C}(\text{CH}_3)_3$ ), 70.8 (69.2) (CHOH), 70.2 (68.7) (NCH), 49.4 (50.4) ( $\text{NCH}_2$ ), 33.3 (33.1) ( $\text{PhCH}_2\text{CH}_2$ ), 32.5 (32.0) ( $\text{PhCH}_2$ ), 28.6 ( $\text{C}(\text{CH}_3)_3$ ), 16.8 (15.0) ( $\text{NCHCH}_2$ ); HRMS (FTMS) calcd for  $[\text{M}+\text{Na}] \text{C}_{17}\text{H}_{25}\text{O}_2\text{N}^{32}\text{Na}$  330.1498, found 330.1498.

**O-(*t*-Butyl) ( $R^*,S^*$ )-2-(( $S^*$ )-4-phenyl-1-(4,4,5,5-tetramethyl-1,3,2-dioxaborolan-2-yl)butan-2-yl)azetidene-1-carbothioate ( $R^*,S^*$ )-SI-20**

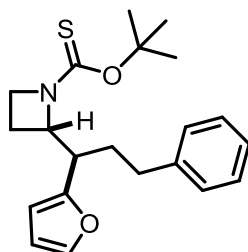


A solution of boronic ester ( $R^*,S^*$ )-**5a'** (34 mg, 0.08 mmol) and  $\text{CH}_2\text{Br}_2$  (20  $\mu\text{L}$ , 0.20 mmol) in THF (0.8 ml) under  $\text{N}_2$  was cooled to  $-78$  °C. *n*-BuLi (90  $\mu\text{L}$ , 2.1 M in hexanes, 0.19 mmol) was added dropwise (10 seconds per drop). The reaction was stirred at  $-78$  °C for 30 mins then the mixture was warmed to rt and further stirred for 12 h. The reaction was diluted with  $\text{Et}_2\text{O}$  (1 mL) and water (1 mL) and the layers separated. The aq layer was extracted with  $\text{Et}_2\text{O}$  (3 x 1 mL), the combined organic layers washed with brine (1 x 2 mL), dried ( $\text{MgSO}_4$ ) and concentrated under reduced pressure to give a pale

yellow oil. This residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, boronic ester (*R*\*,*S*\*)-**SI-20** (24 mg, 70%).

*R<sub>f</sub>* 0.52 (25% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>3</sup>) 2976 (w), 2927 (w), 1480 (m), 1440 (m), 1390 (m), 1365 (m), 1318 (m), 1278 (s), 1142 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (8.7:1 rotamer mixture by analysis of the NCH signals in the 4.76 – 4.39 region) 7.29 – 7.12 (5H, m, Ph), 4.45 (4.73 – 4.61) (1H, dt, *J* = 9.3, 5.5 Hz, (m), NCH), 3.99 (1H, td, *J* = 9.9, 6.2 Hz, NCHH'), 3.90 (1H, td, *J* = 9.9, 6.0 Hz, NCHH'), 2.60 (2H, t, *J* = 8.1 Hz, PhCH<sub>2</sub>), 2.52 – 2.40 (2.90 – 2.82) (1H, m, NCHCH), 2.18 – 1.98 (1H, m, NCHCHH'), 1.98 – 1.88 (1H, m, NCHCHH'), 1.59 (1.62) (9H, s, C(CH<sub>3</sub>)<sub>3</sub>), 1.56 – 1.40 (2H, m, PhCH<sub>2</sub>CH<sub>2</sub>), 1.23 (12H, s, C(CH<sub>3</sub>)<sub>2</sub>), 0.92 (1H, dd, *J* = 15.6, 3.2 Hz, BCHH'), 0.68 (1H, dd, *J* = 15.5, 10.4 Hz, BCHH'); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (rotamer mixture) 185.7 (C=S), 142.3 (*i*-Ph), 128.5 (*m*-Ph), 128.4 (*o*-Ph), 125.9 (*p*-Ph), 85.1 (C(CH<sub>3</sub>)<sub>3</sub>), 83.3 (C(CH<sub>3</sub>)<sub>2</sub>), 67.9 (67.0) (NCH), 49.8 (NCH<sub>2</sub>), 35.3 (NCHCH), 34.6 (PhCH<sub>2</sub>CH<sub>2</sub>), 33.9 (PhCH<sub>2</sub>), 28.5 (28.6) (C(CH<sub>3</sub>)<sub>3</sub>), 25.2 (C(CH<sub>3</sub>)<sub>2</sub>), 24.9 (C(CH<sub>3</sub>)<sub>2</sub>), 15.8 (NCHCH<sub>2</sub>). BCH carbon not observed due to quadrupolar relaxation. δ<sub>B</sub> (128 MHz, CDCl<sub>3</sub>) 34; HRMS (FTMS) calcd for [M+H] C<sub>24</sub>H<sub>39</sub>O<sub>3</sub>N<sup>11</sup>B<sup>32</sup>S 432.2740, found 431.2741.

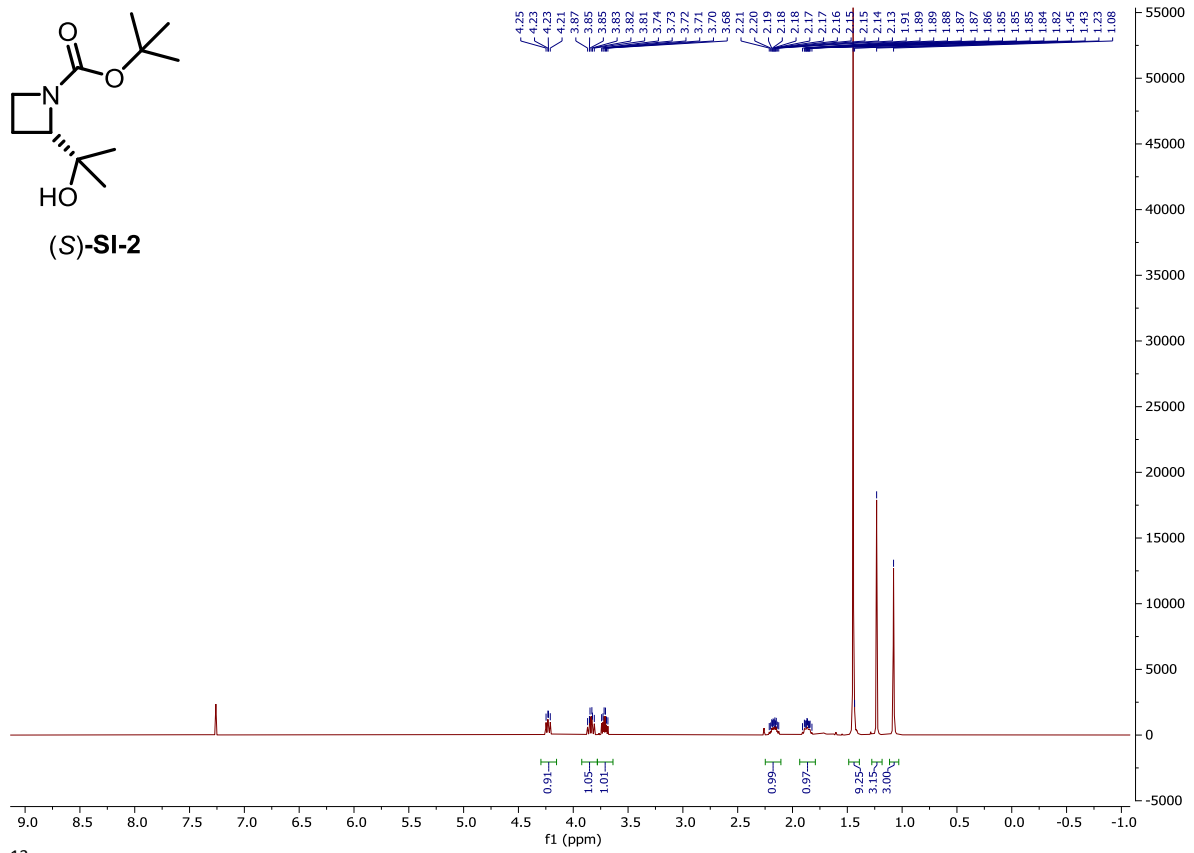
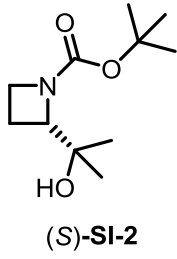
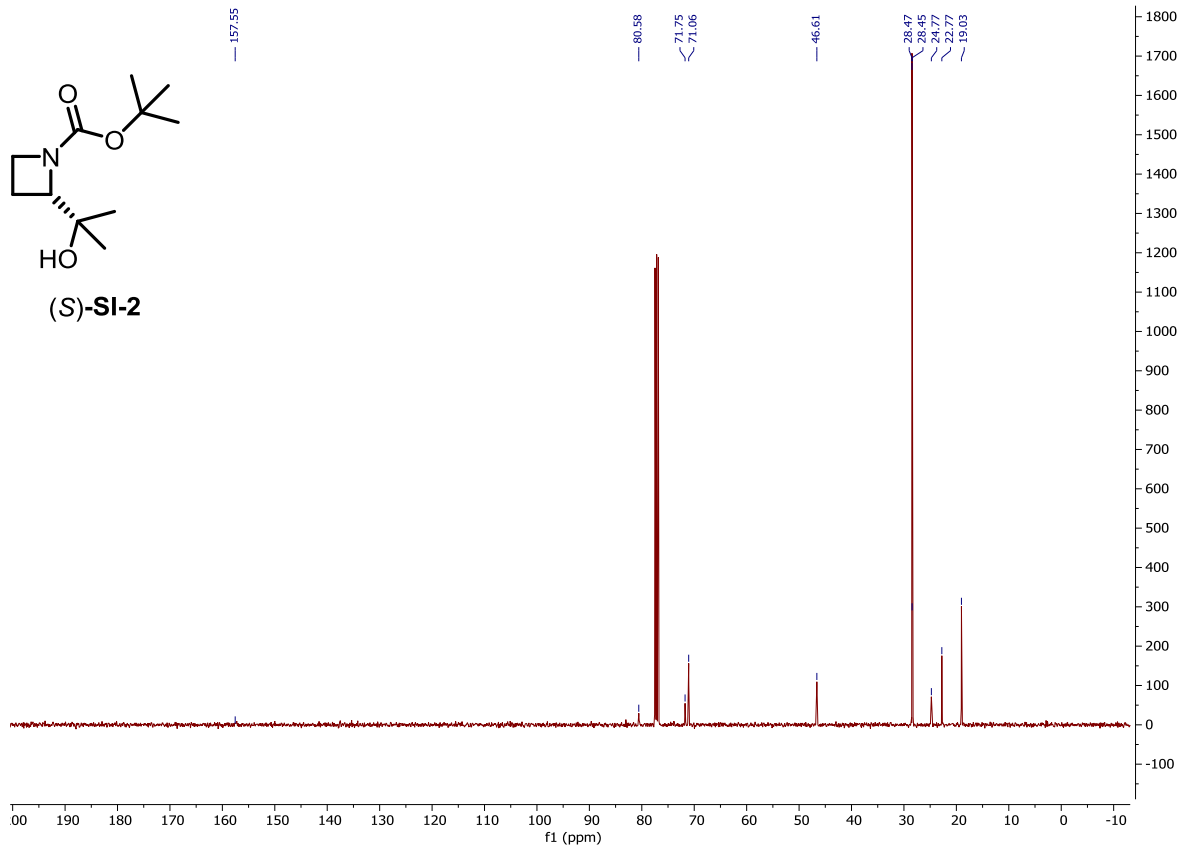
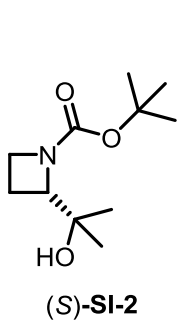
**O-(*t*-Butyl) (*R*\*)-2-((*S*\*)-1-(furan-2-yl)-3-phenylpropyl)azetidone-1-carbothioate (*R*\*,*S*\*)-**SI-21****

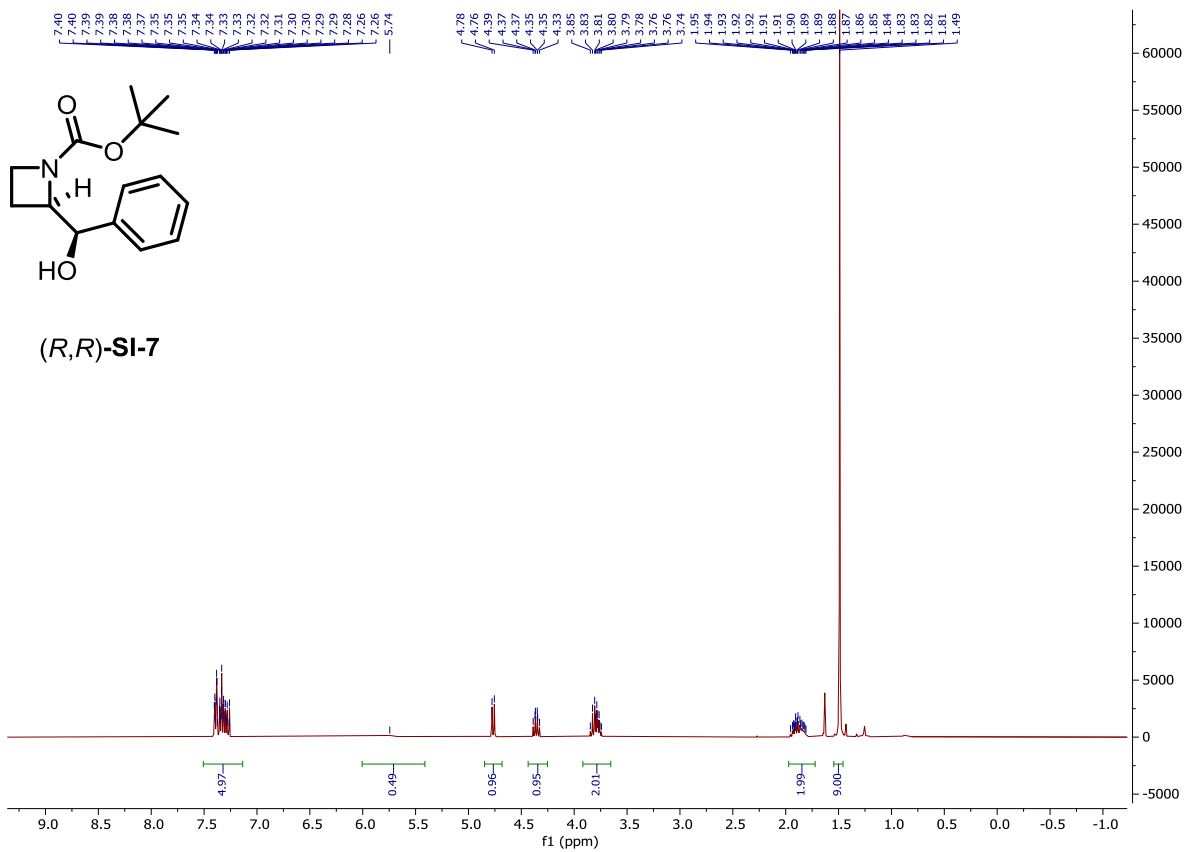
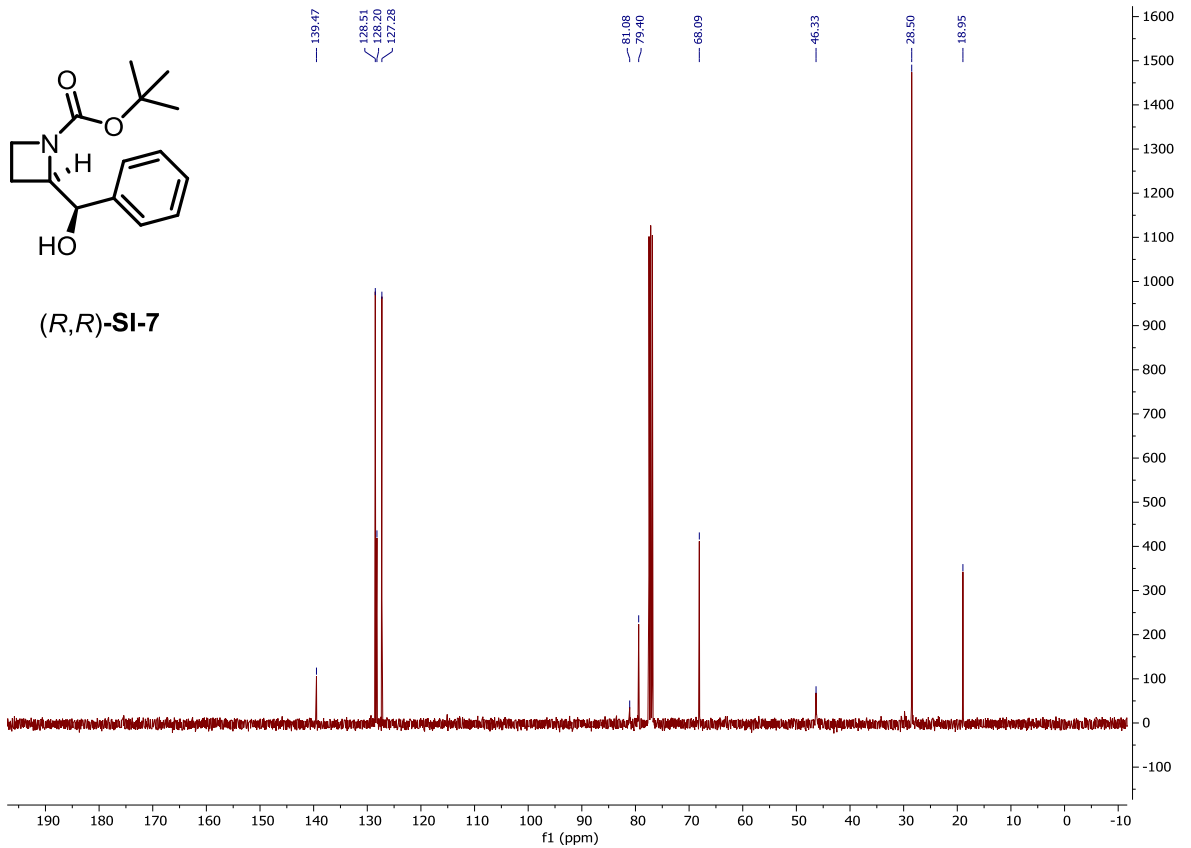


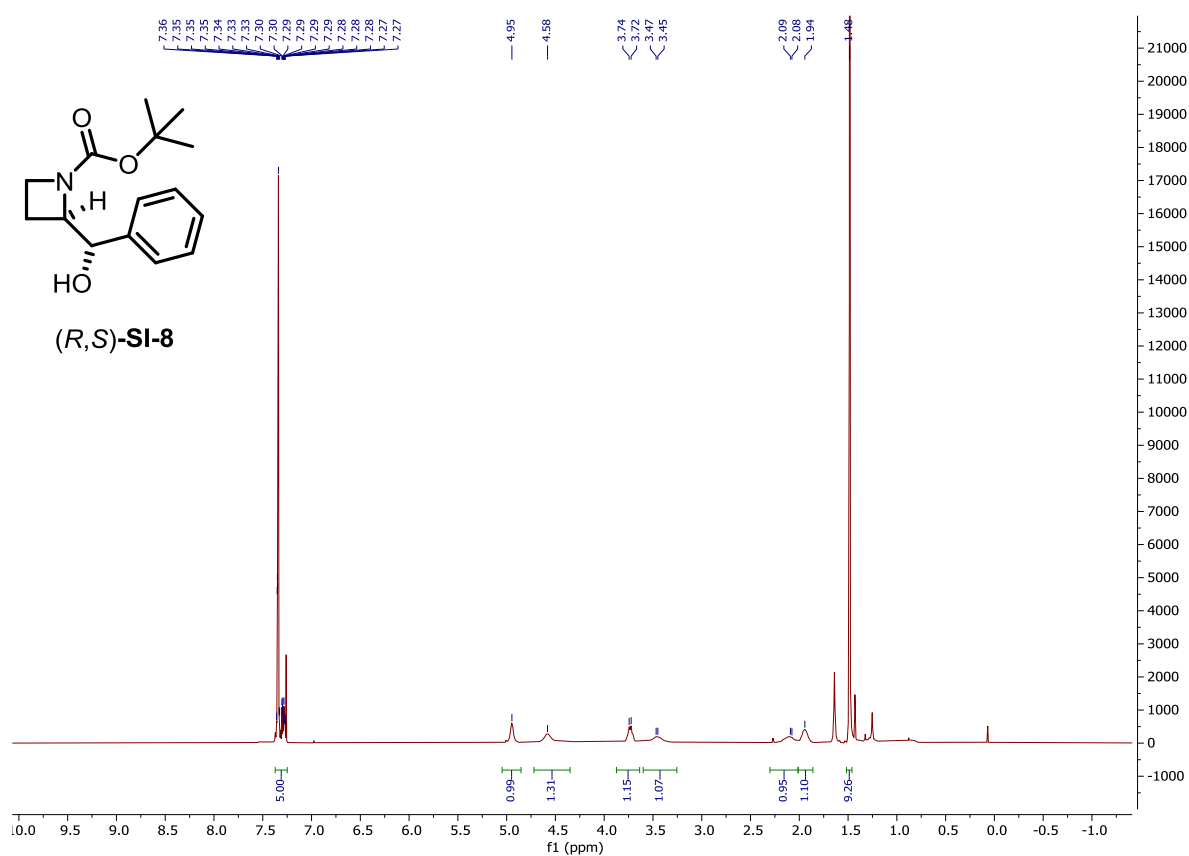
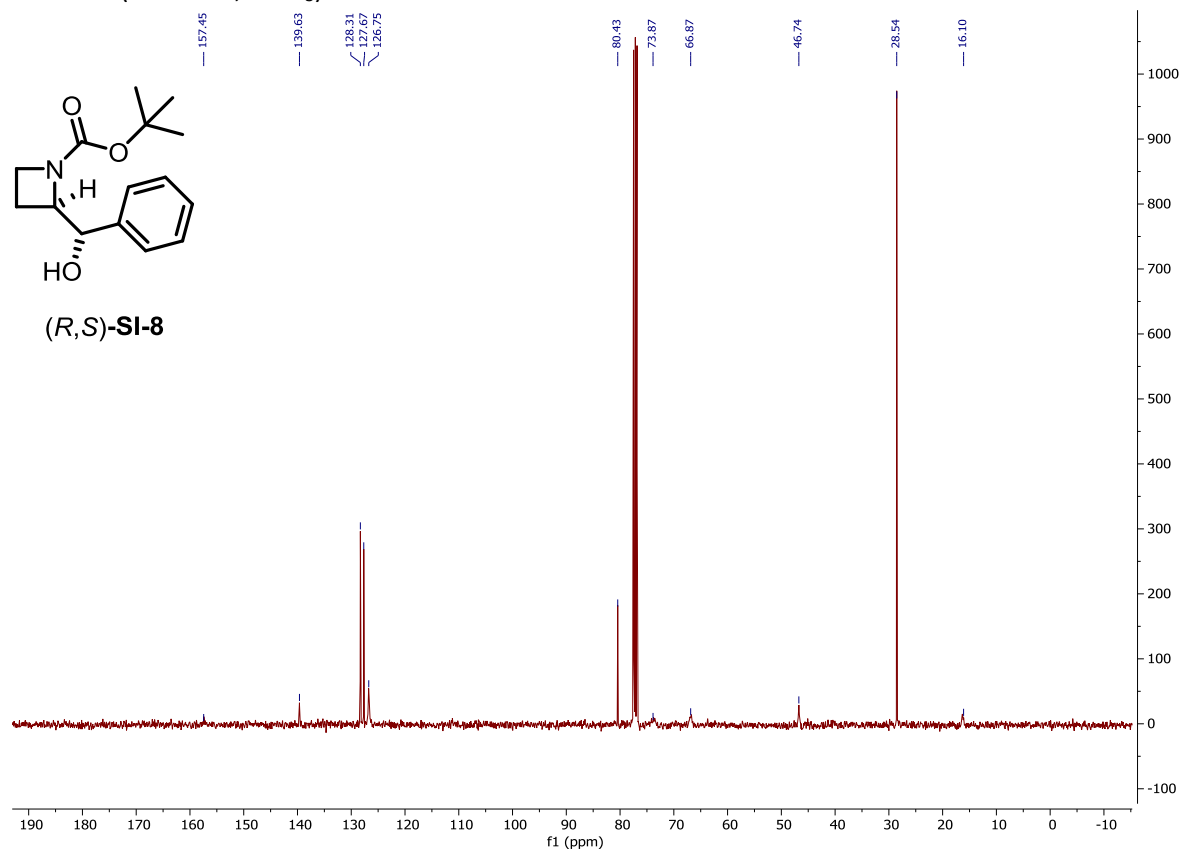
A solution of furan (18 μL, 0.23 mmol) in THF (0.76 mL) under N<sub>2</sub> was cooled down to –78 °C. *n*-BuLi (0.11 mL, 2.1 M in hexanes, 0.23 mmol) was added dropwise and the reaction mixture was then warmed to rt. The mixture was stirred at rt for 1 h, then cooled to –78 °C. A solution of boronic ester (*R*\*,*S*\*)-**5a'** (0.38 mL, 0.5 M in THF, 0.19 mmol) was added dropwise and the reaction was stirred at –78 °C for 1 h. A solution of DDQ (0.96 mL, 0.3 M in THF, 0.29 mmol) was added dropwise and the reaction mixture was stirred at –78 °C for 1 h. The reaction was quenched with sat. aq Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> (2 mL) at –78 °C, and the mixture was warmed to rt. To the mixture was added Et<sub>2</sub>O (2 mL) and H<sub>2</sub>O (2 mL), the layers were separated and the aq layer was extracted with Et<sub>2</sub>O (3 x 2 mL). The combined organic layers were washed with brine (1 x 3 mL), dried (MgSO<sub>4</sub>) and concentrated under

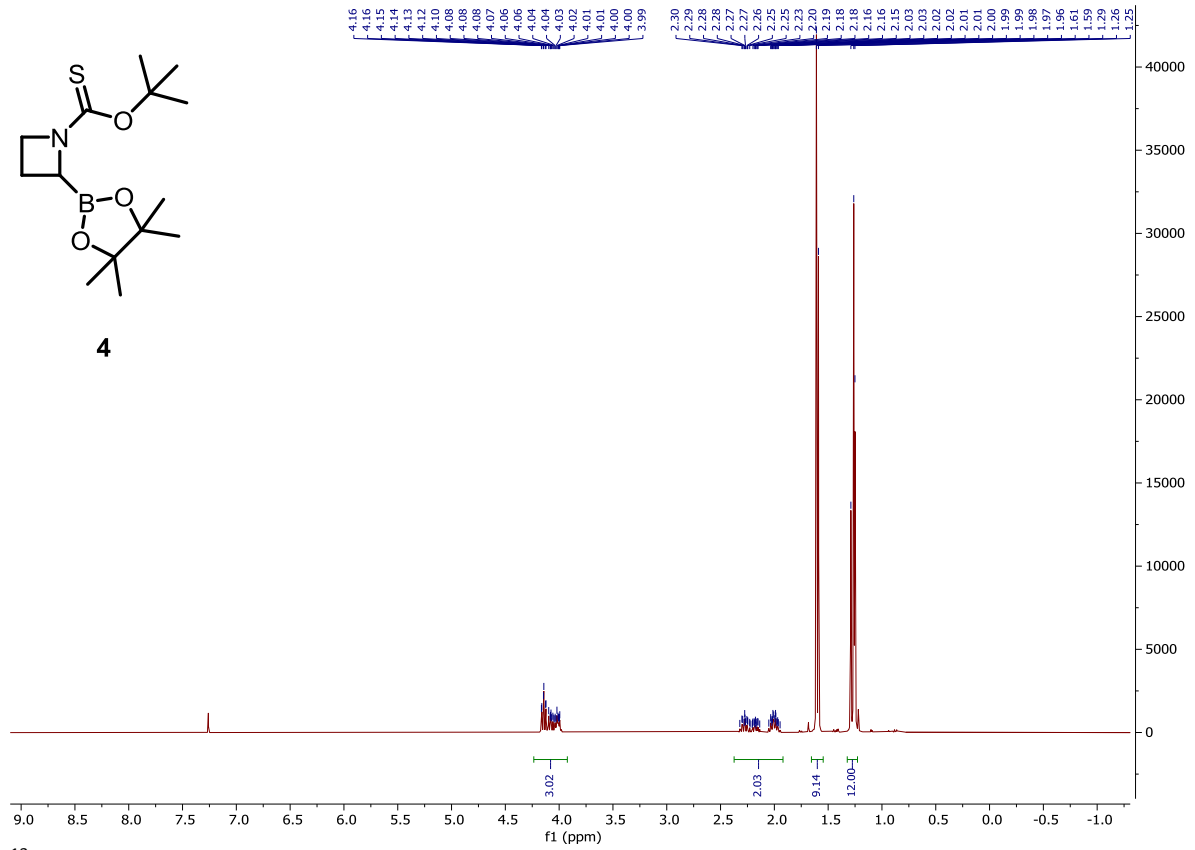
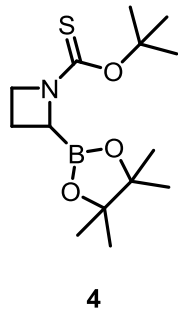
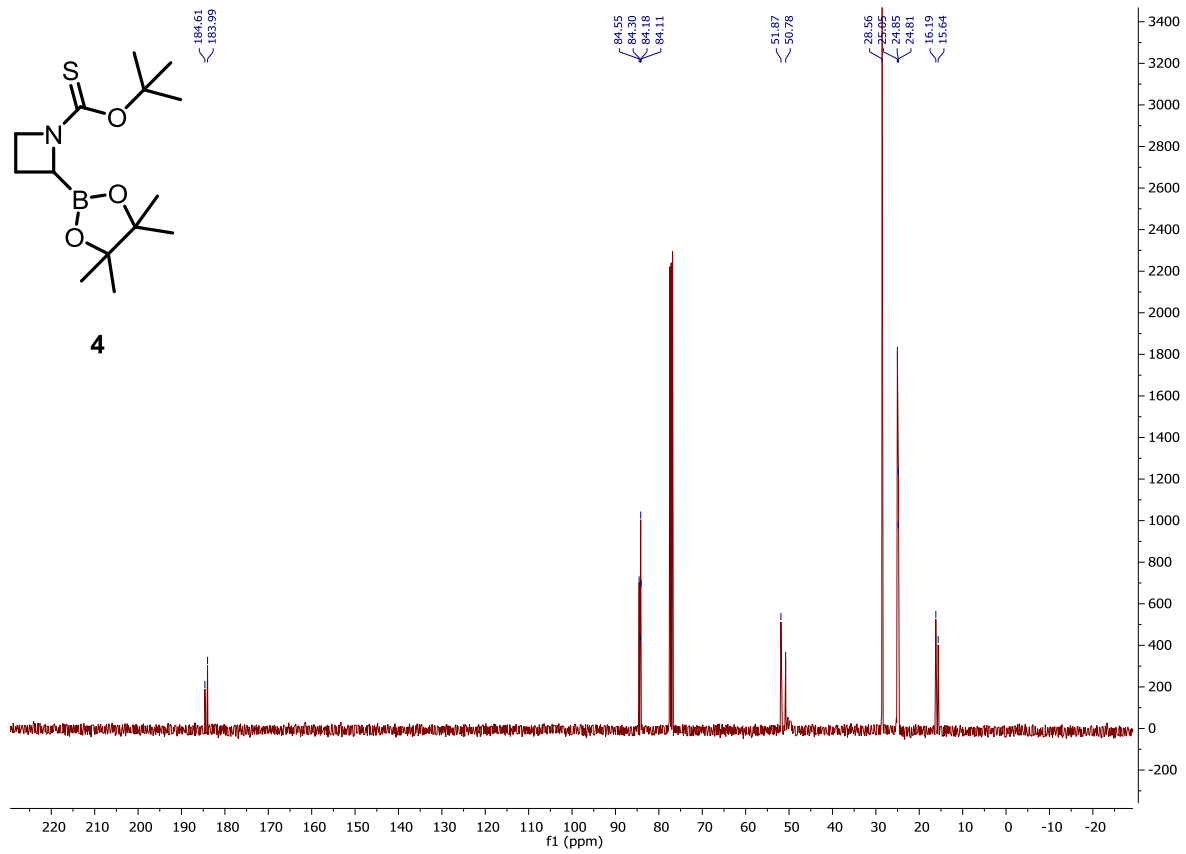
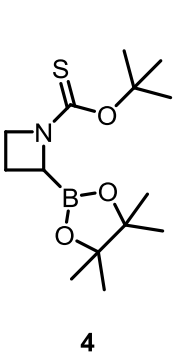
reduced pressure to give a brown oil. The residue was purified by column chromatography (5% Et<sub>2</sub>O/petroleum ether) to give a colourless oil, furan (*R*\*,*S*\*)-**SI-21** (33 mg, 49%).

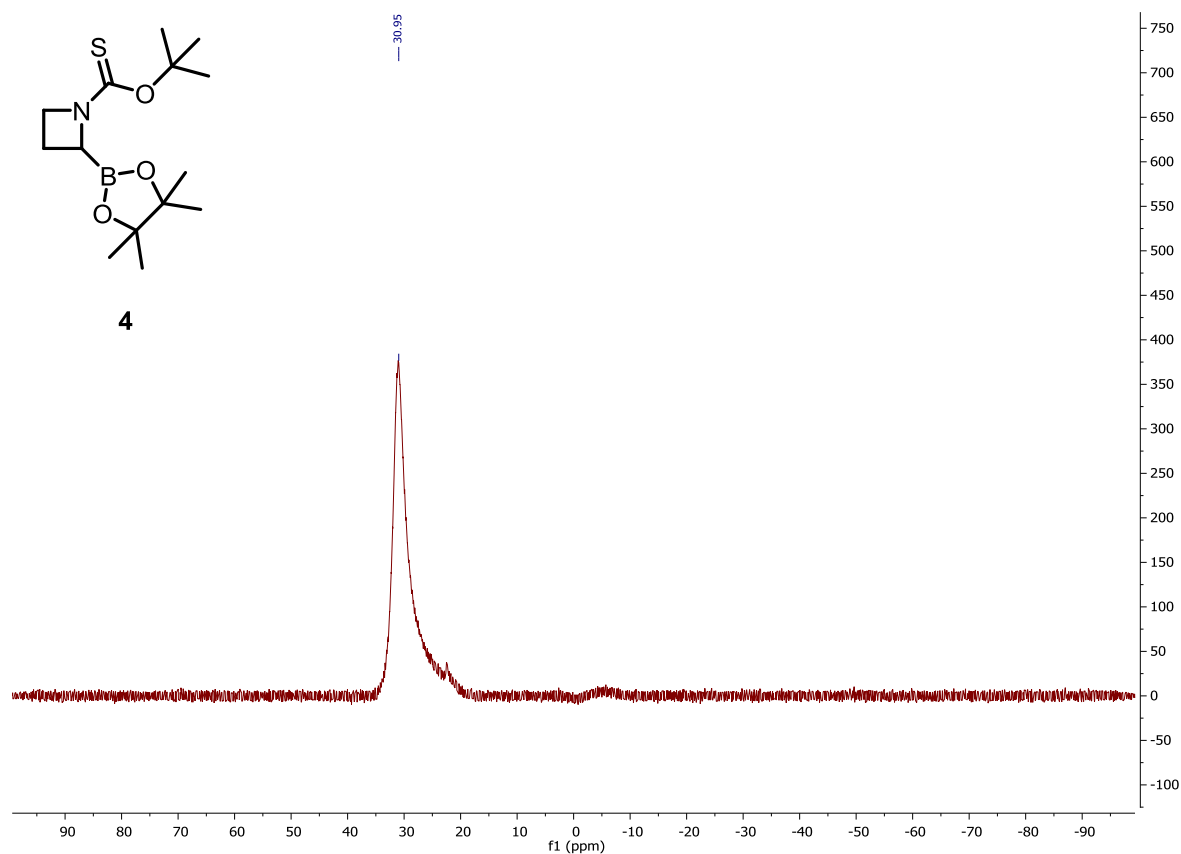
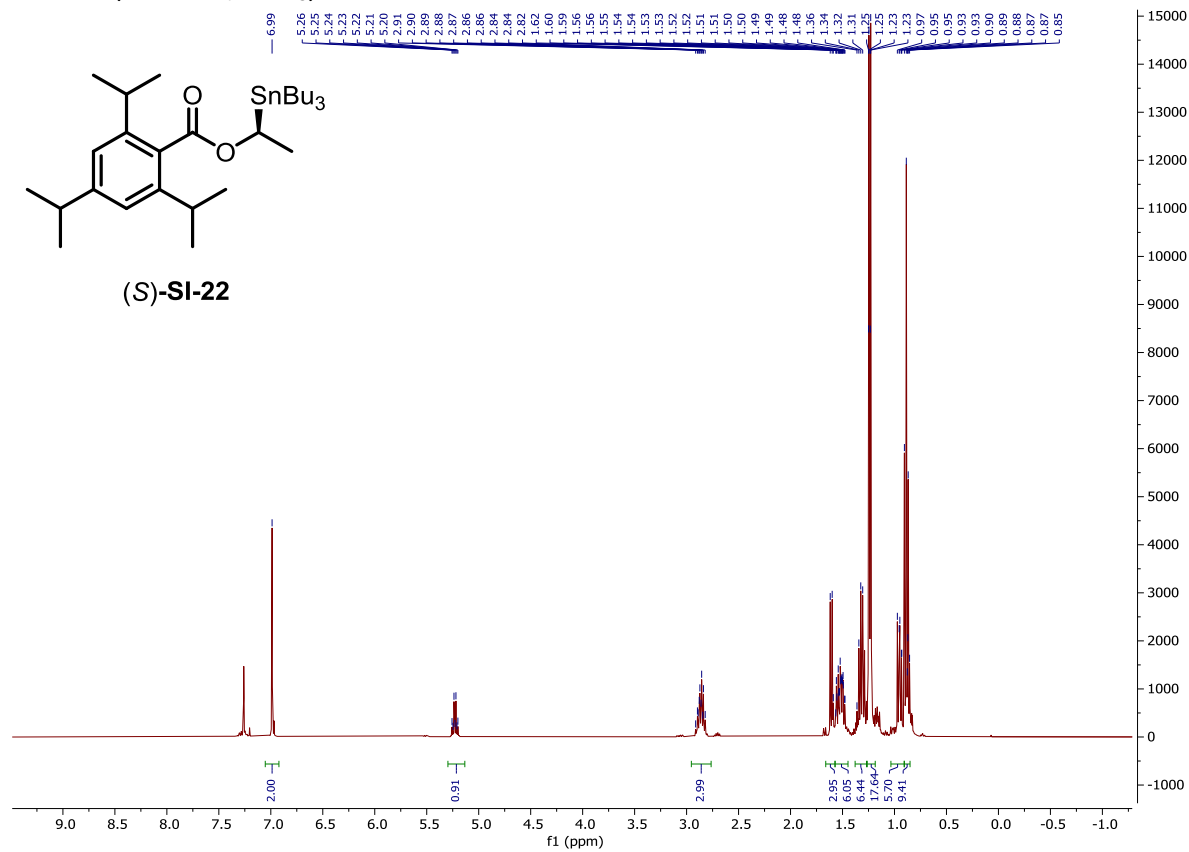
*R*<sub>f</sub> 0.58 (25% Et<sub>2</sub>O/petroleum ether); IR (neat/cm<sup>3</sup>) 3025 (w), 2967 (w), 1479 (s), 1464 (m), 1439 (s), 1390 (m), 1365 (m), 1280 (s), 1144 (s); δ<sub>H</sub> (400 MHz, CDCl<sub>3</sub>) (2.8:1 rotamer mixture by analysis of the NCH signals in the 4.63 – 4.34 region) 7.41 (1H, d, *J* = 1.8 Hz, OCH=), 7.30 – 7.24 (2H, m, *m*-Ph), 7.20 – 7.09 (3H, m, *o*-Ph & *p*-Ph), 6.37 (1H, dd, *J* = 3.2, 1.8 Hz, OCH=CH), 6.13 (6.24) (1H, d, *J* = 3.2 Hz, (d, *J* = 3.2 Hz), OCq=CH), 4.37 (4.60) (1H, dt, *J* = 9.2, 5.1 Hz, (dt, *J* = 8.8, 4.6 Hz), NCH), 3.83 (3.69) (1H, td, *J* = 9.8, 5.6 Hz, (td, *J* = 9.7, 5.2 Hz) NCHH'), 3.50 – 3.40 (4.32 – 4.20 & 3.30 – 3.15) (2H, m, NCHH' & NCHCH), 2.74 – 2.55 (1H, m, PhCHH'), 2.48 (1H, dt, *J* = 13.8, 8.2 Hz, PhCHH'), 2.24 – 1.94 (3H, m, NCHCH<sub>2</sub> & PhCH<sub>2</sub>CHH'), 1.87 – 1.72 (1H, m, PhCH<sub>2</sub>CHH'), 1.57 (1.60) (9H, s, OC(CH<sub>3</sub>)<sub>3</sub>); δ<sub>C</sub> (100 MHz, CDCl<sub>3</sub>) (rotamer mixture) 185.3 (C=S), 153.6 (OCq=), 142.1 (OCH=), 141.6 (*i*-Ph), 128.6 (128.5) (*o*-Ph & *m*-Ph), 126.2 (128.5) (*p*-Ph), 110.5 (OCH=CH), 108.2 (OCq=CH), 85.1 (C(CH<sub>3</sub>)<sub>3</sub>), 66.5 (67.3) (NCH), 49.5 (49.2) (NCH<sub>2</sub>), 40.0 (NCHCH), 33.6 (34.0) (PhCH<sub>2</sub>), 30.7 (30.6) (PhCH<sub>2</sub>CH<sub>2</sub>), 28.6 (28.7) (C(CH<sub>3</sub>)<sub>3</sub>), 17.5 (17.7) (NCHCH<sub>2</sub>); HRMS (FTMS) calcd for [M+Na] C<sub>21</sub>H<sub>27</sub>O<sub>2</sub>N<sup>32</sup>SNa 380.1655, found 380.1654.

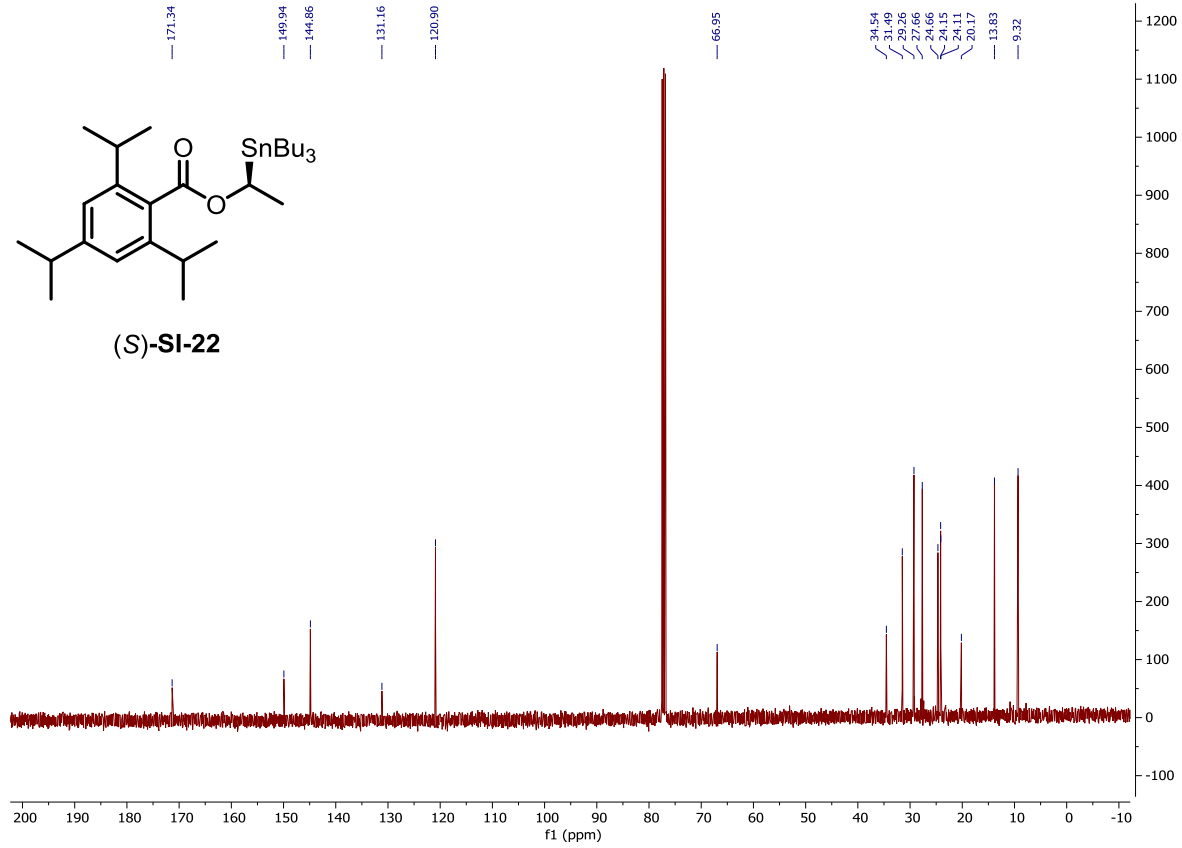
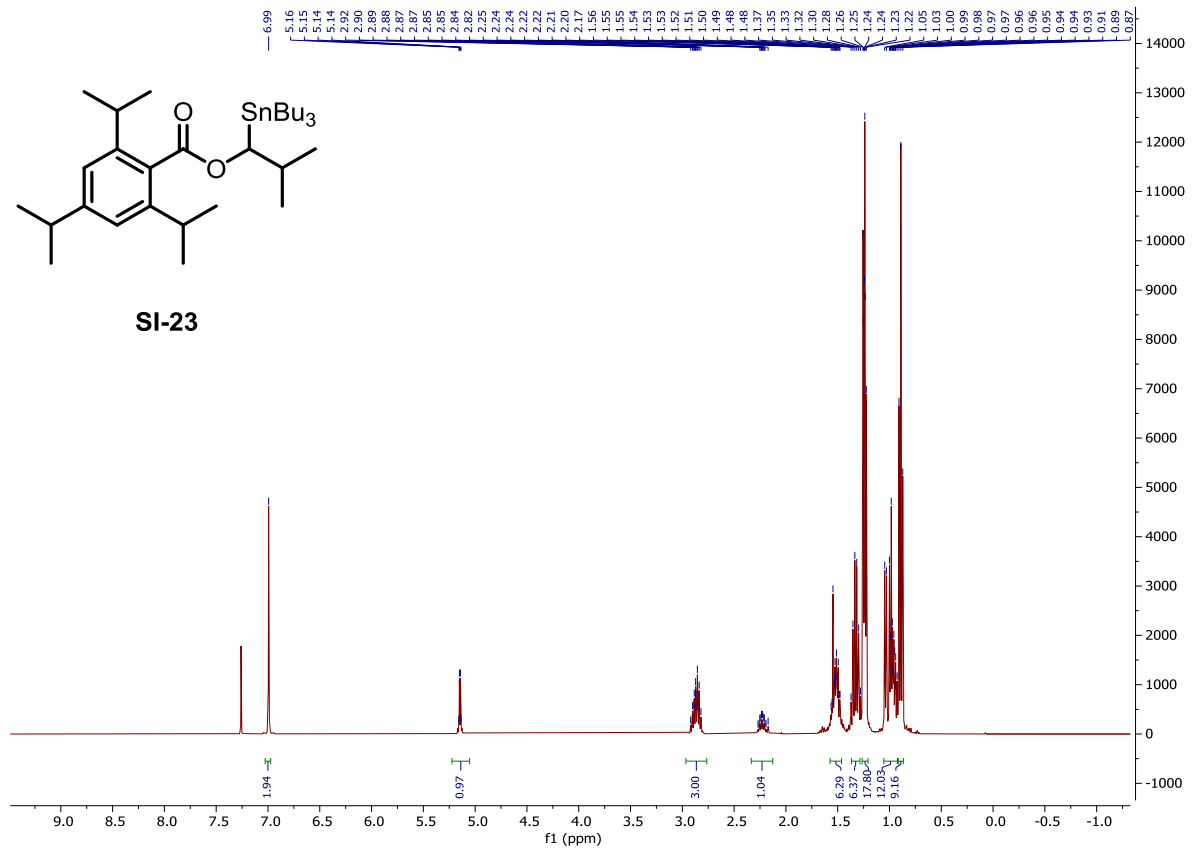
6.  $^1\text{H}$ ,  $^{13}\text{C}$  and  $^{11}\text{B}$  NMR spectra $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )

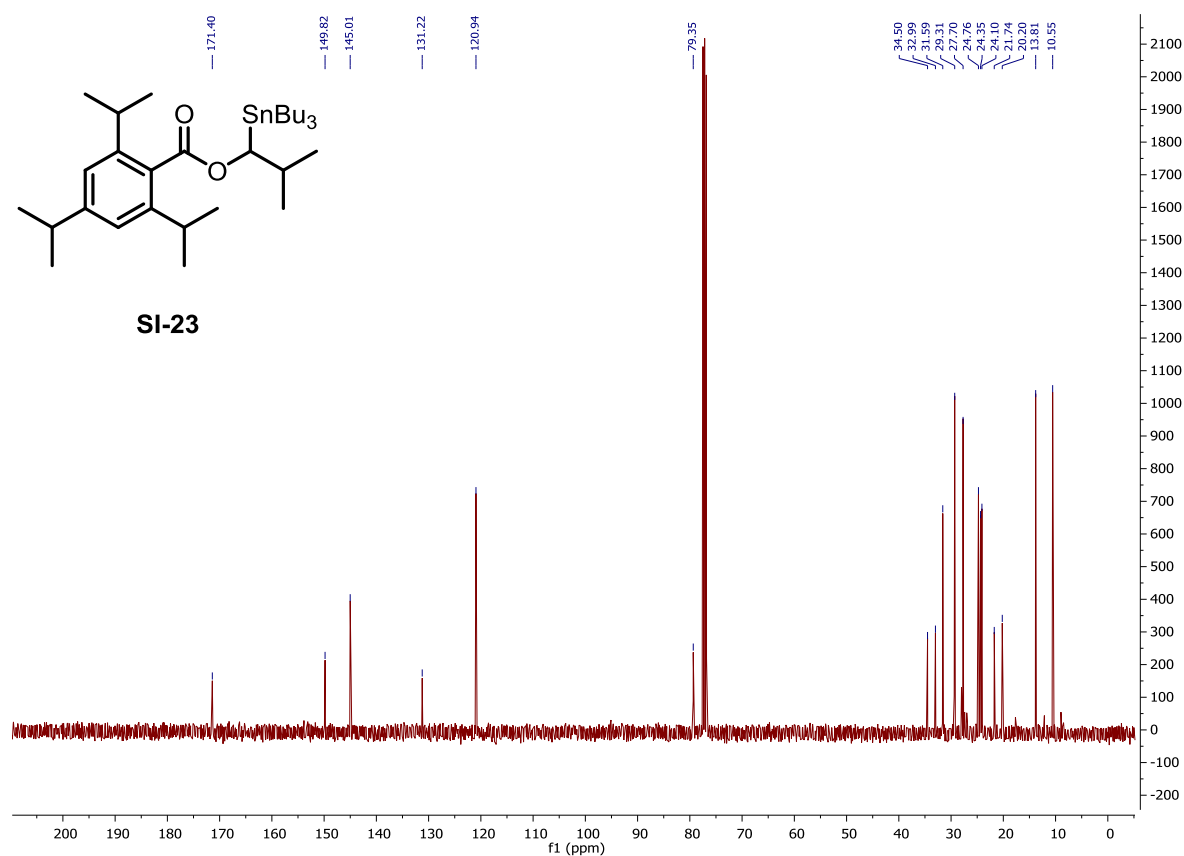
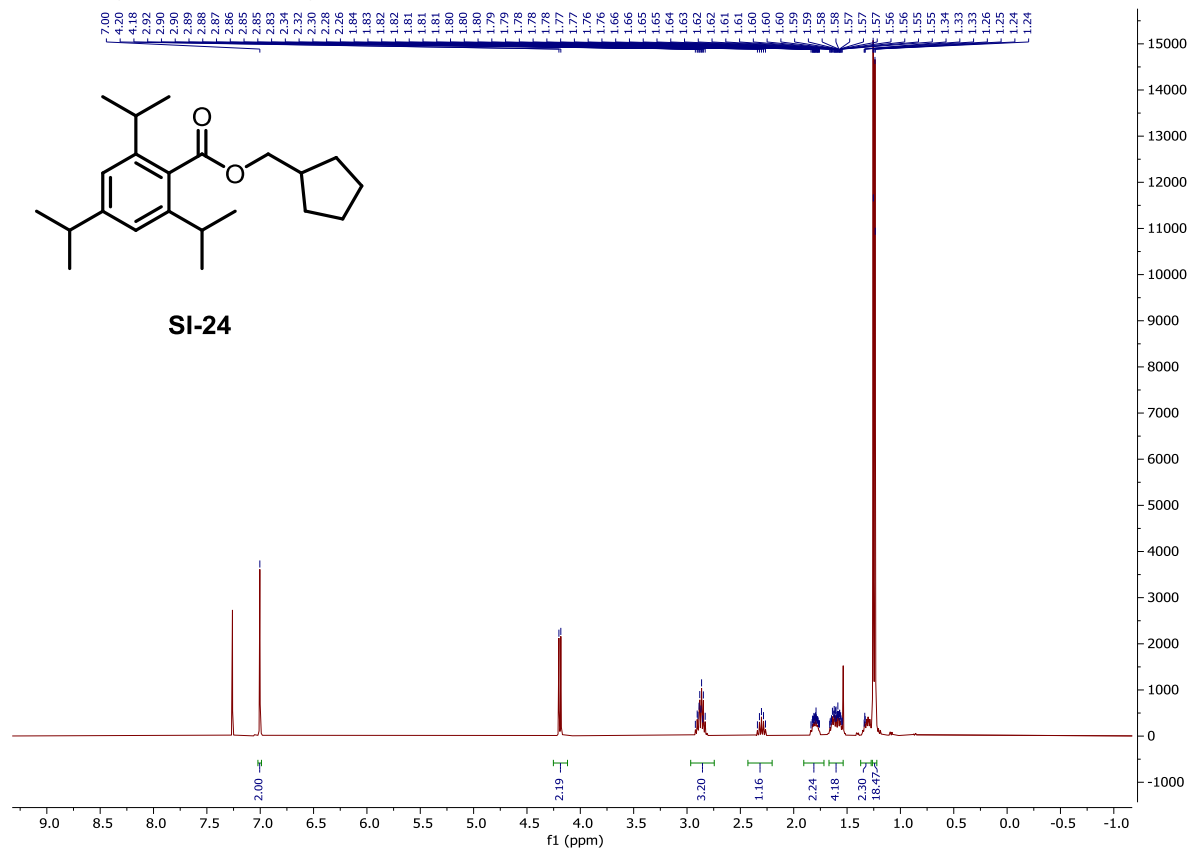
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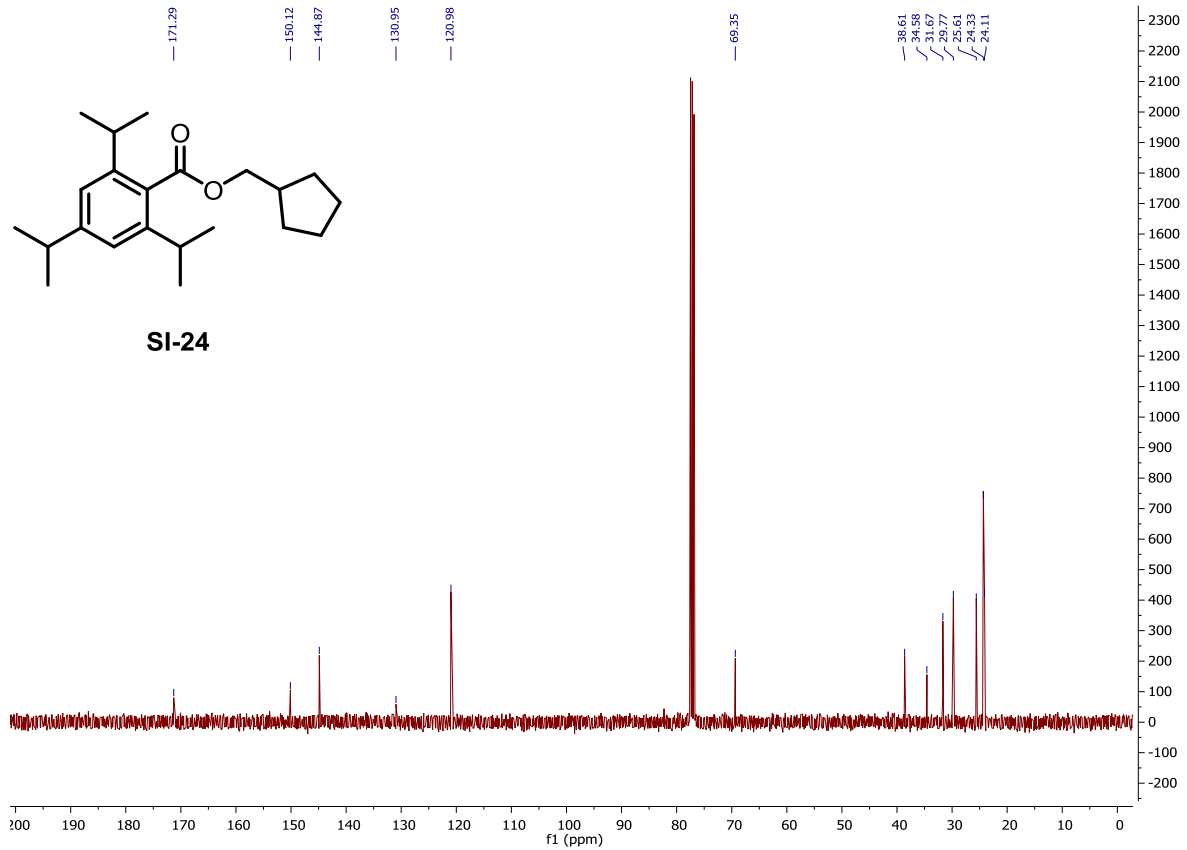
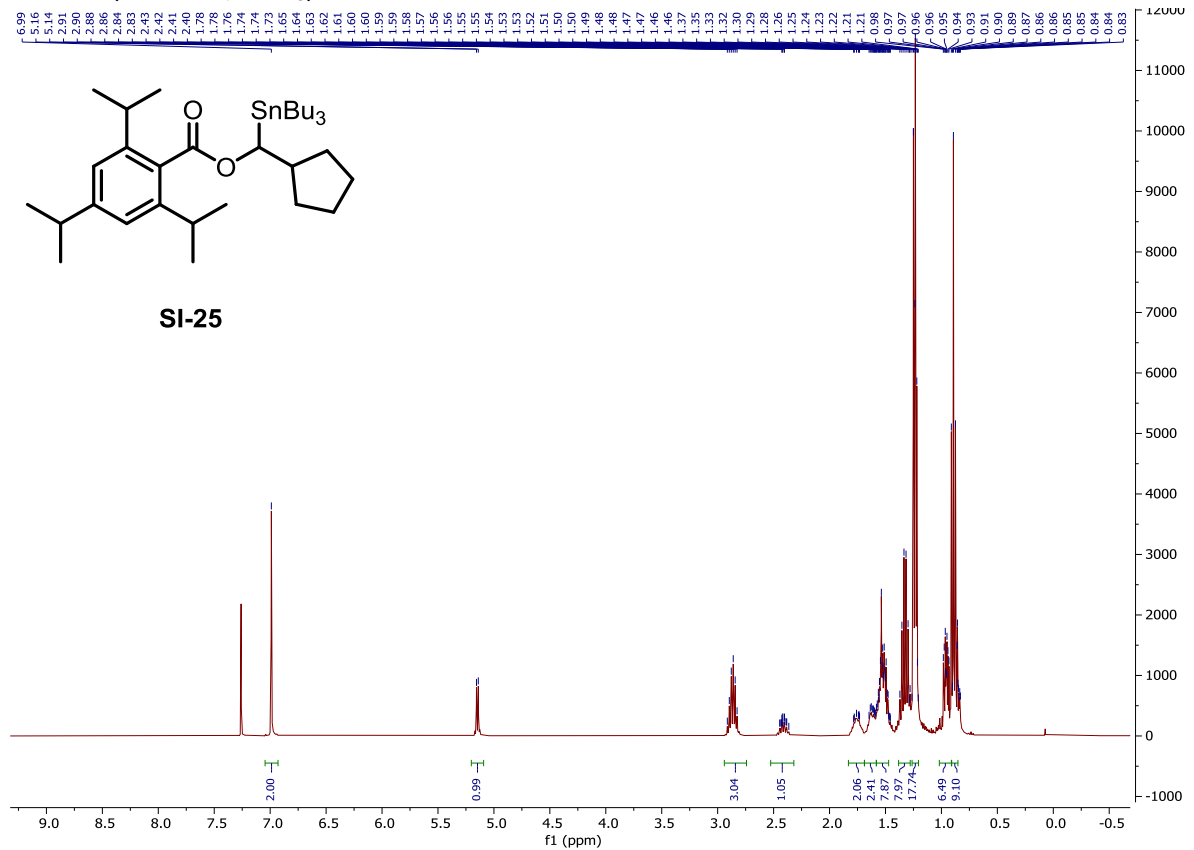
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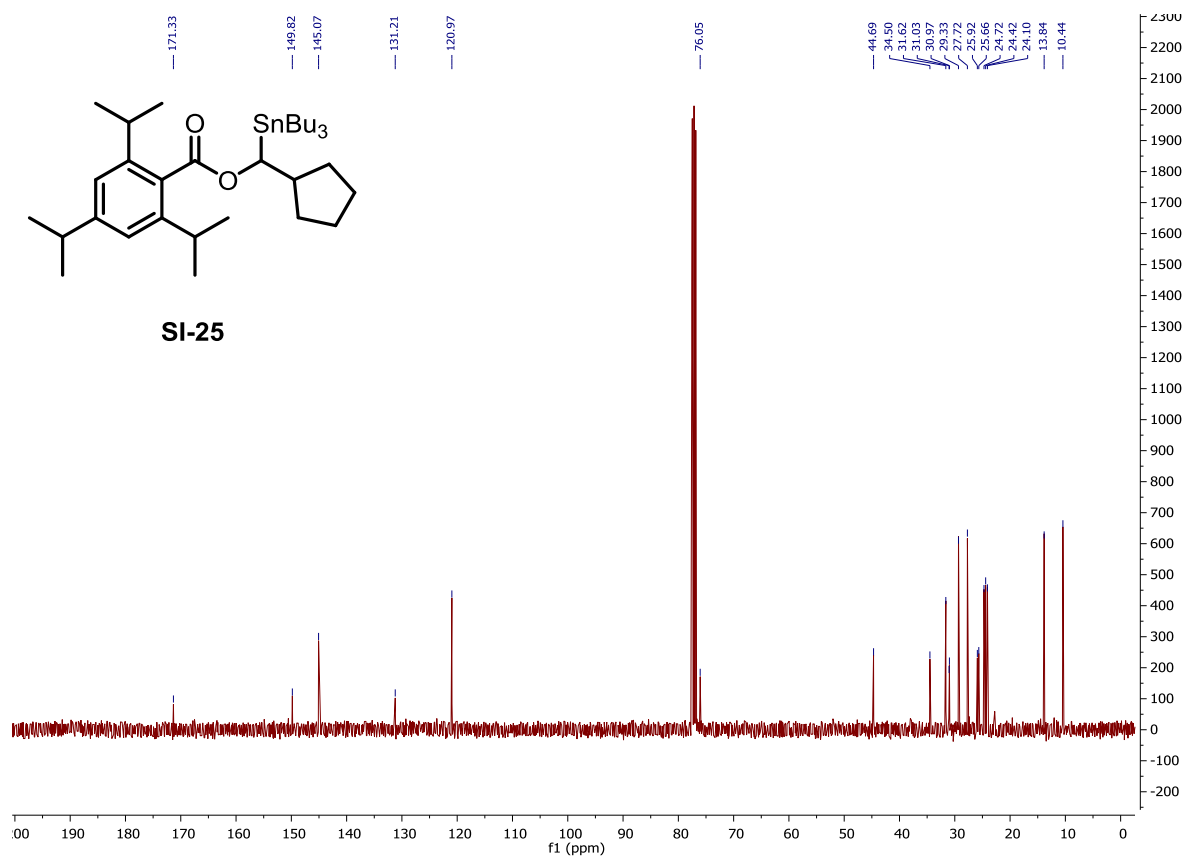
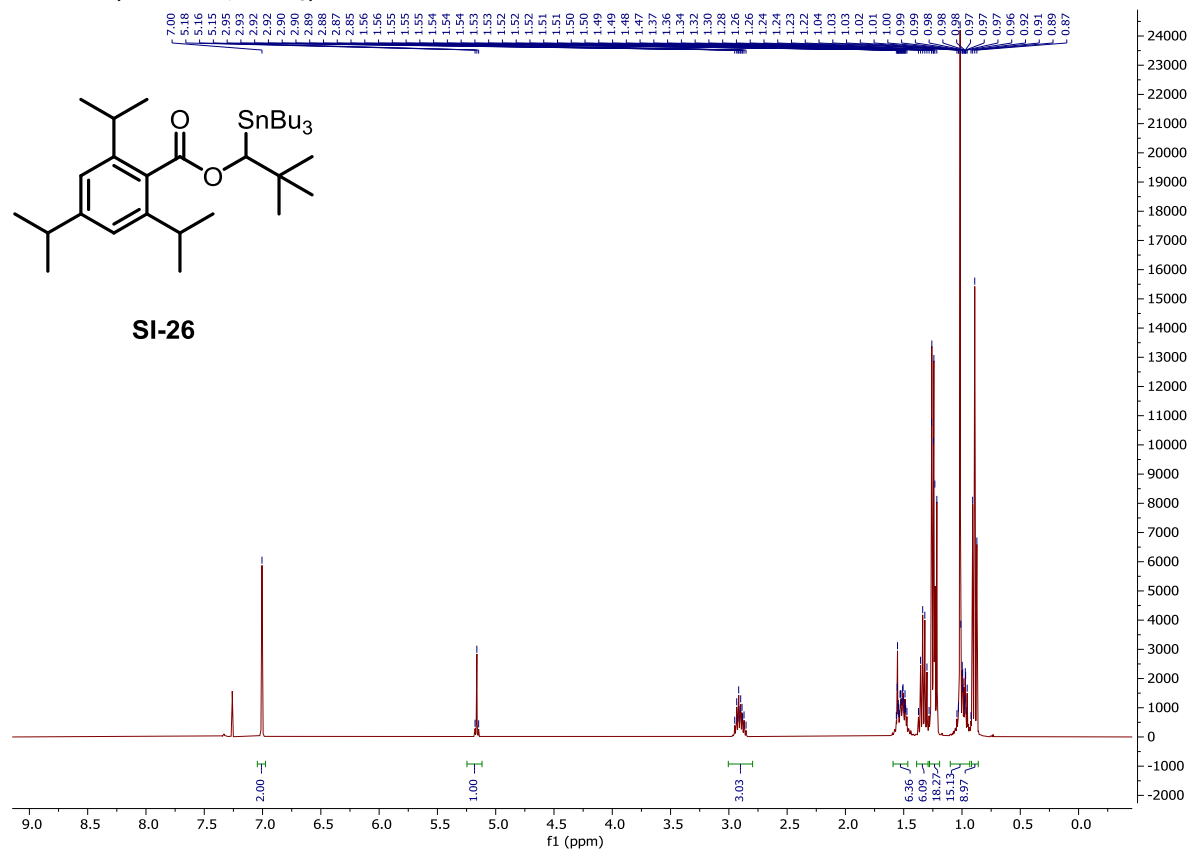
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)

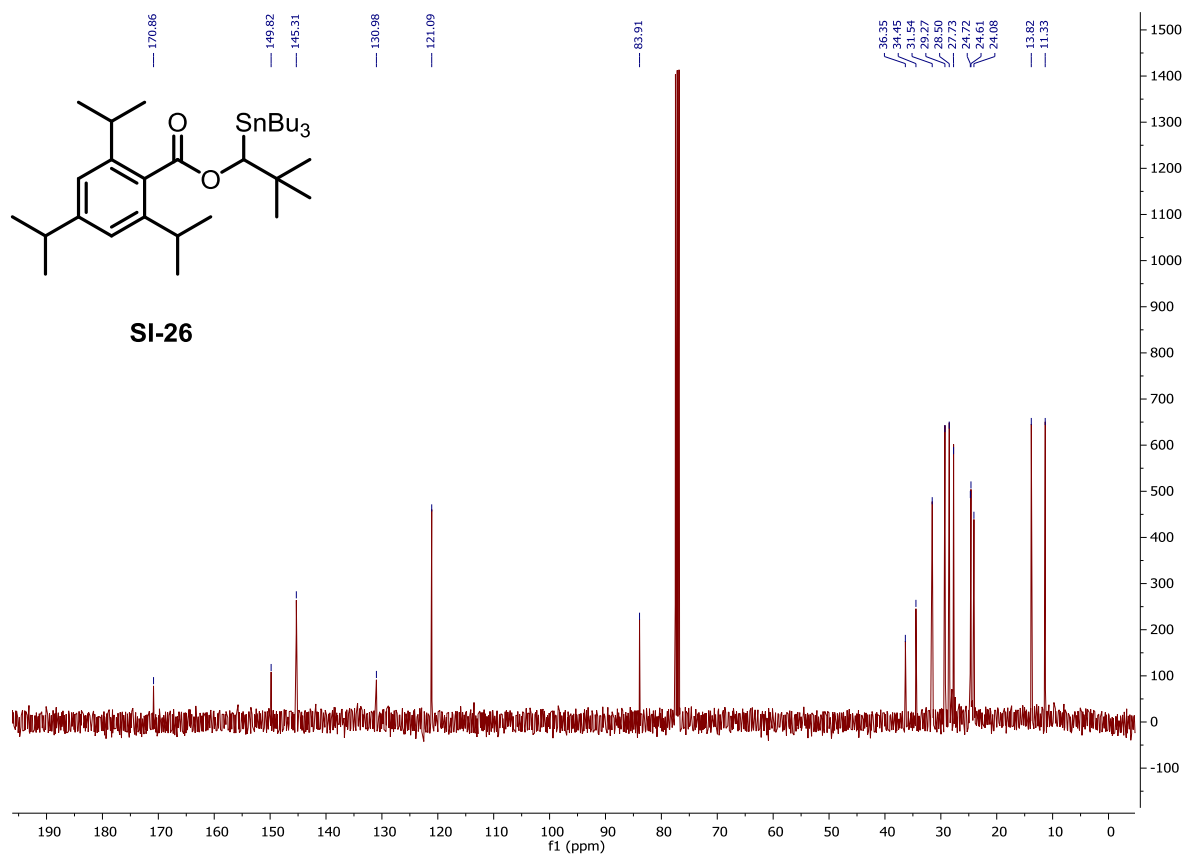
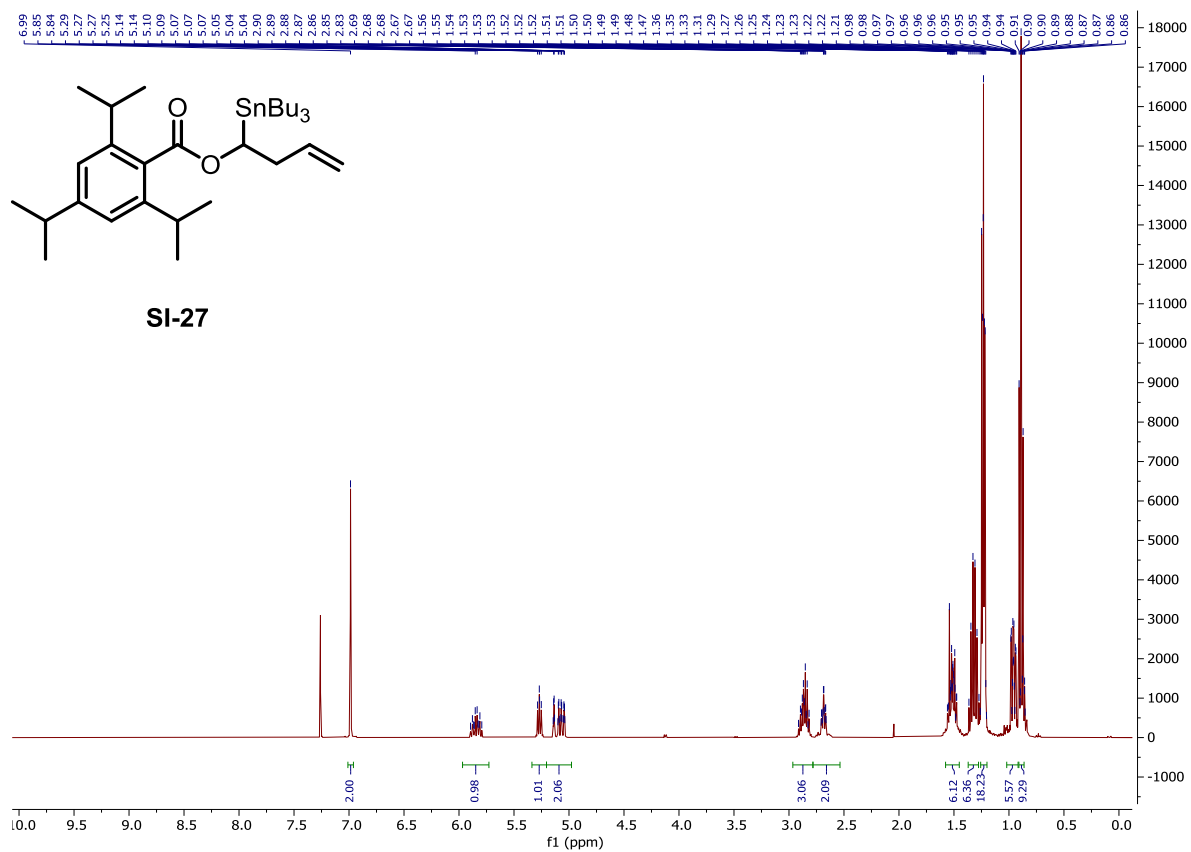
$^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

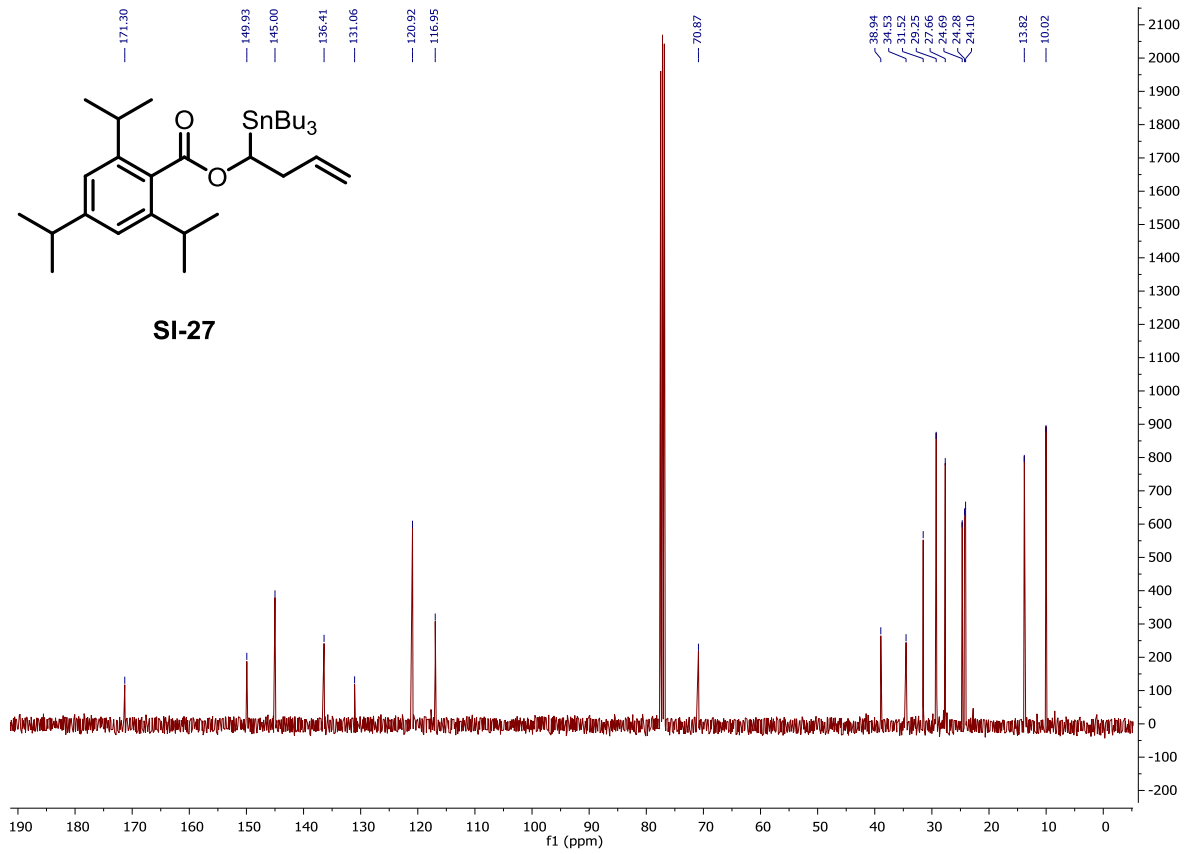
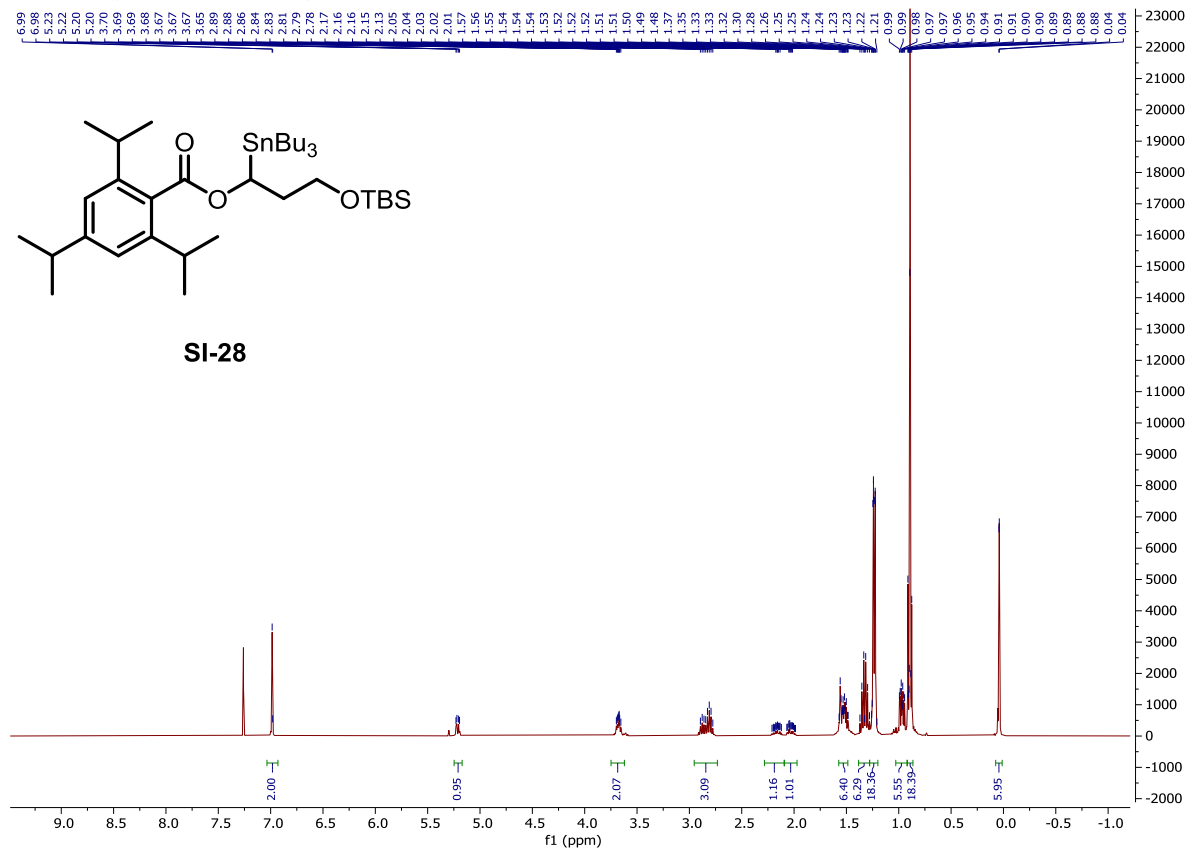
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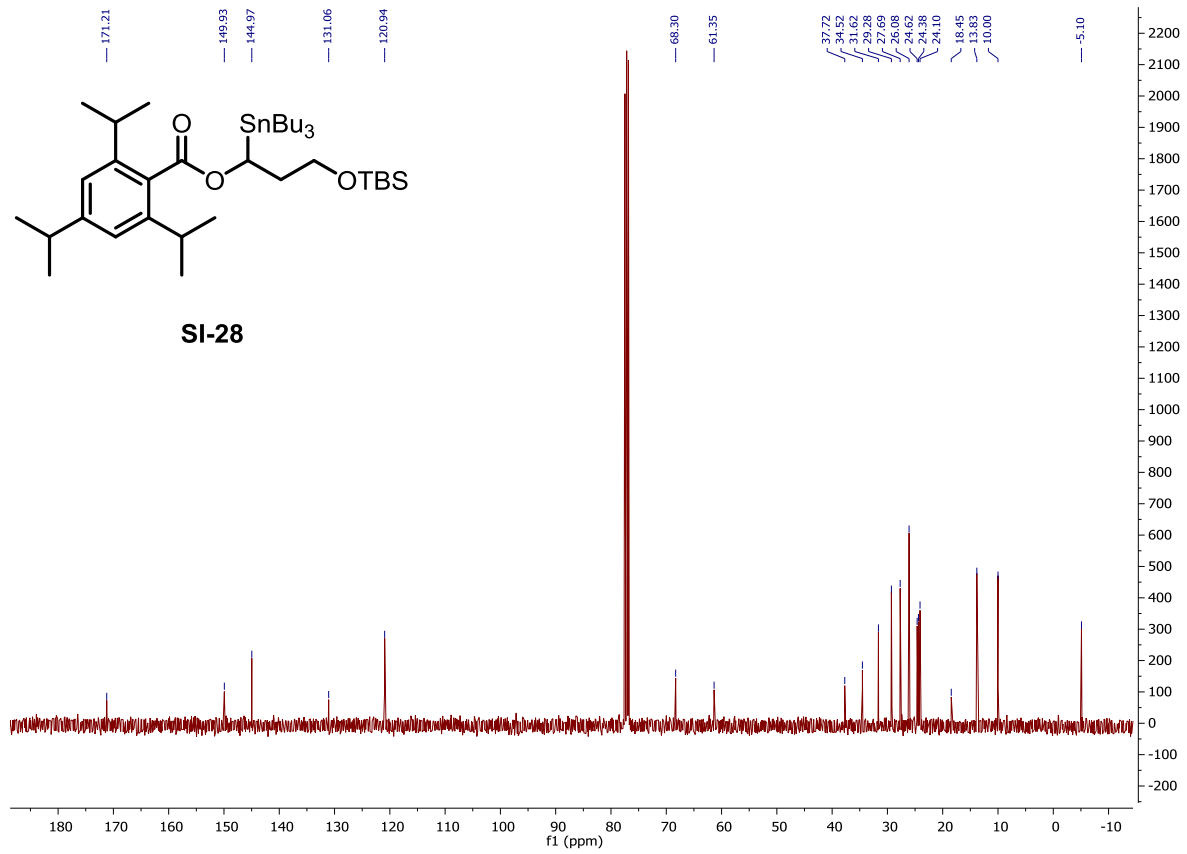
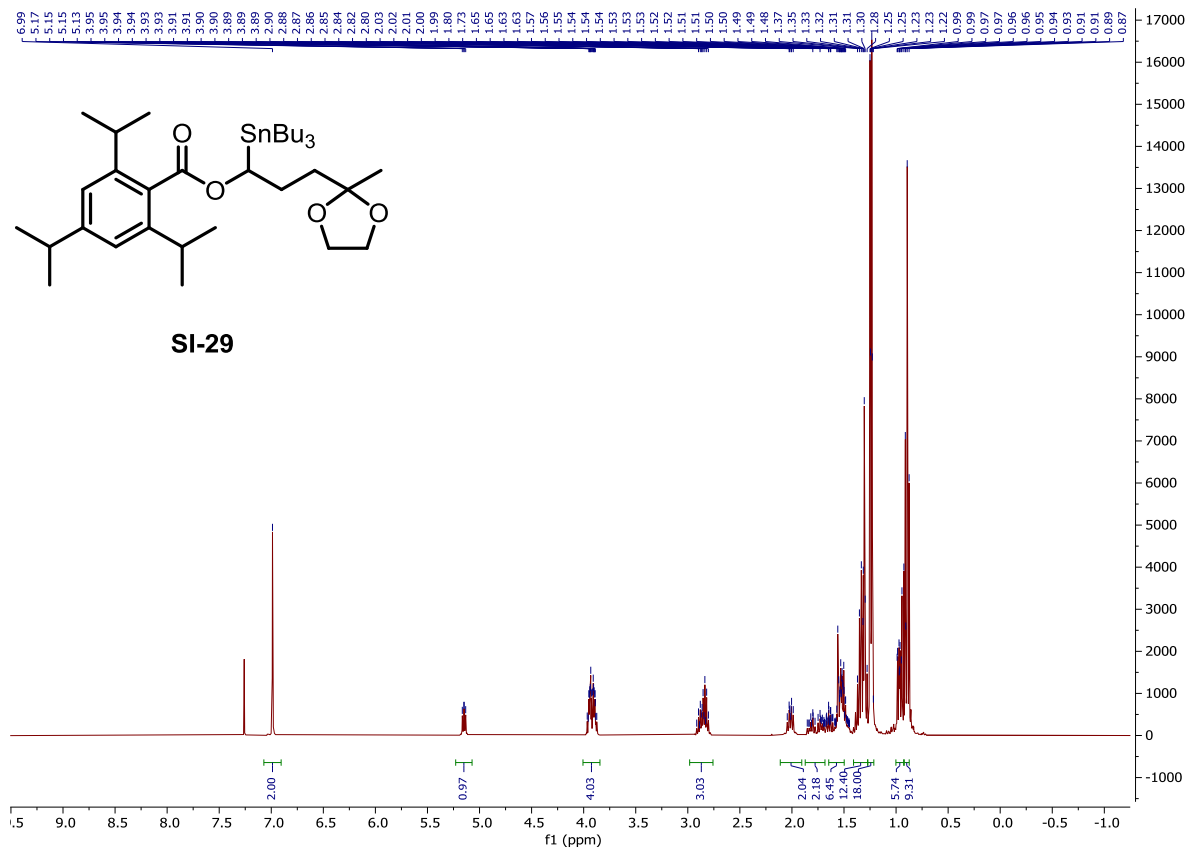
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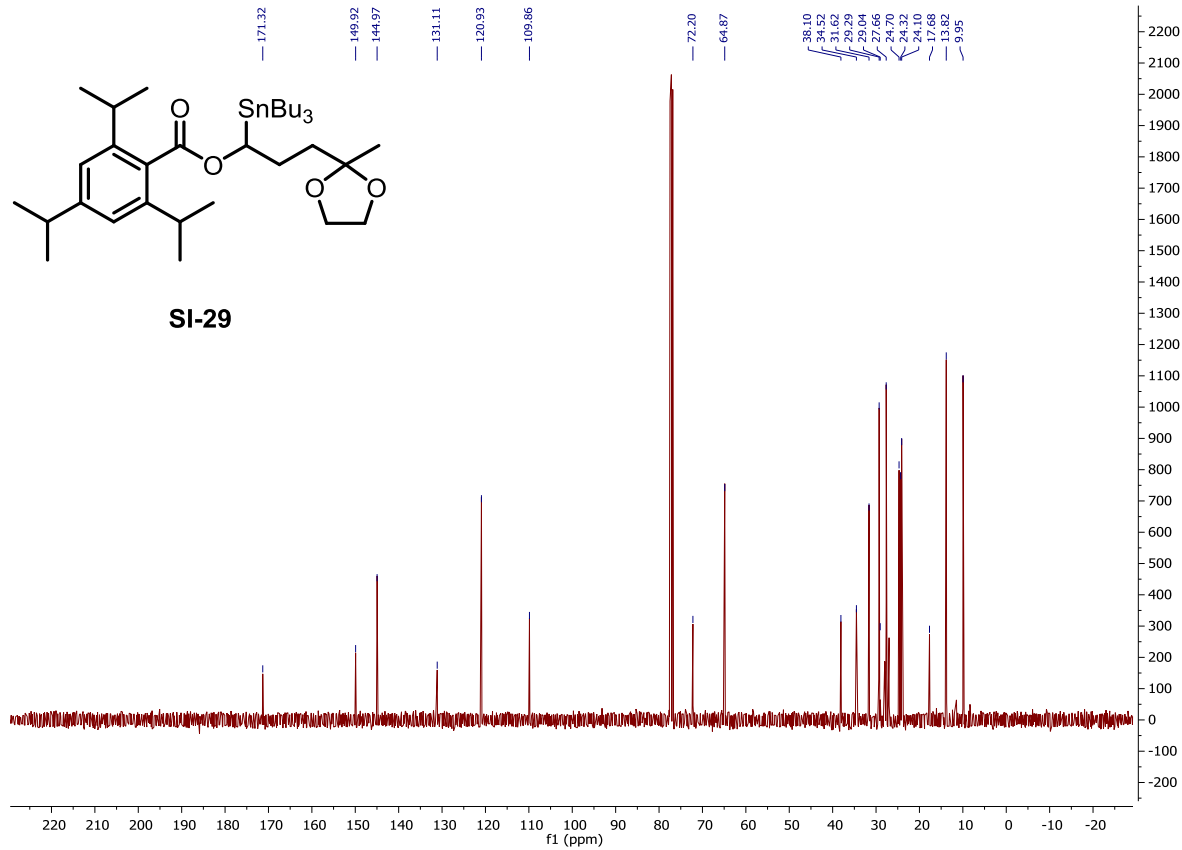
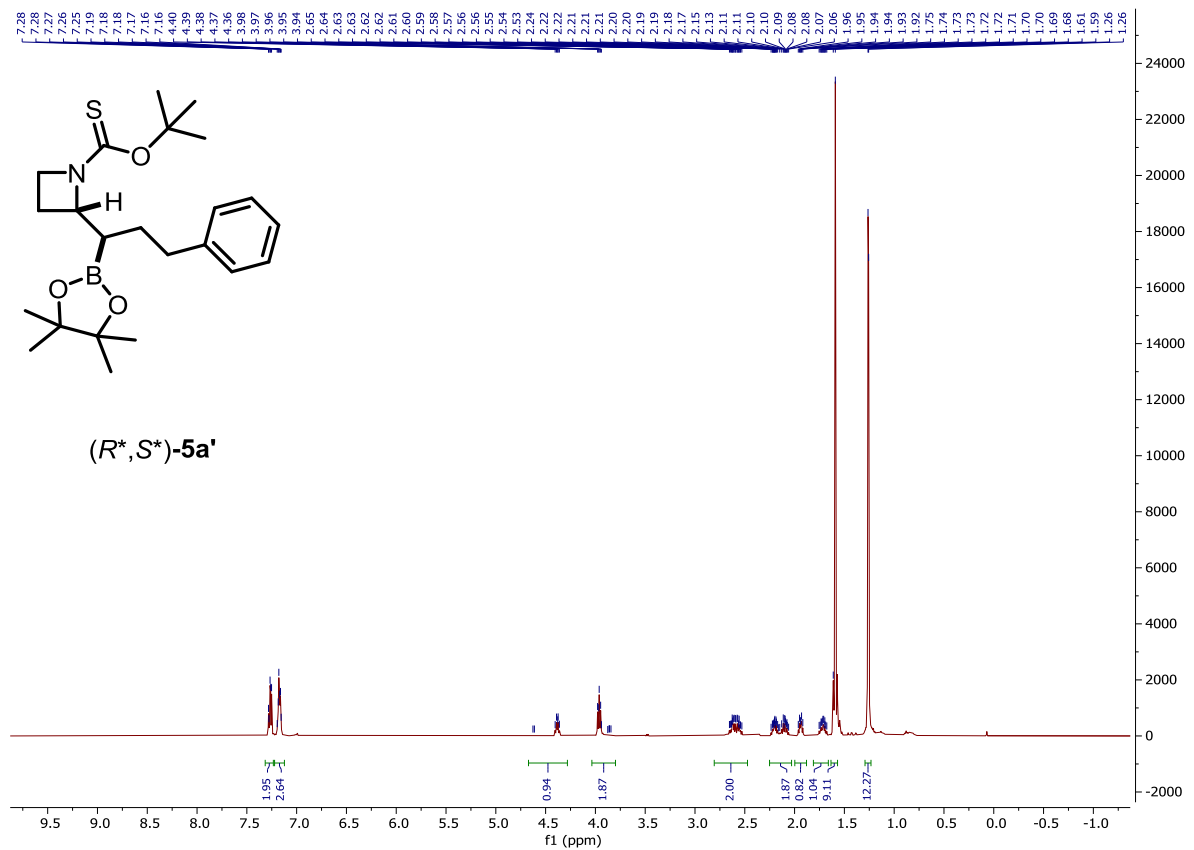
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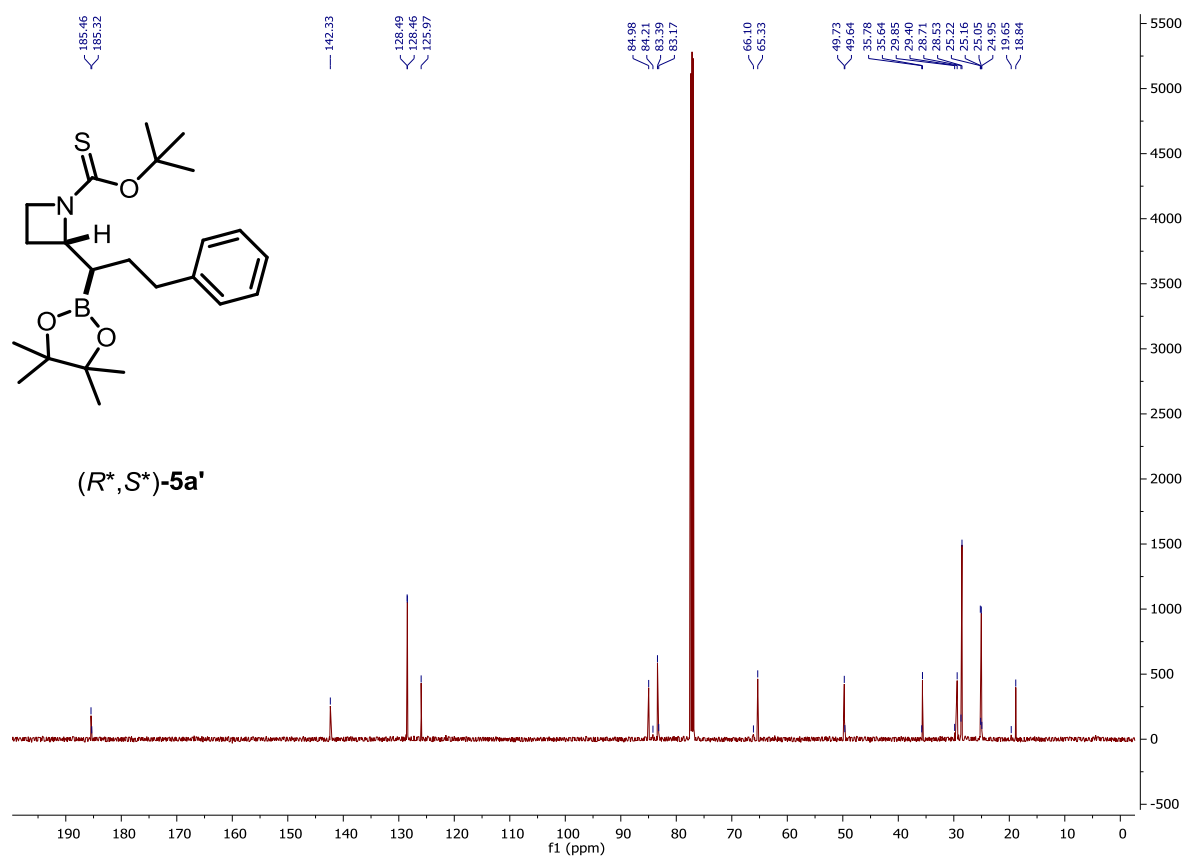
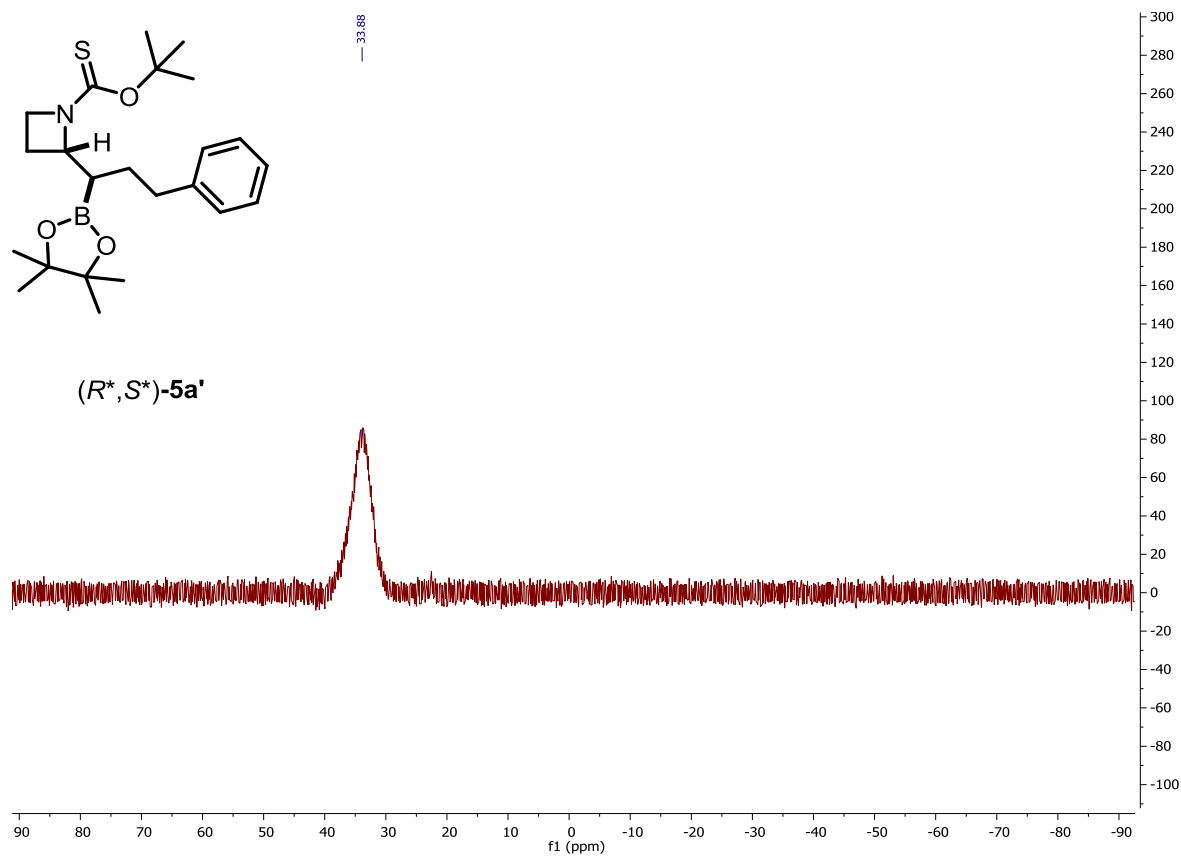
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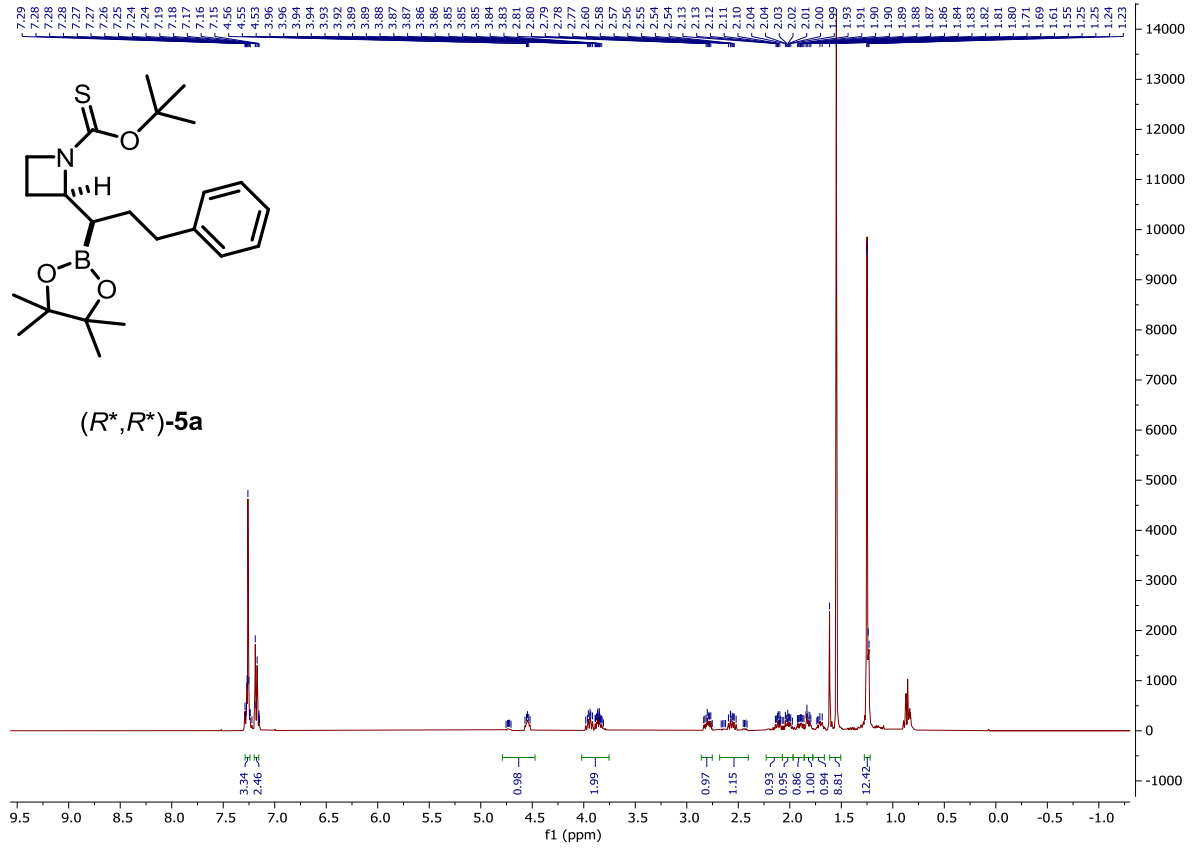
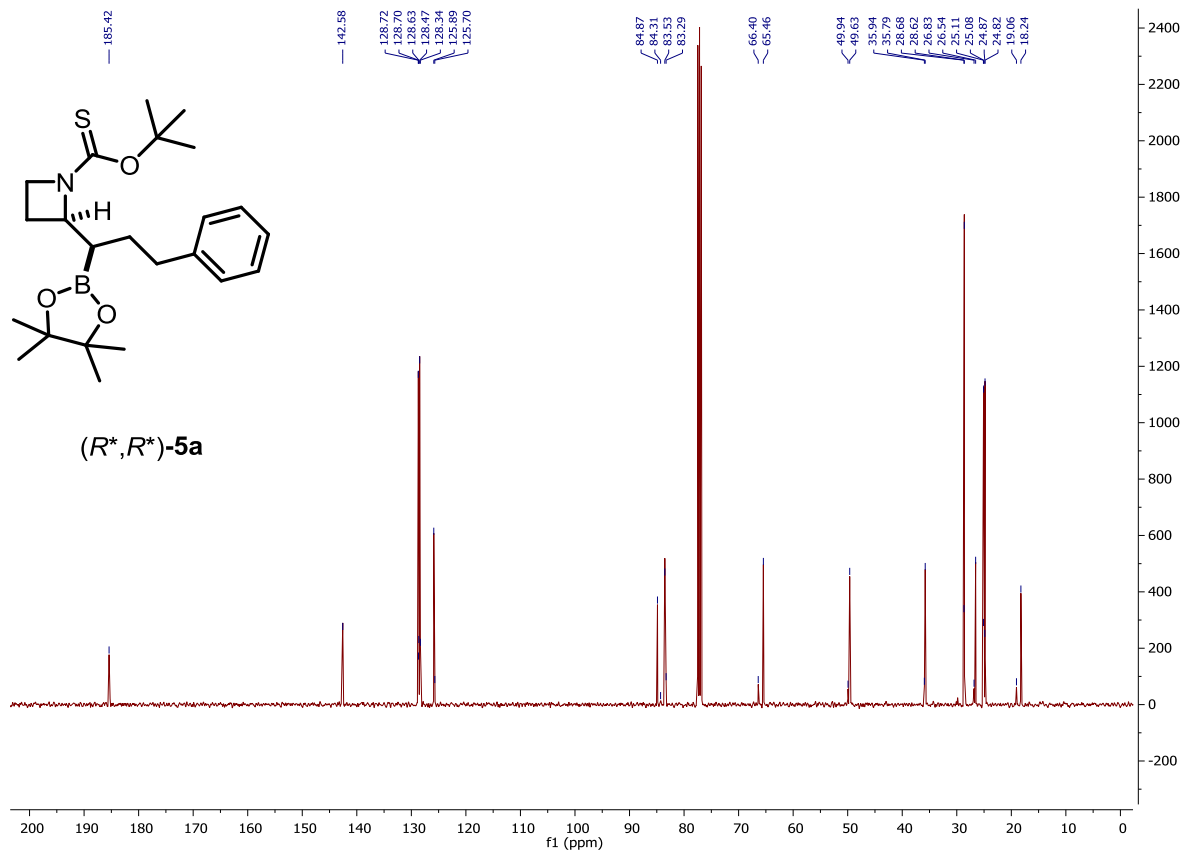
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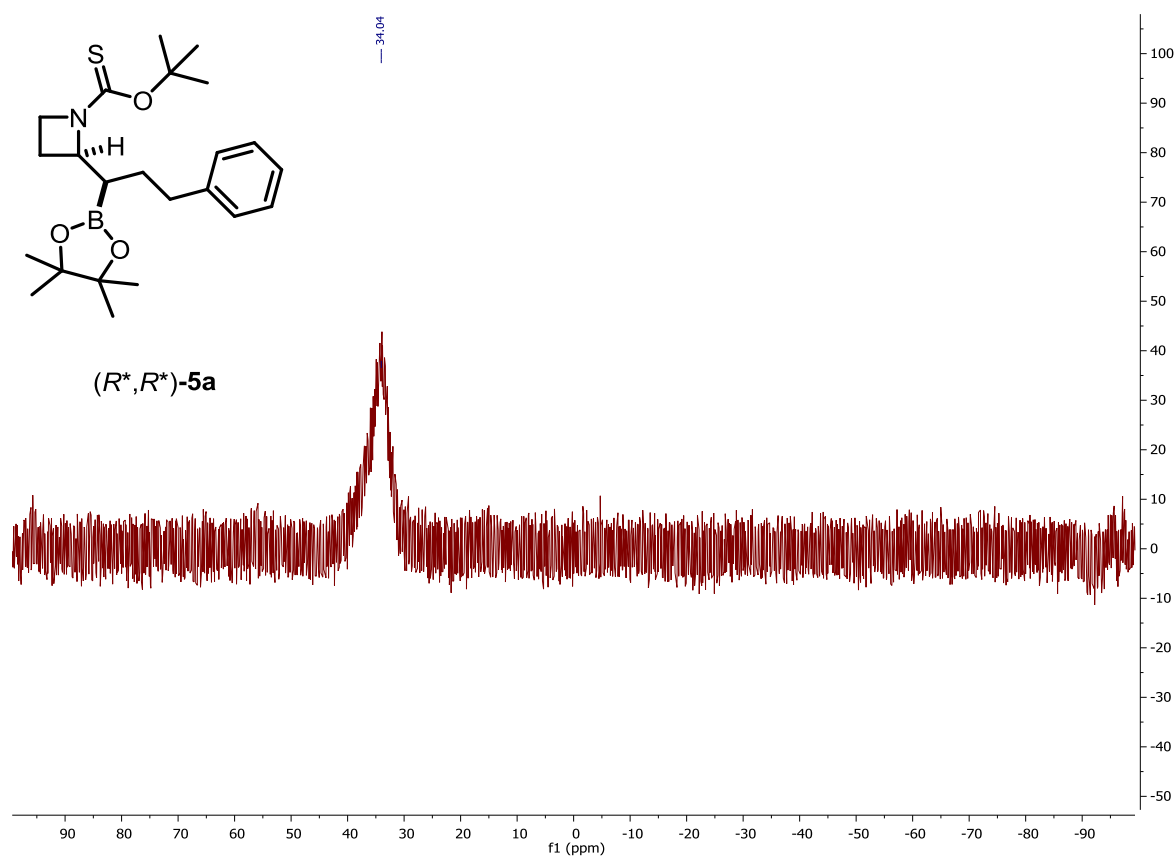
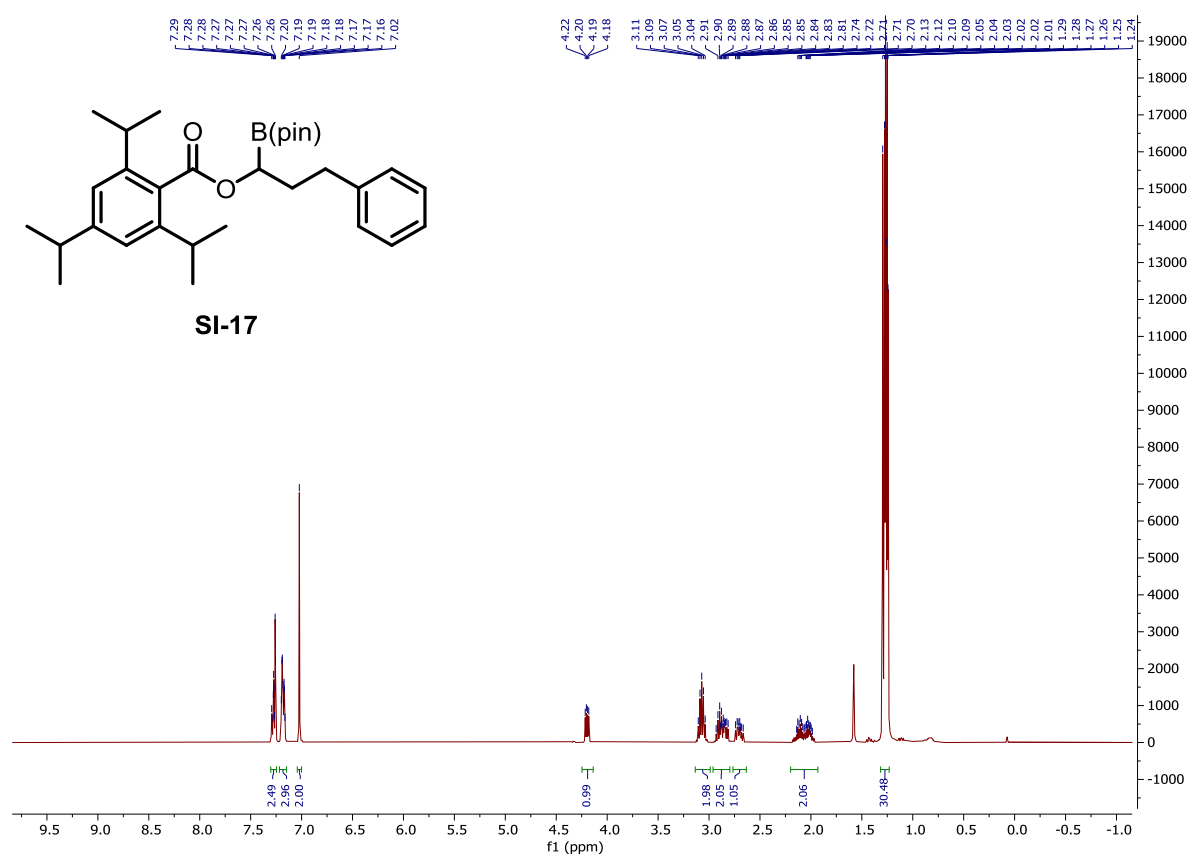
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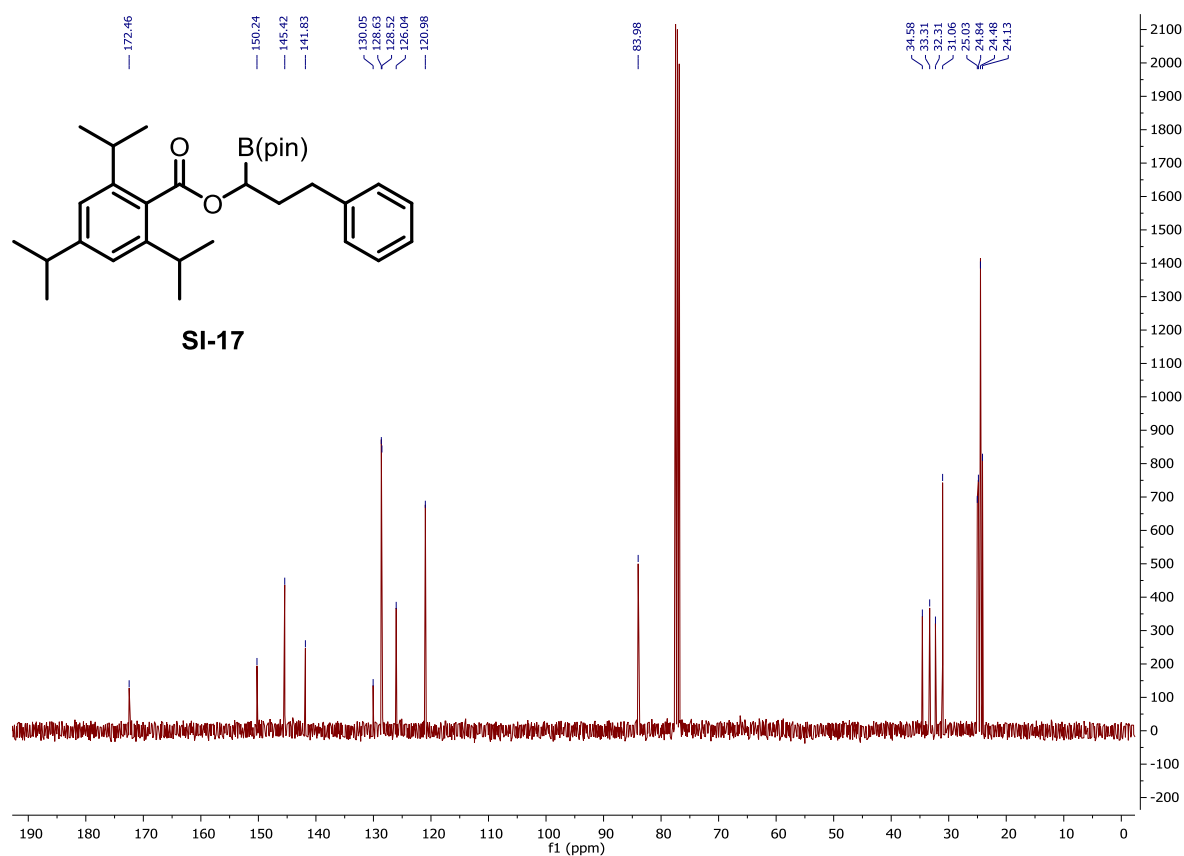
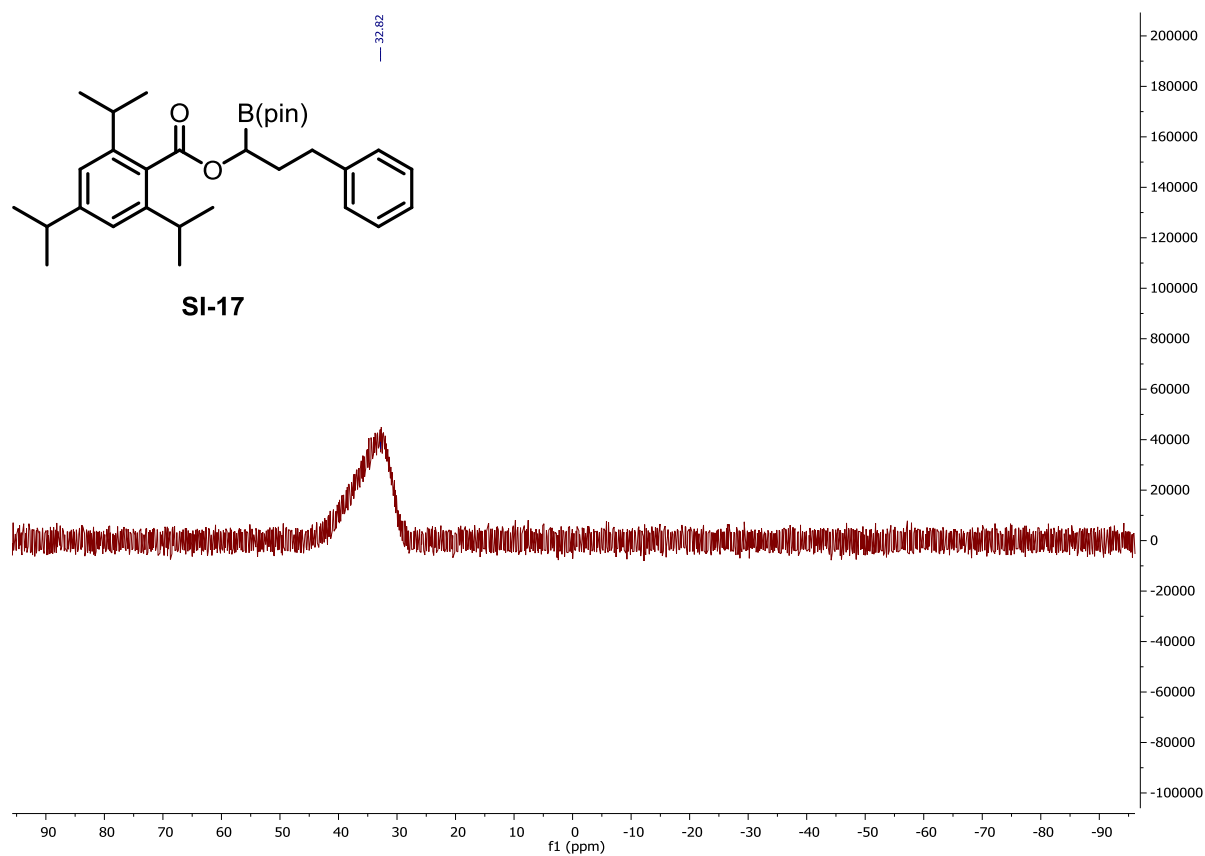
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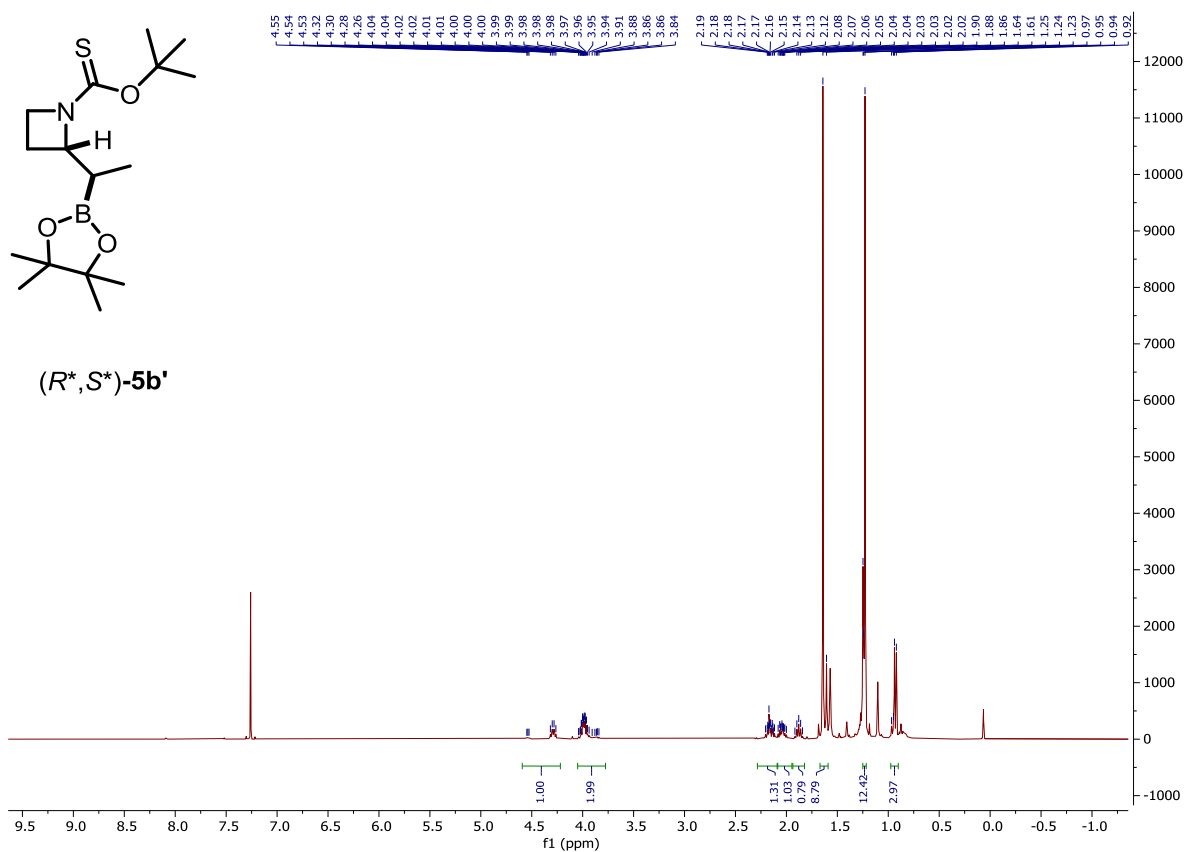
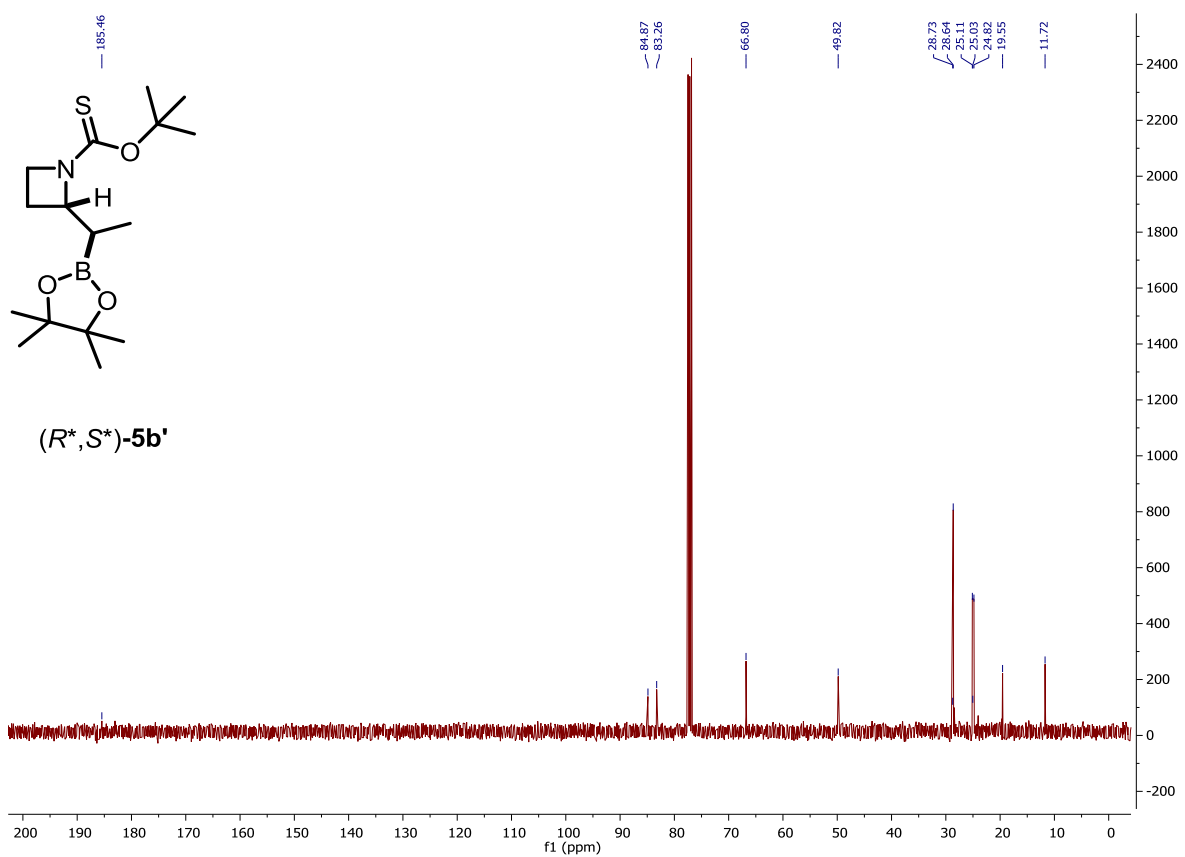
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$^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) $^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ )

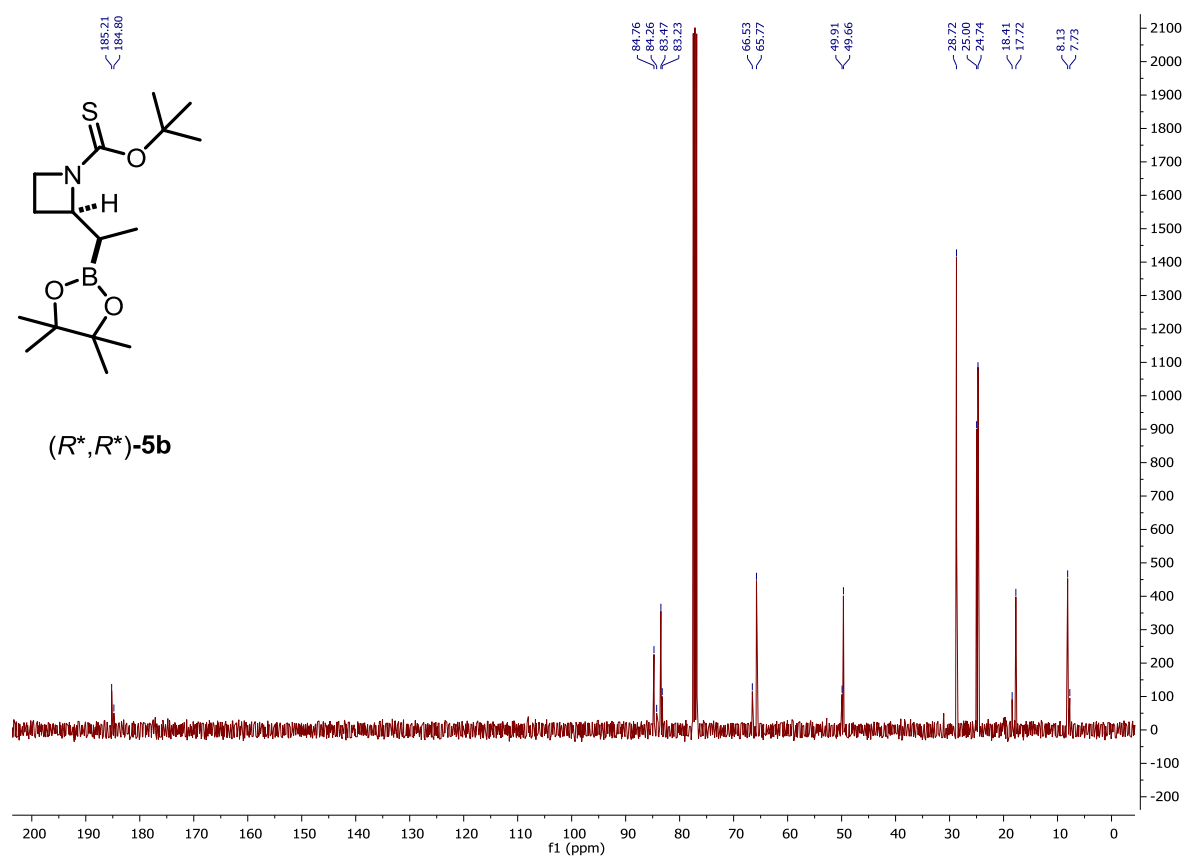
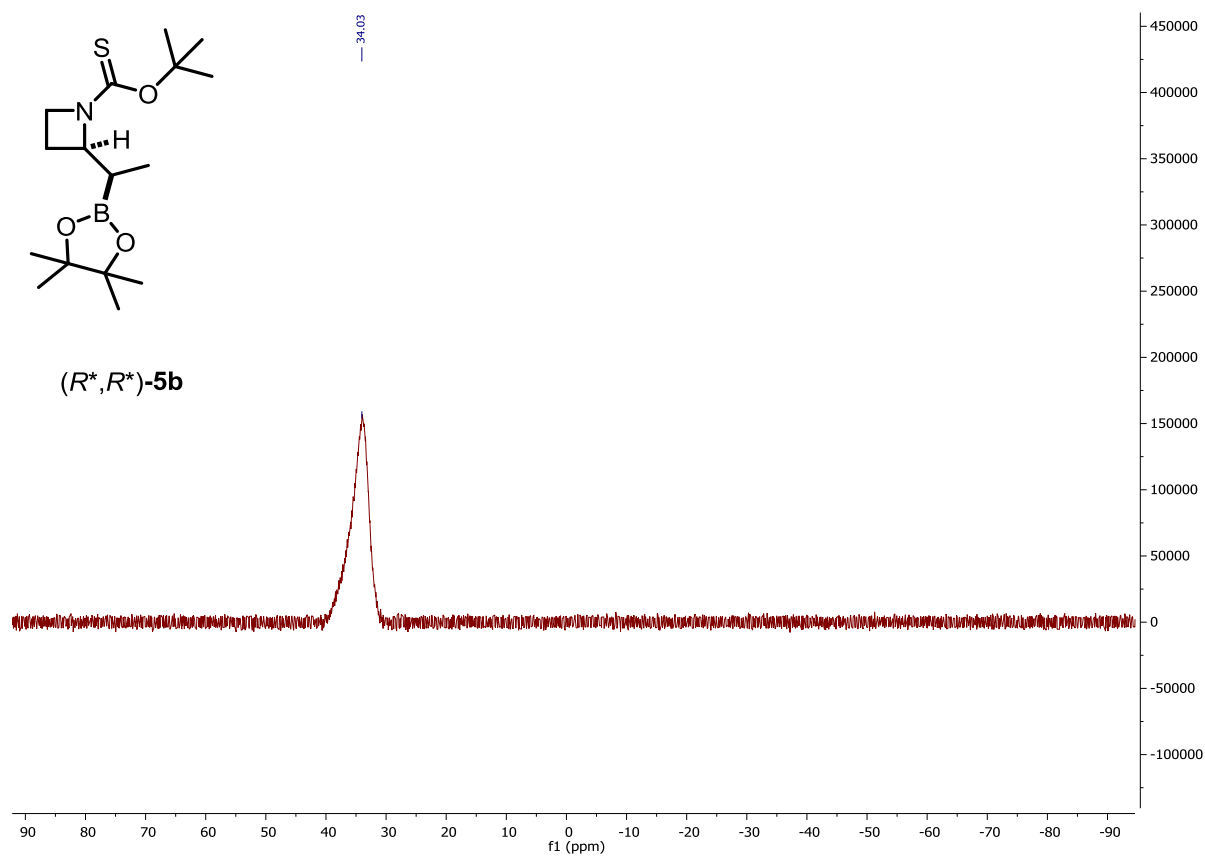
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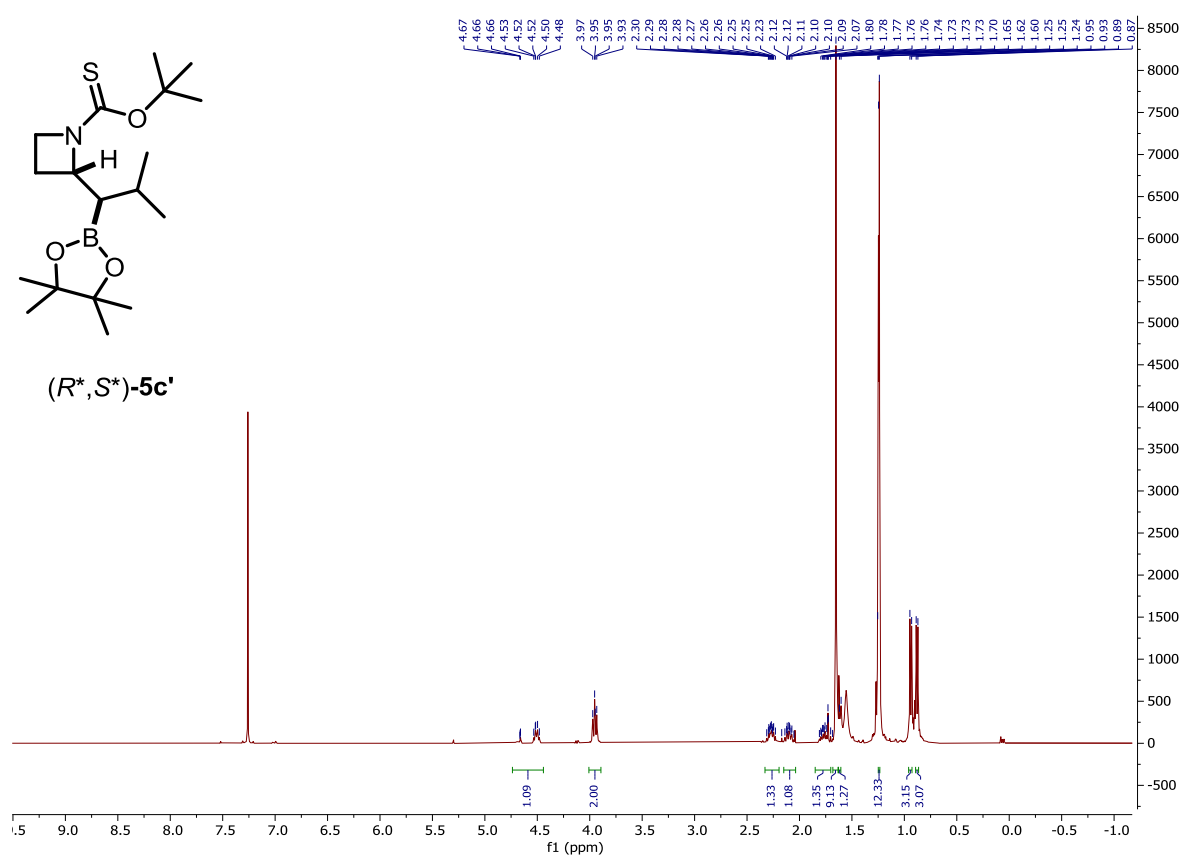
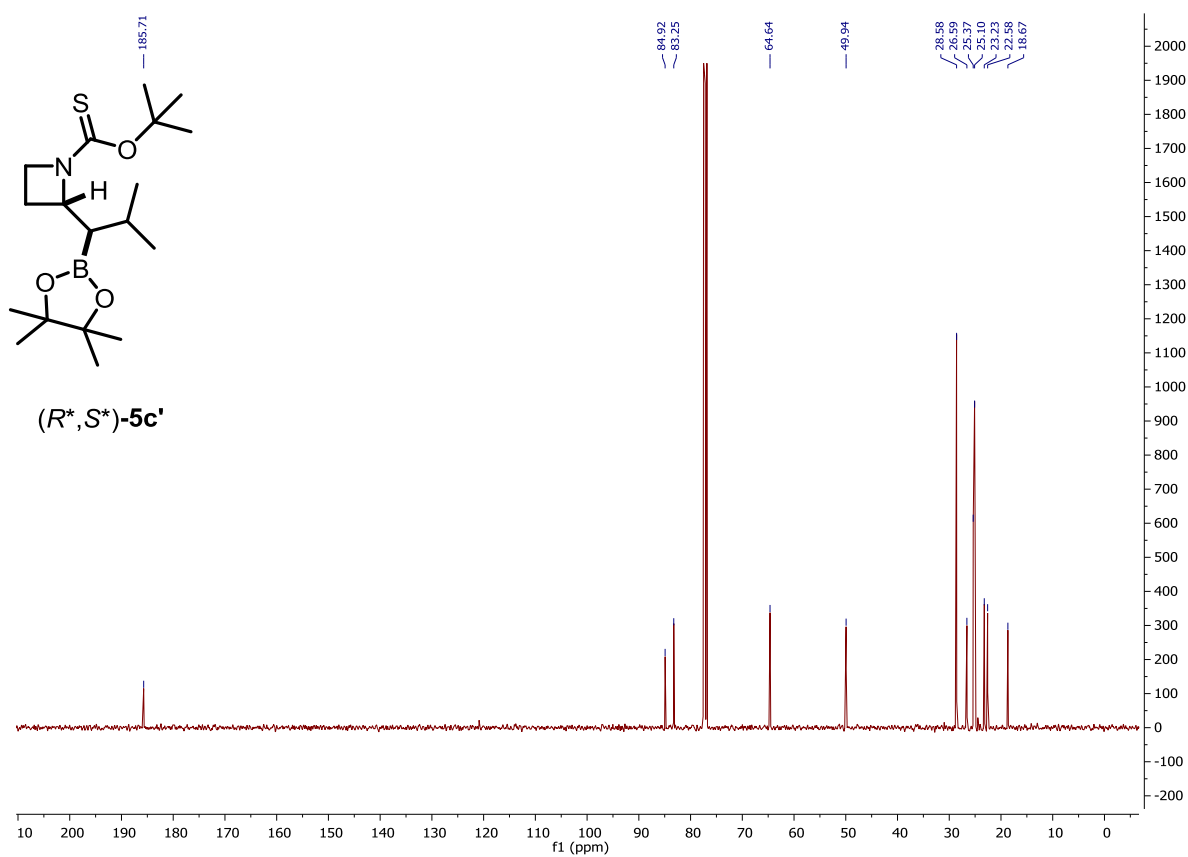
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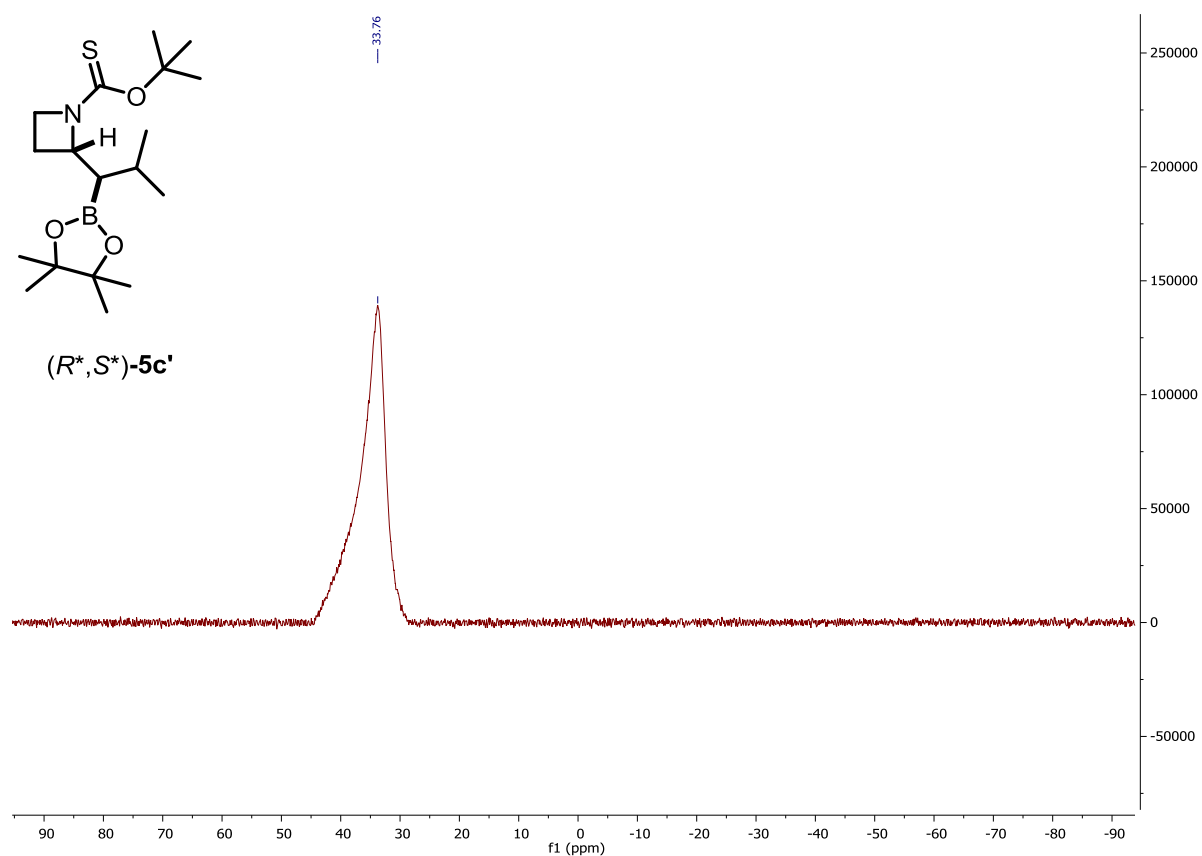
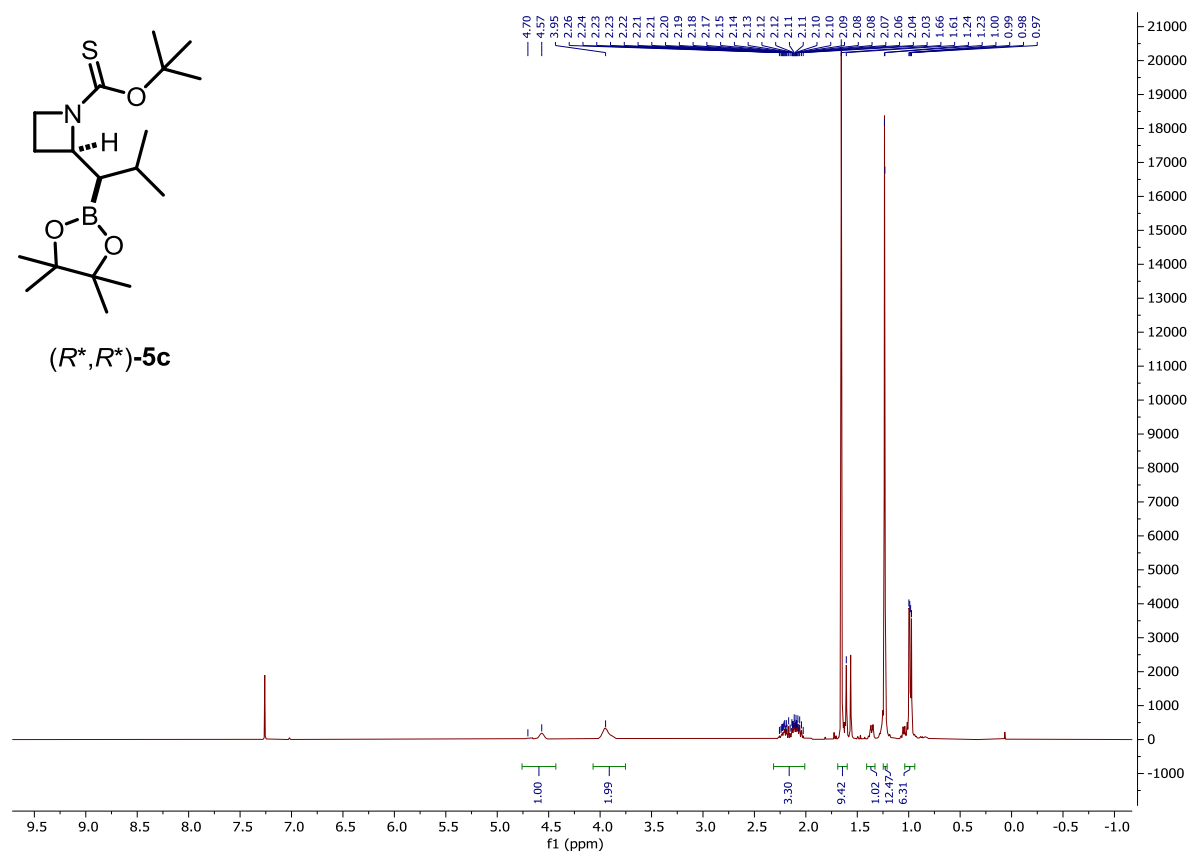
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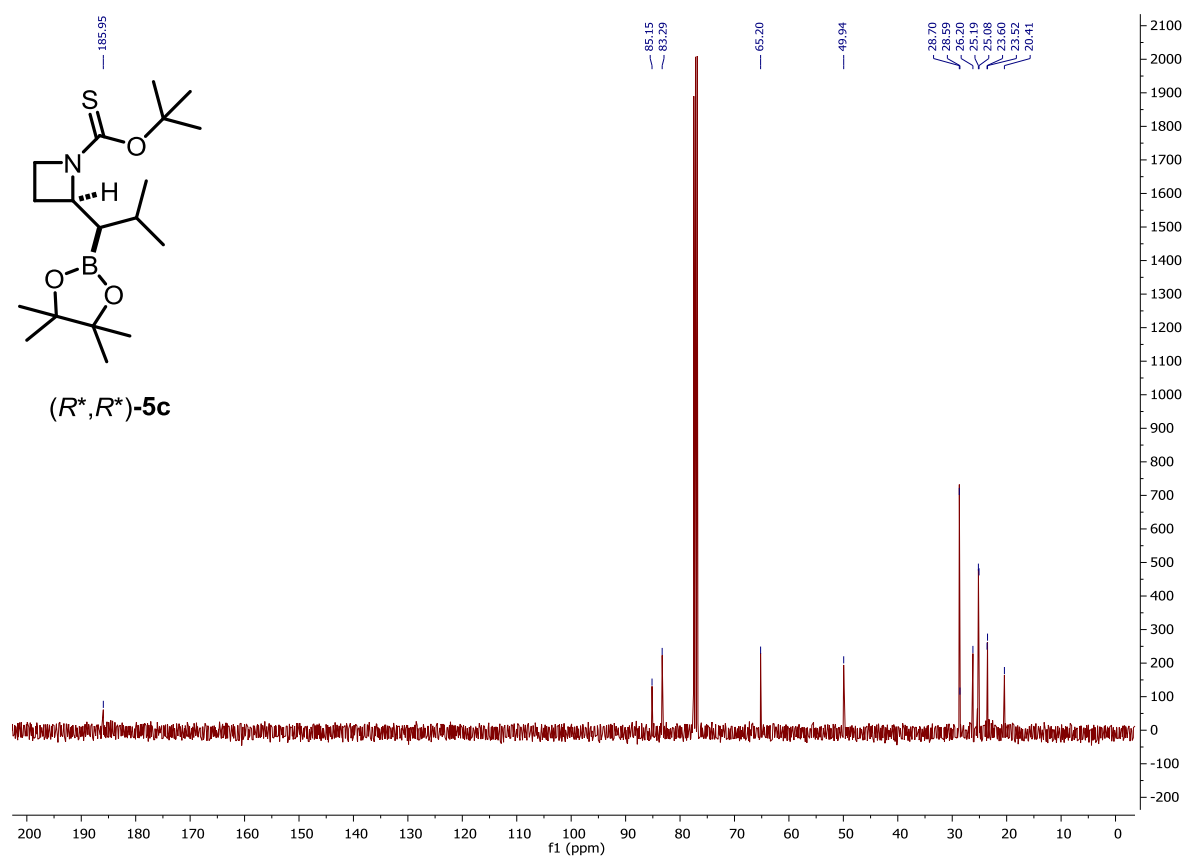
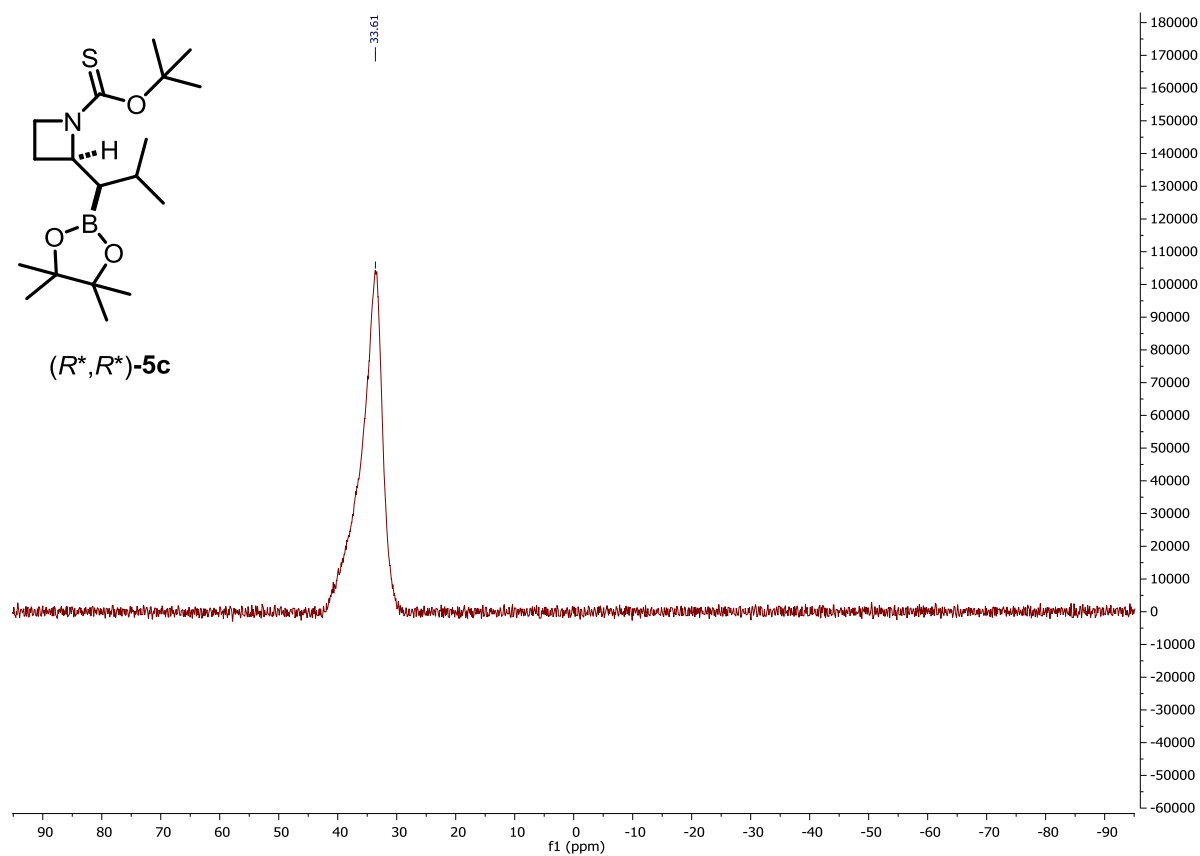
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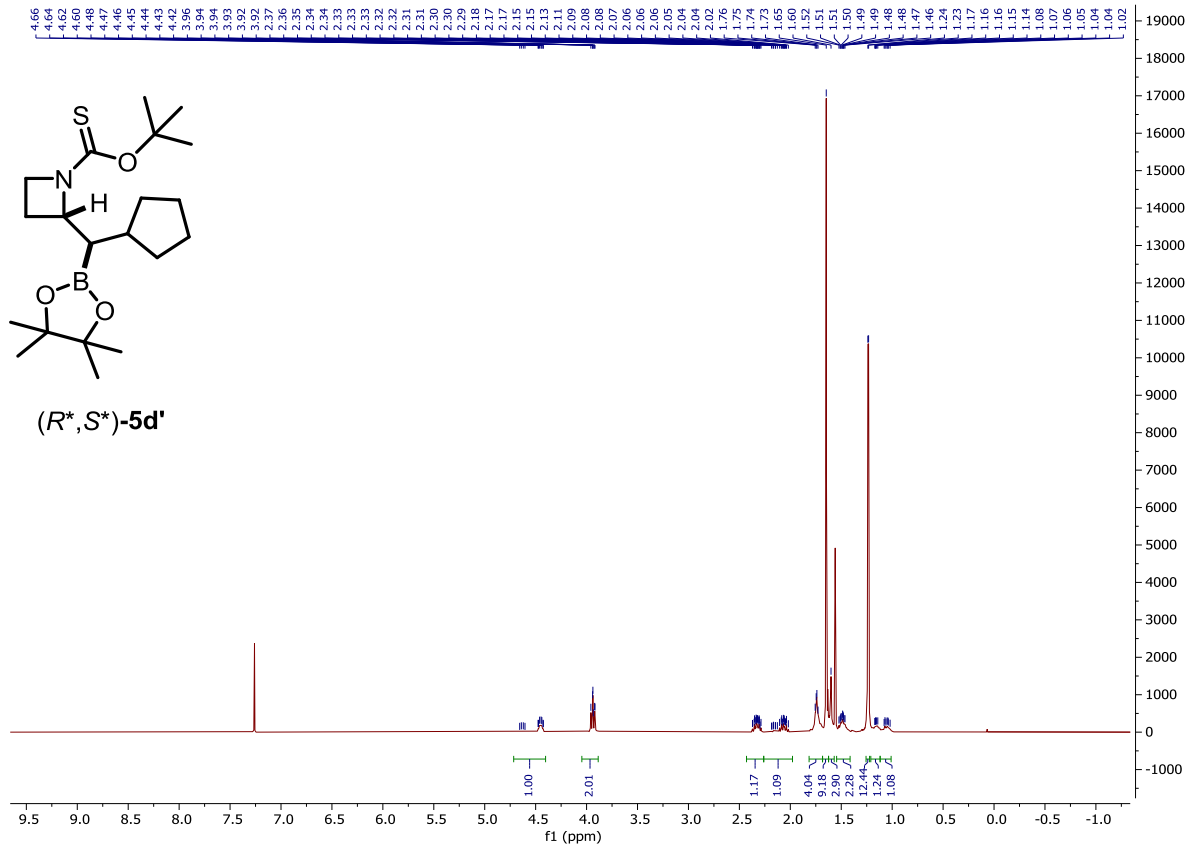
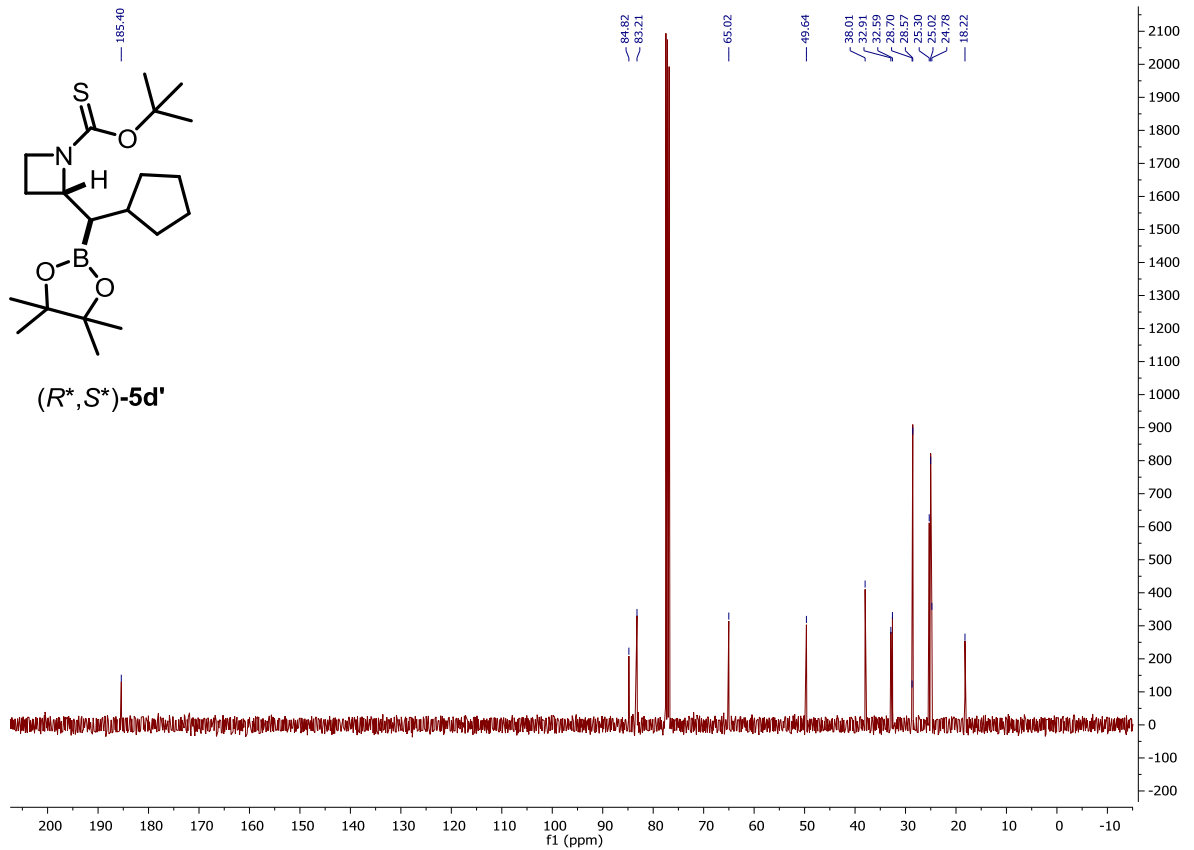


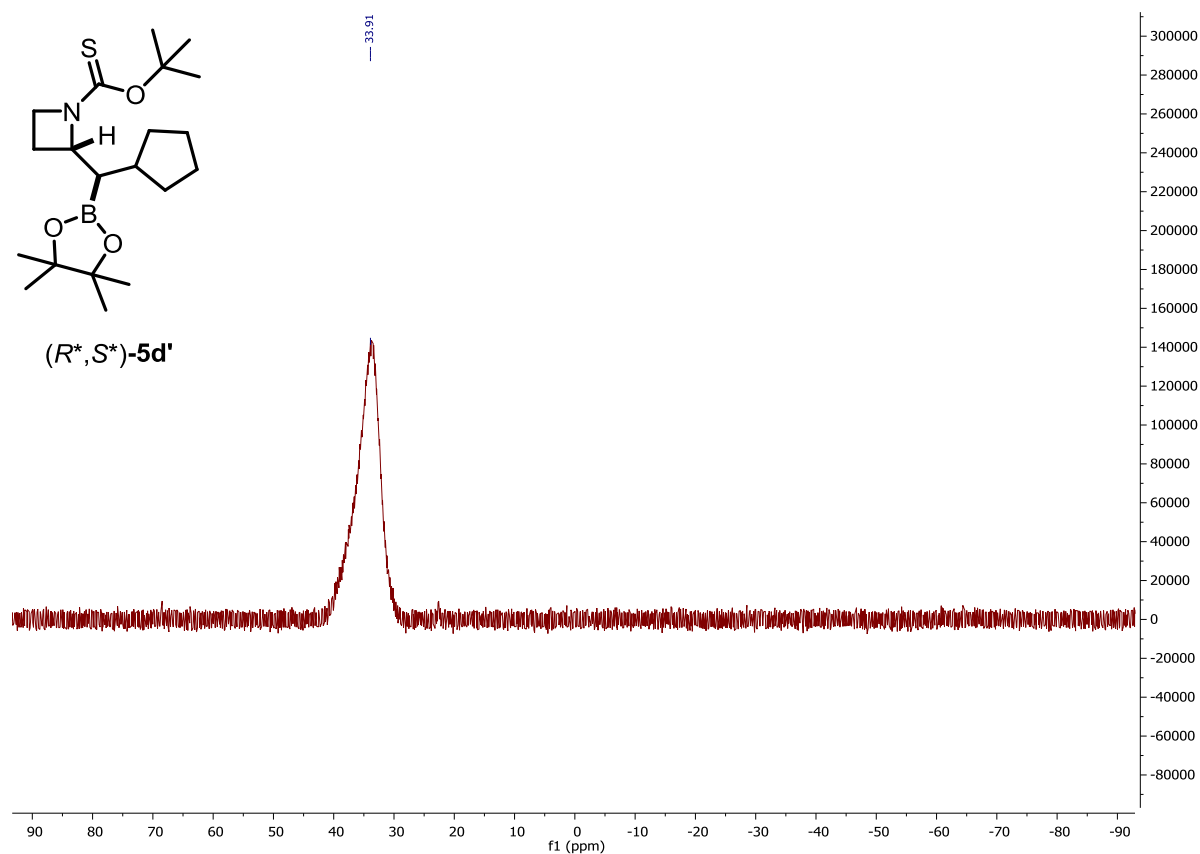
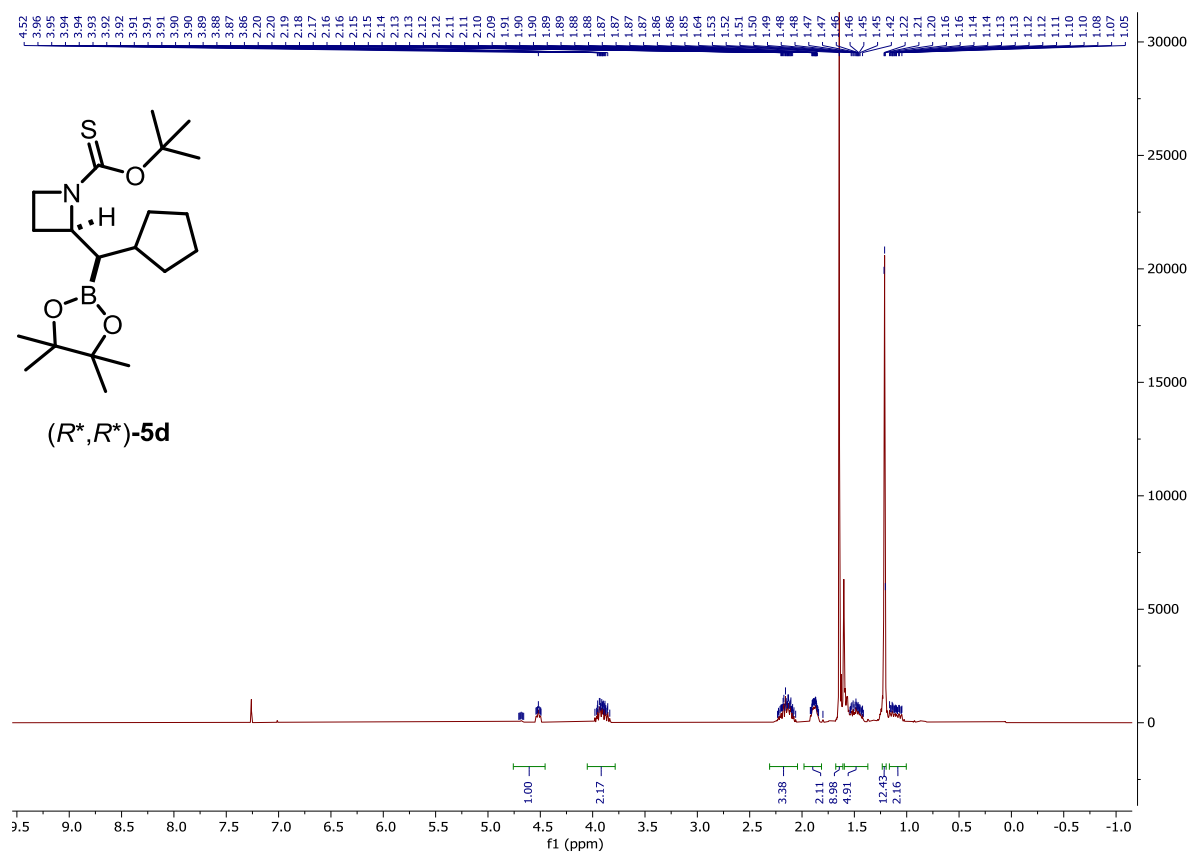
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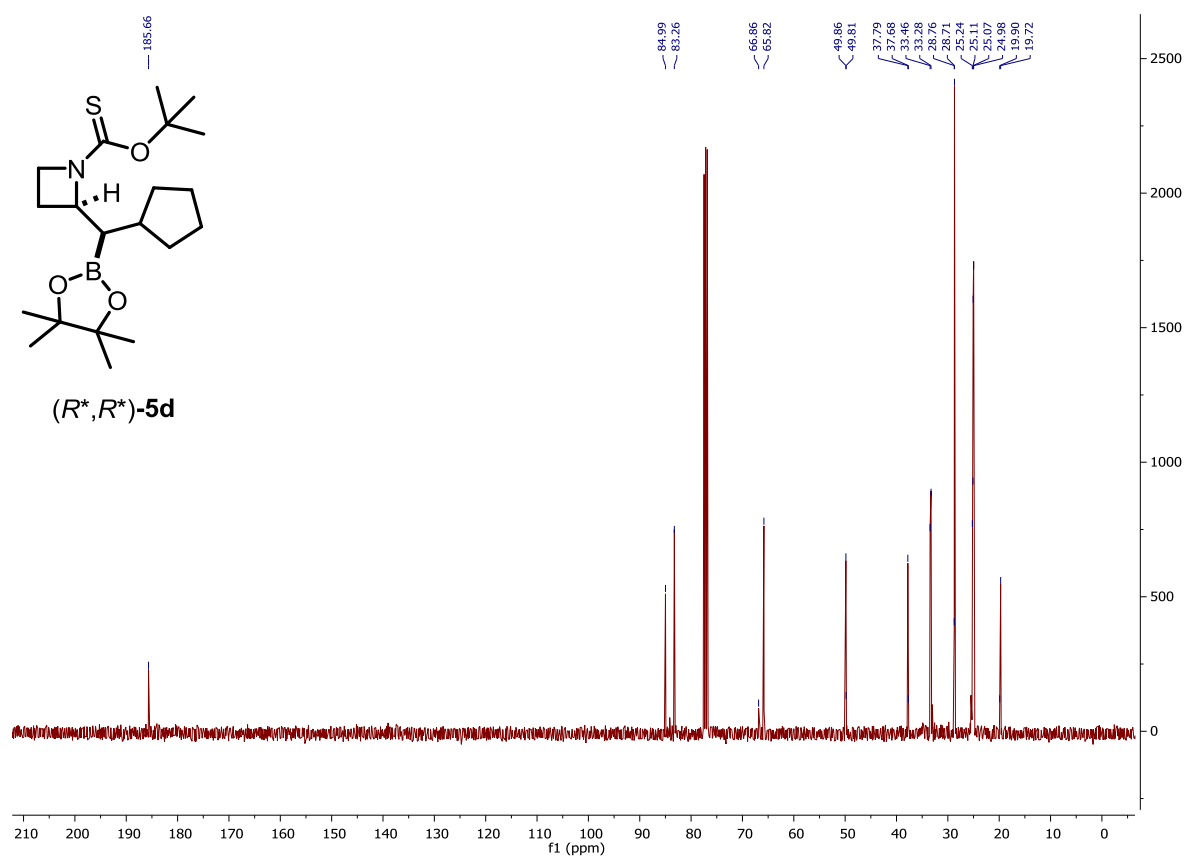
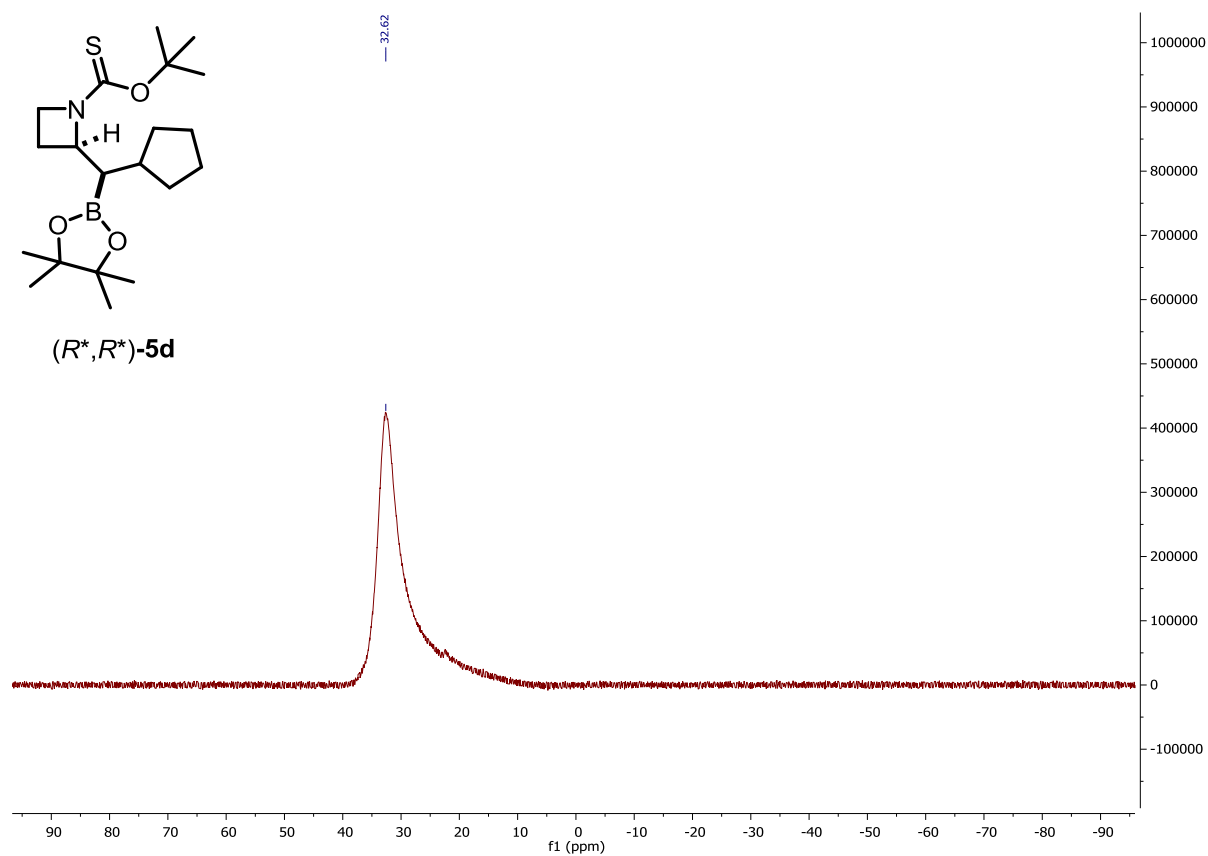
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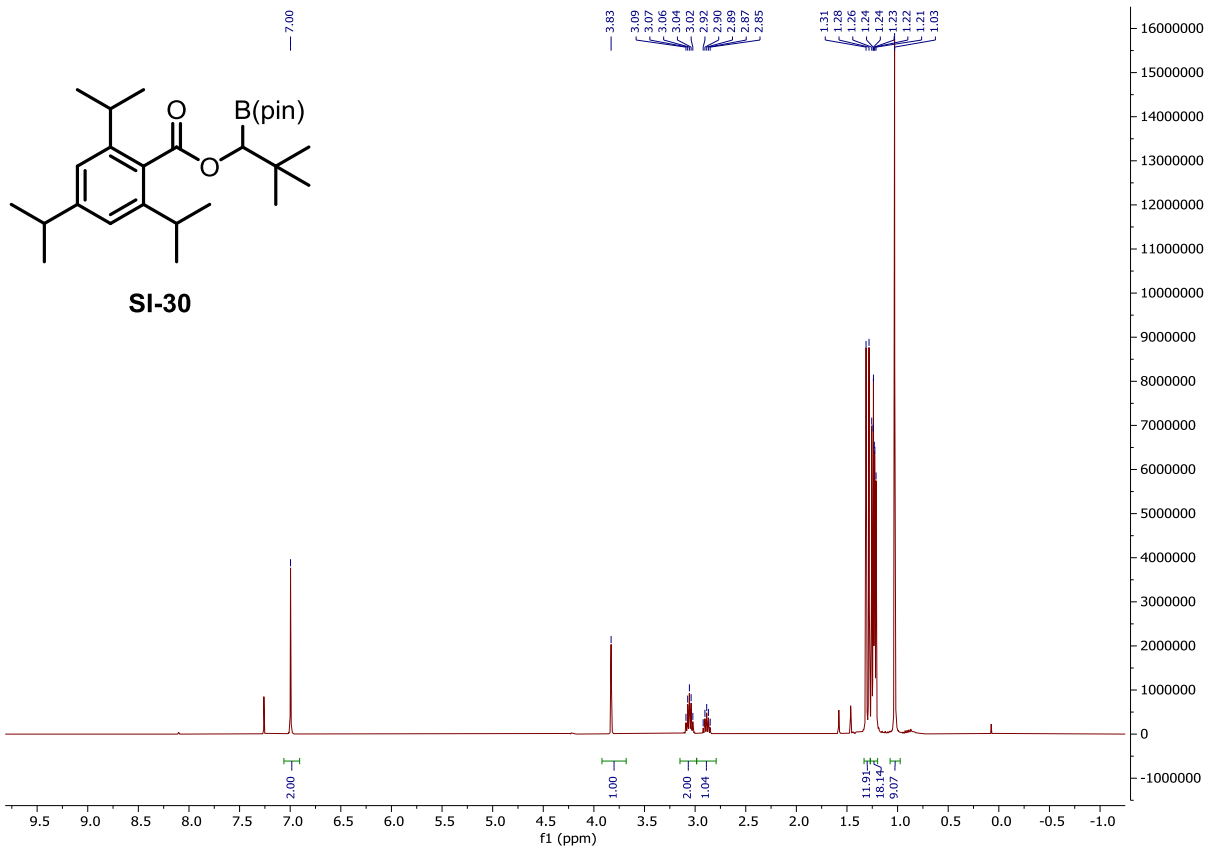
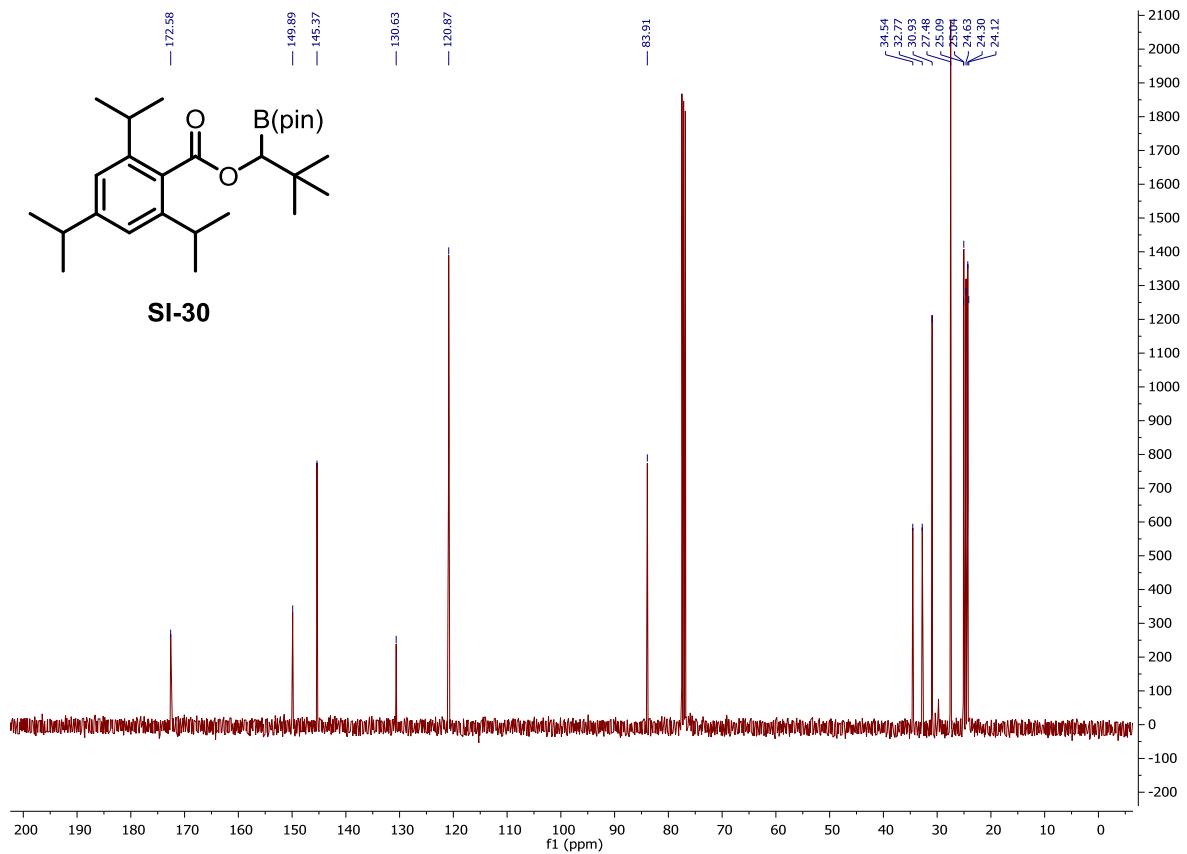
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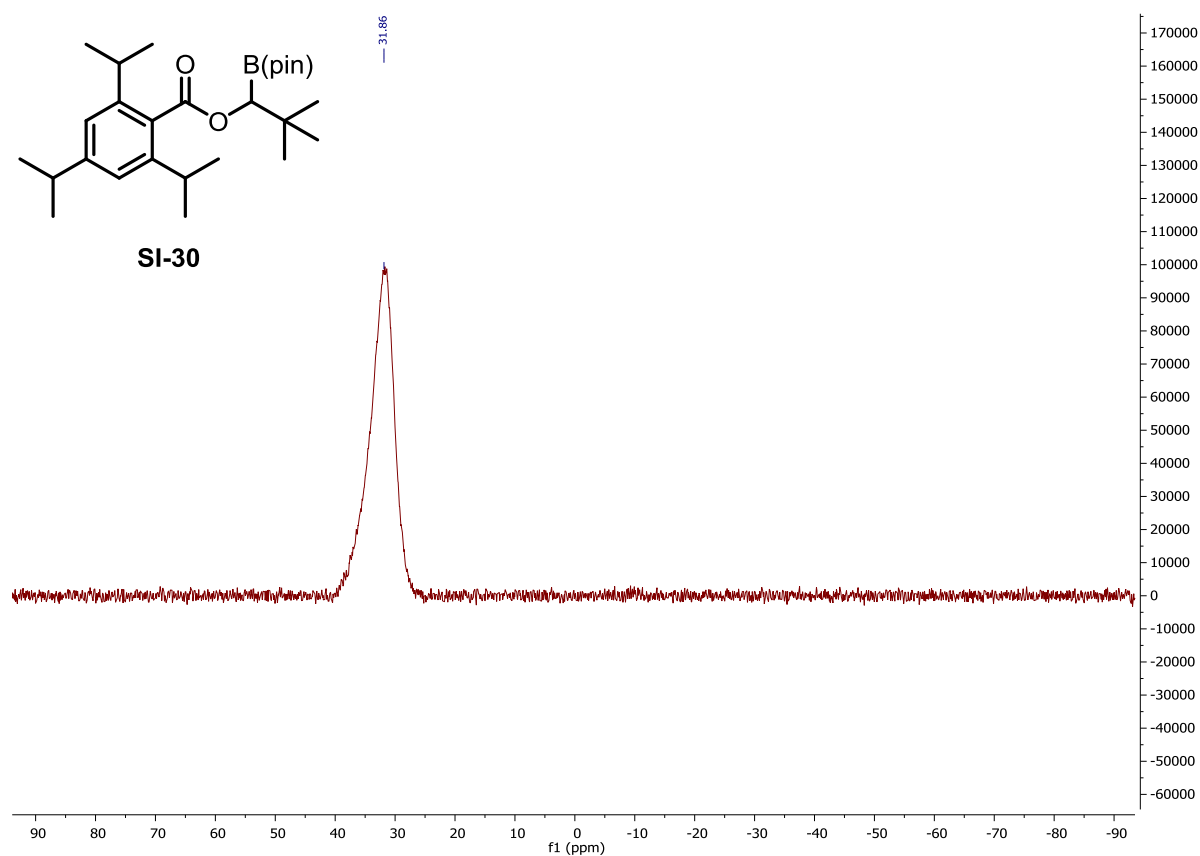
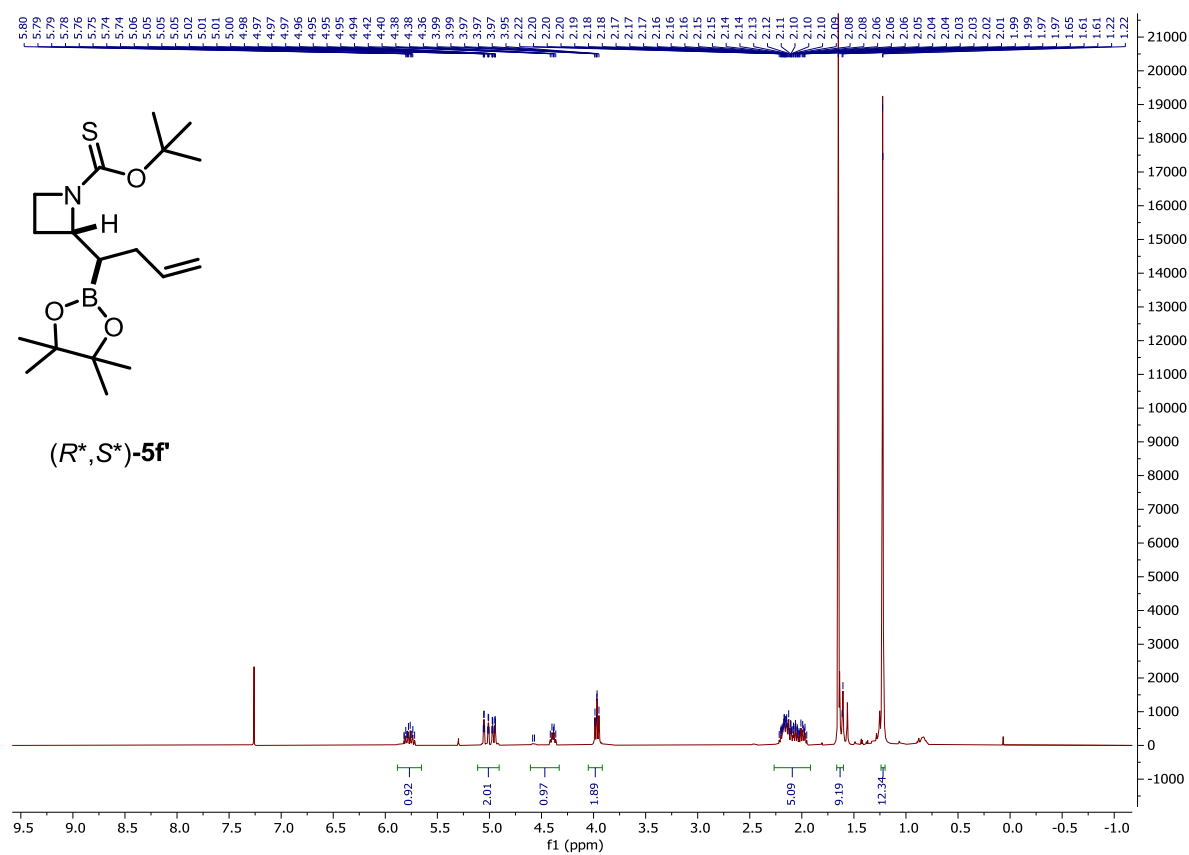
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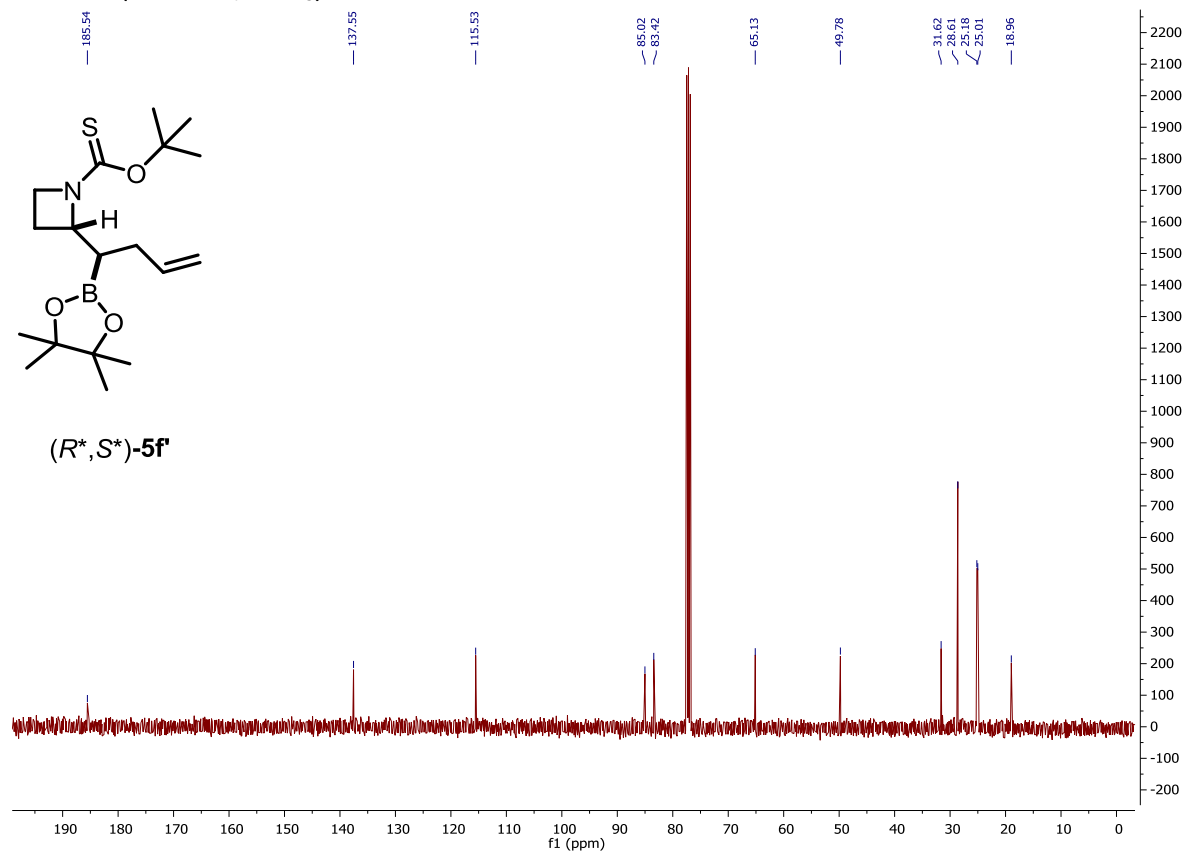
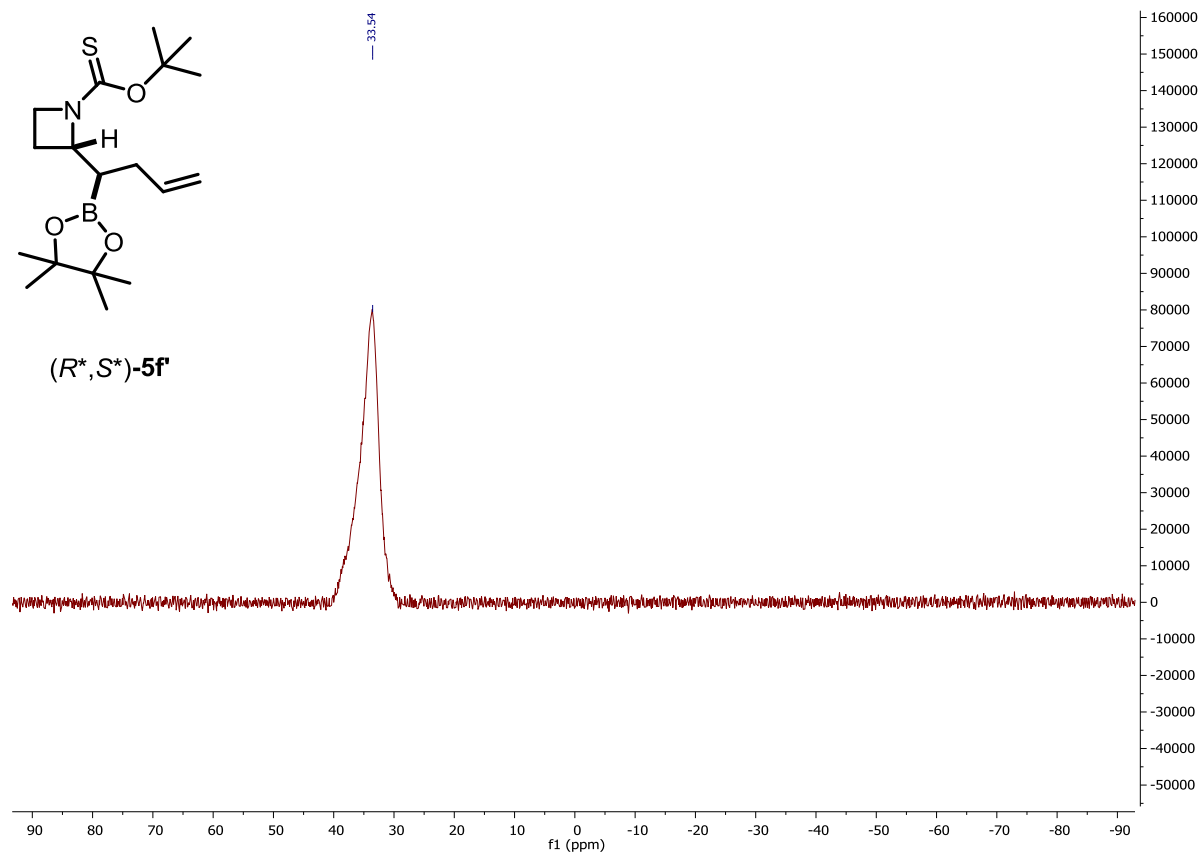
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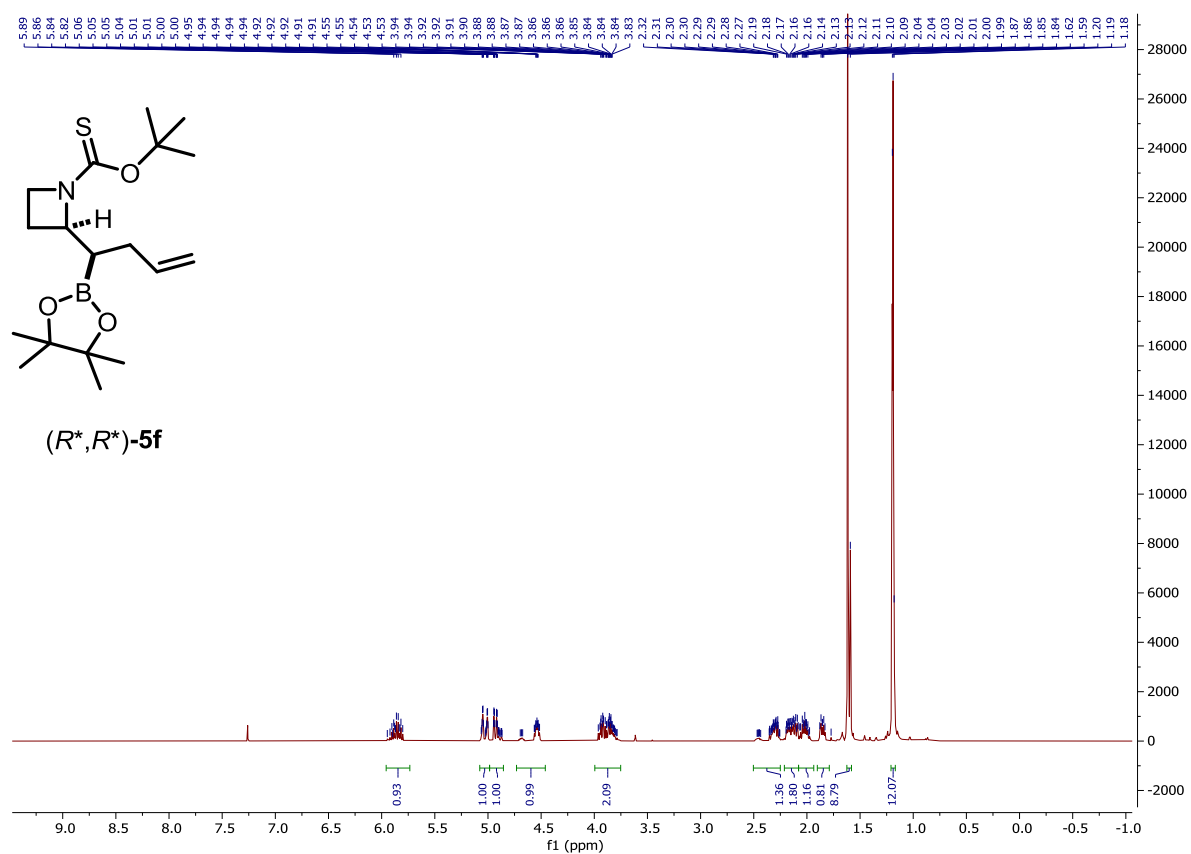
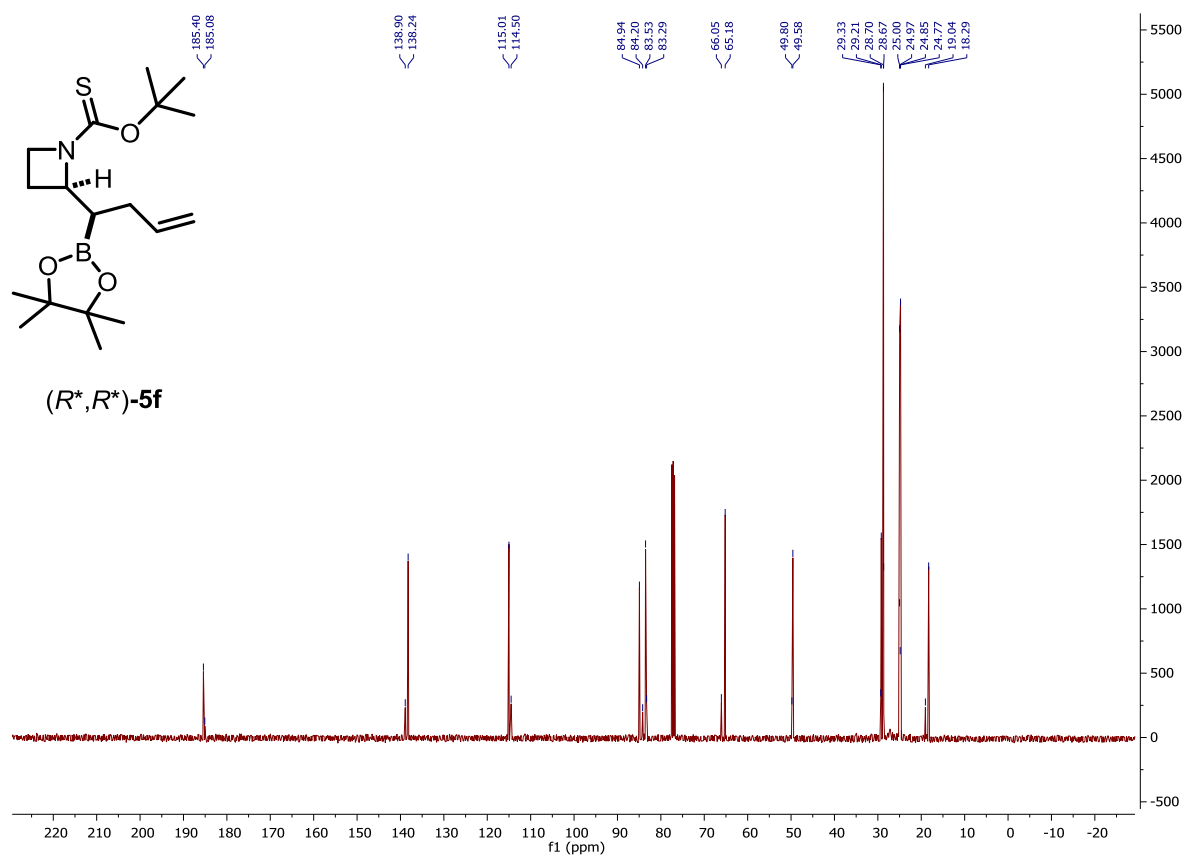
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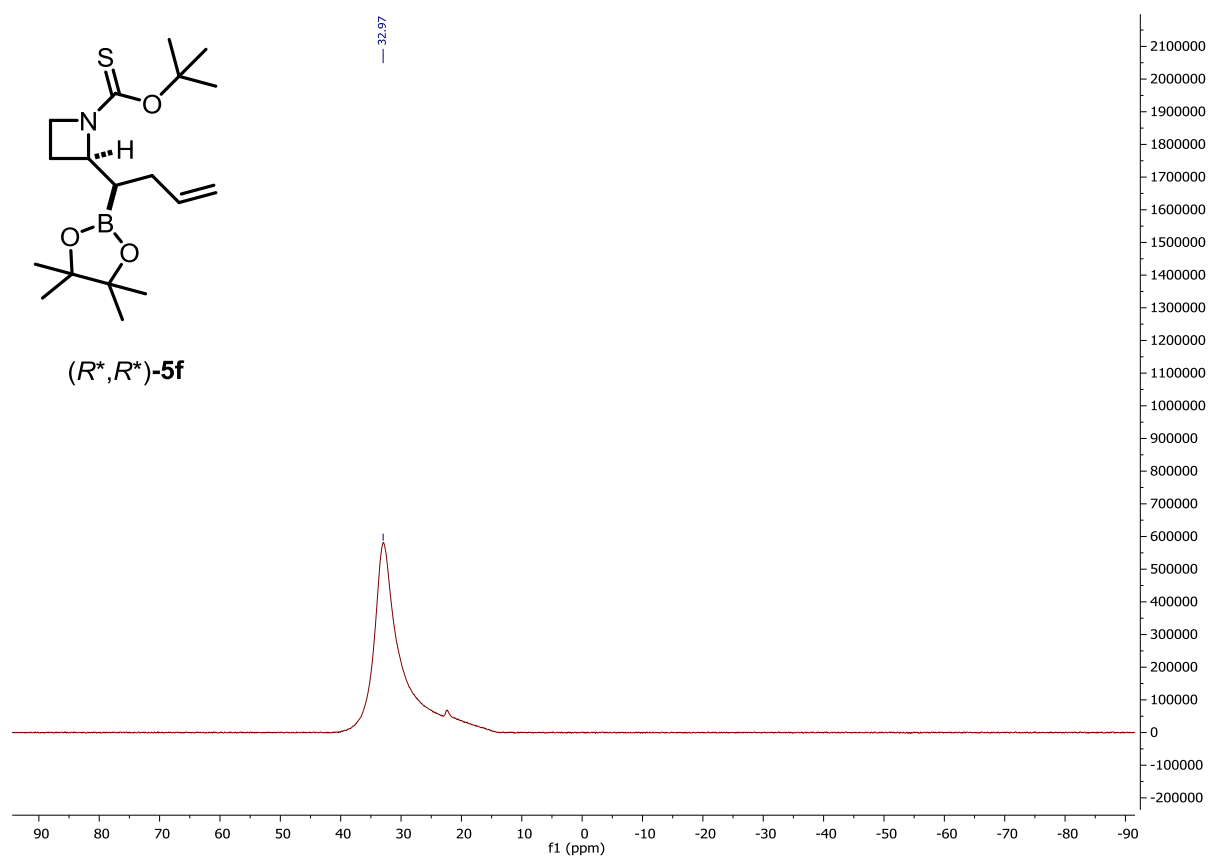
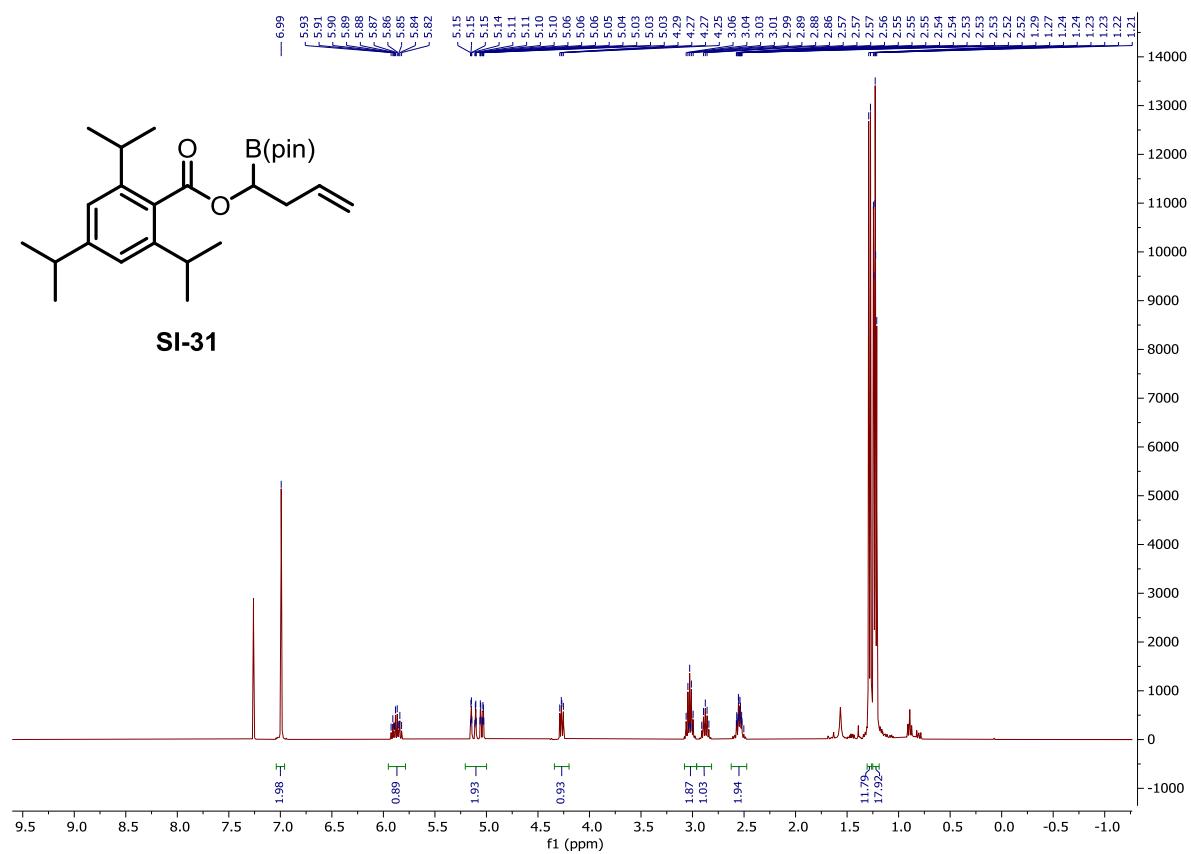
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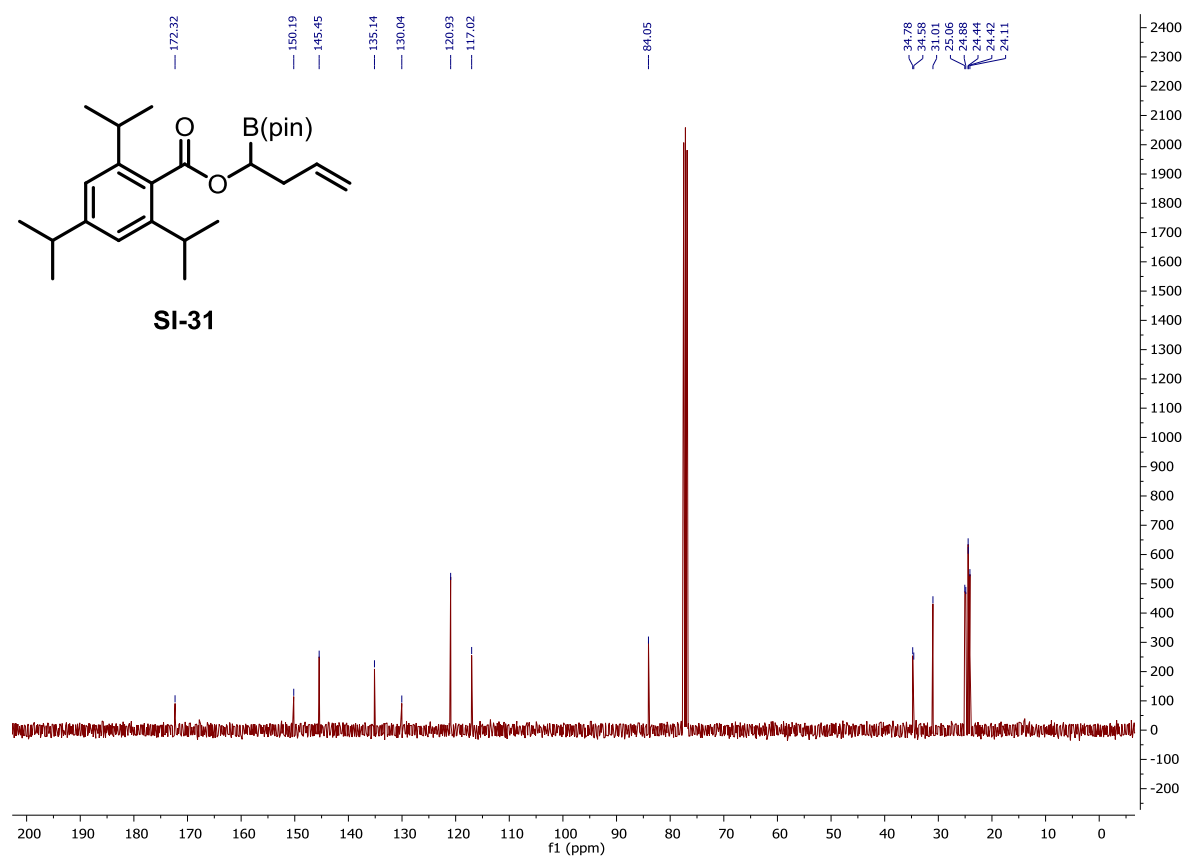
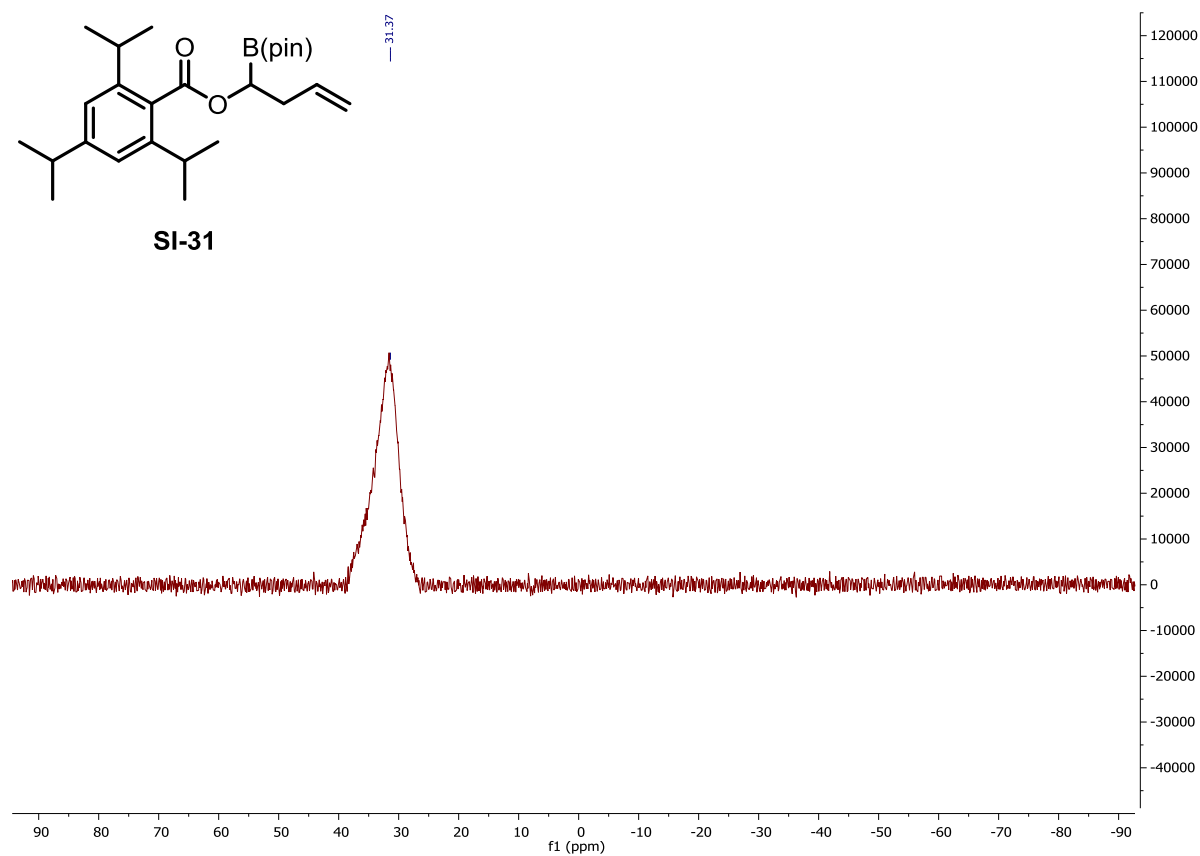
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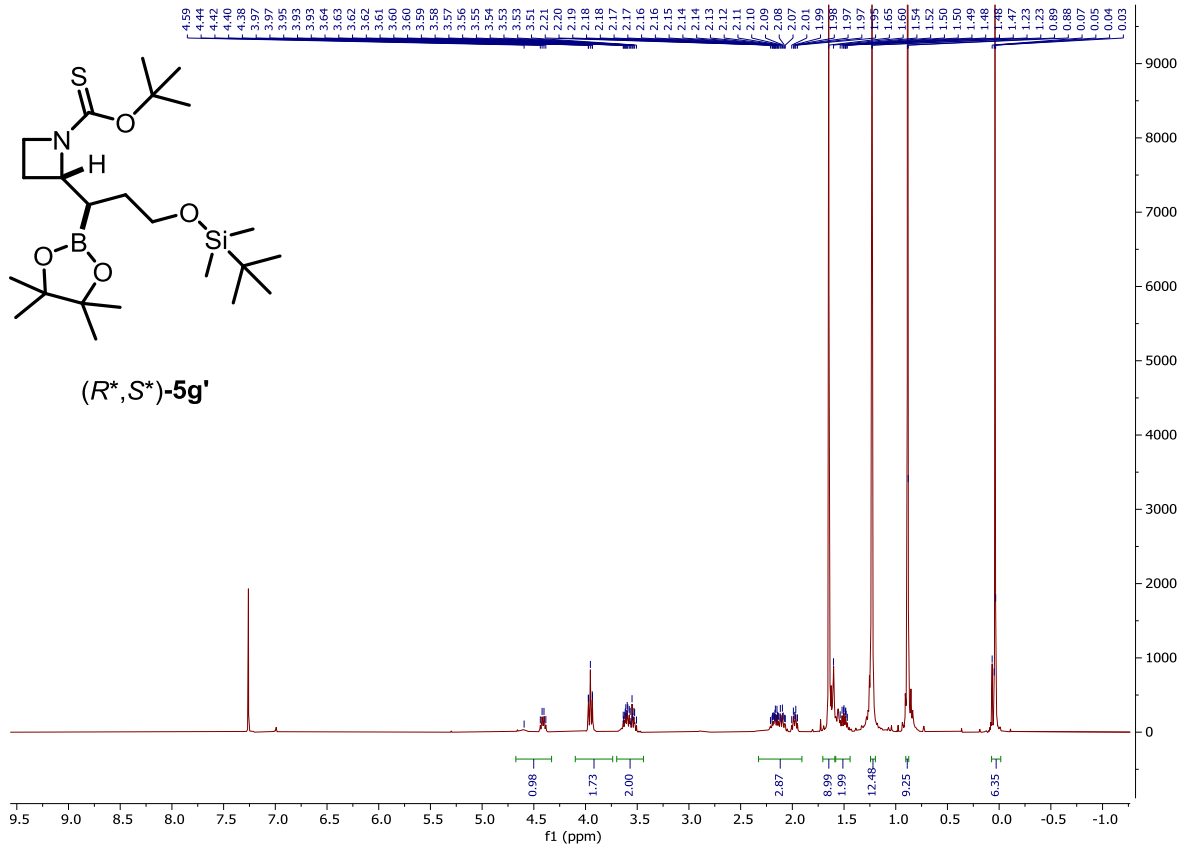
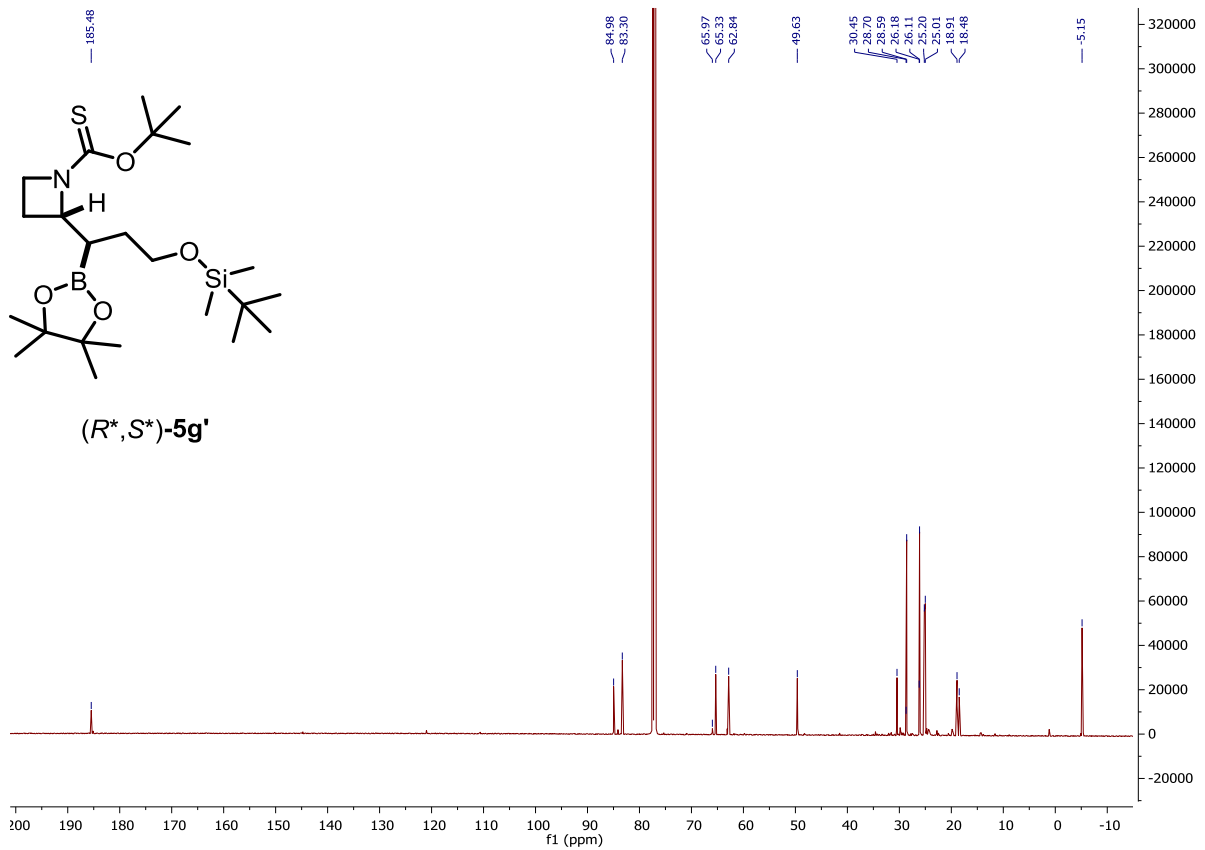
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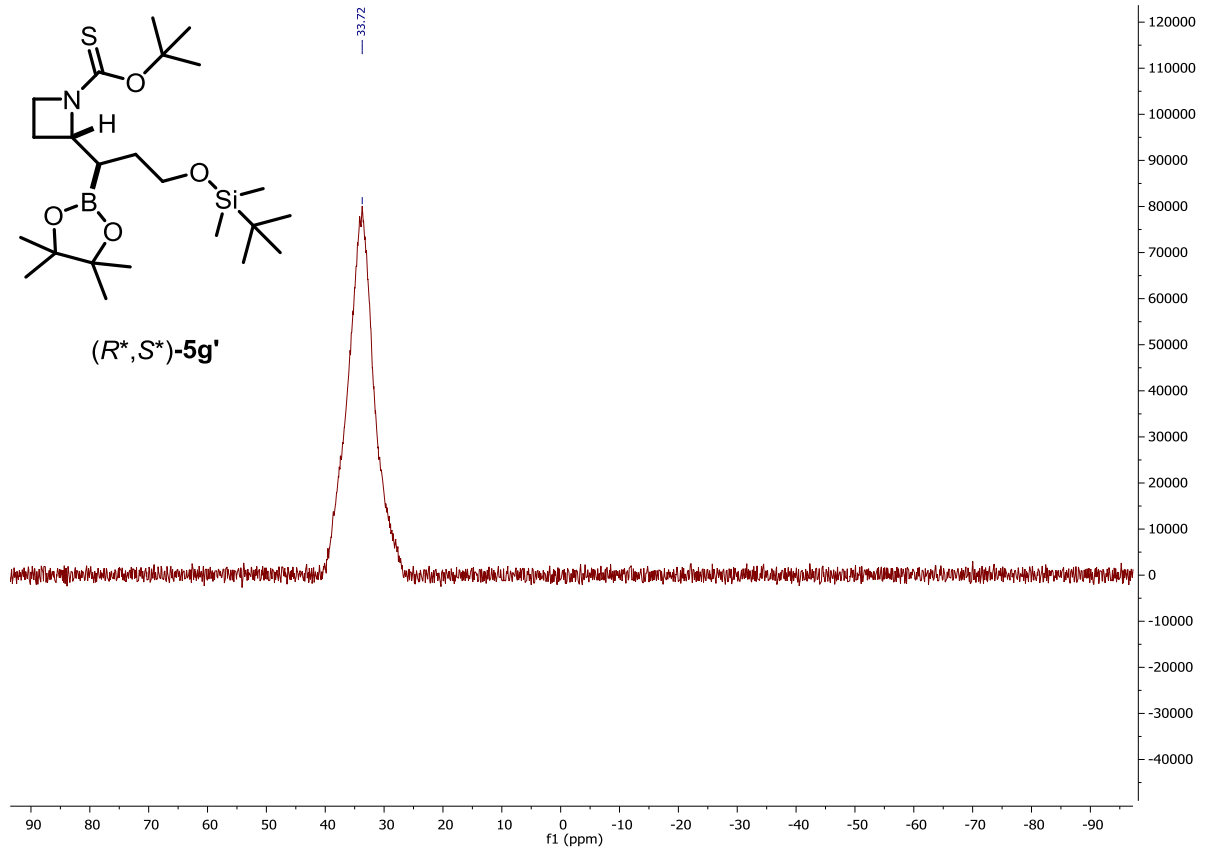
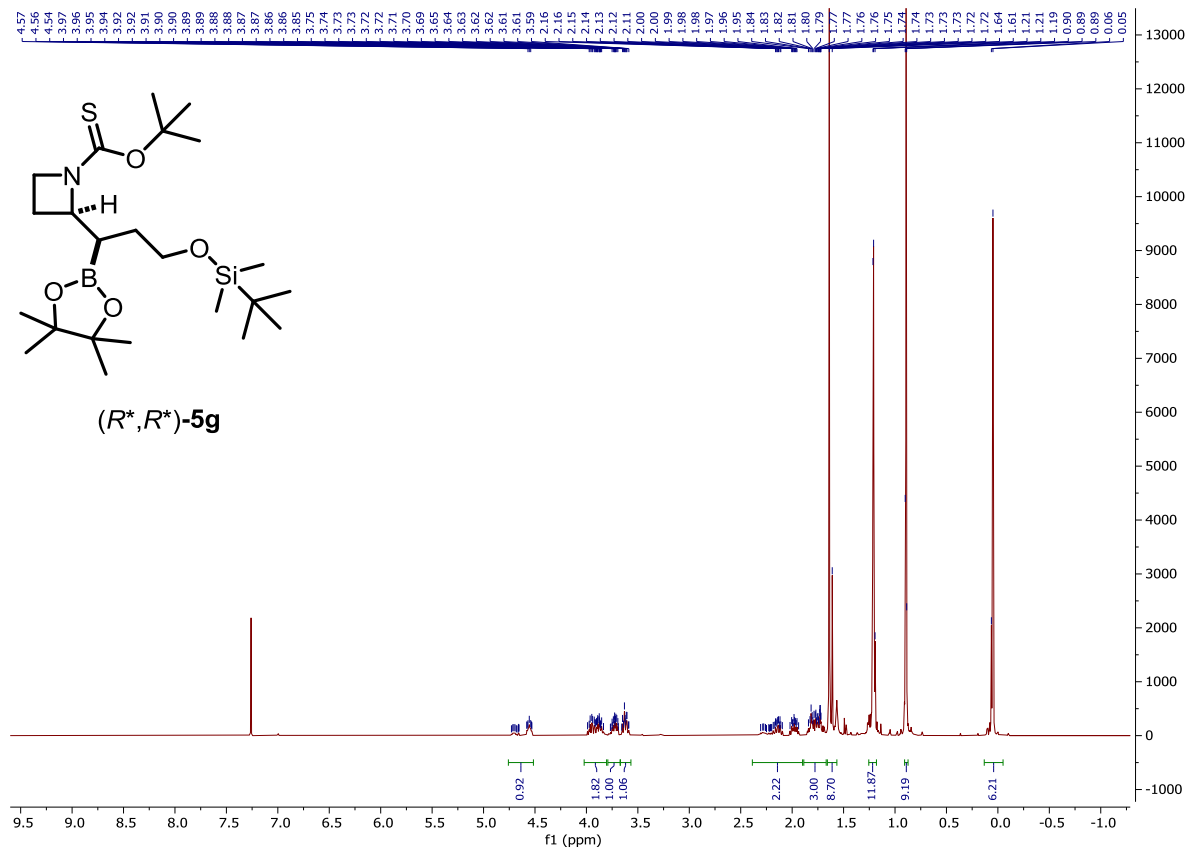
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ )

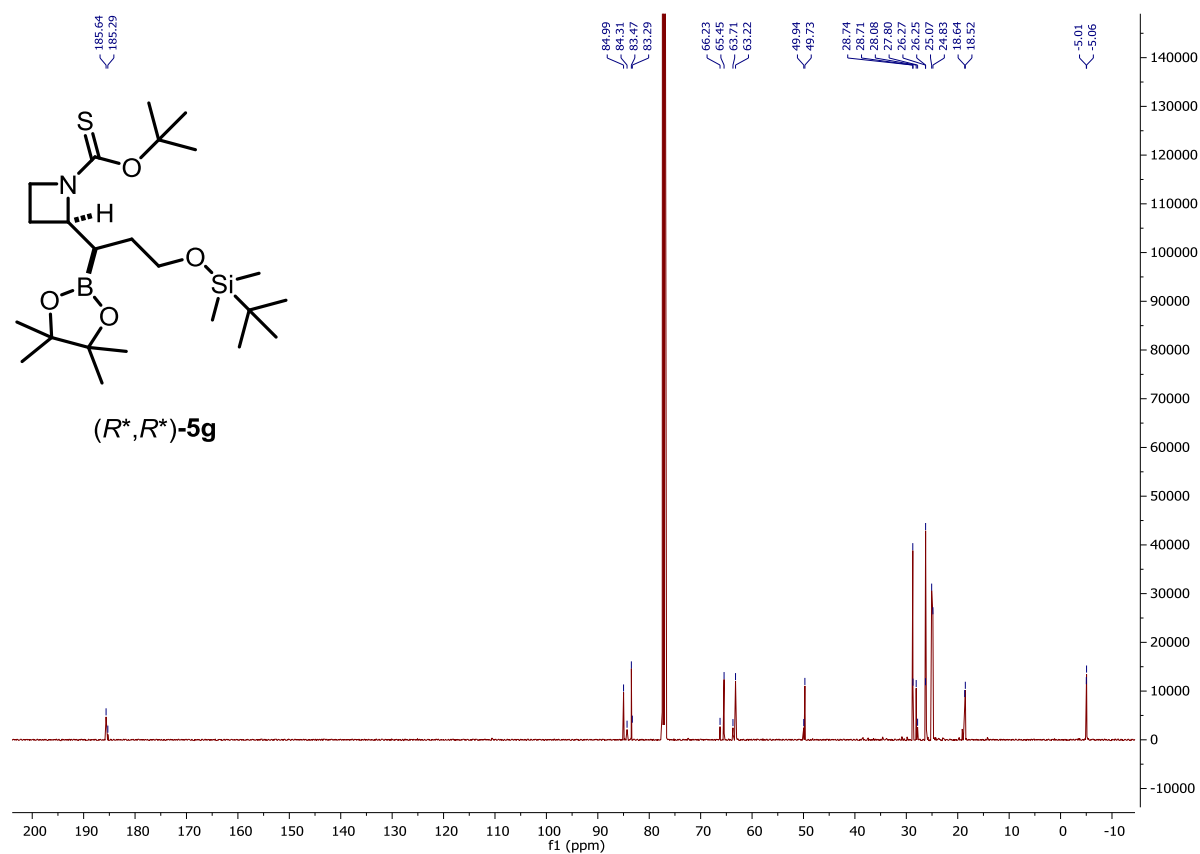
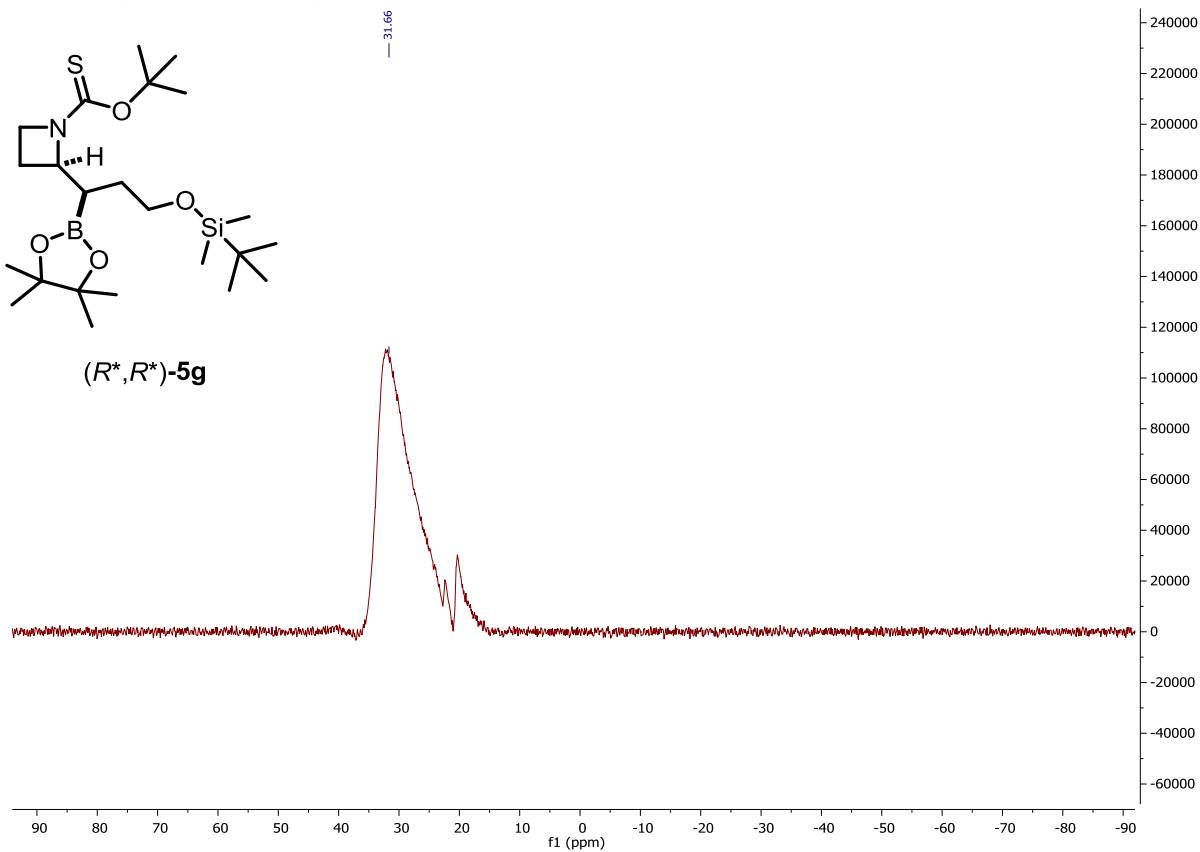
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )

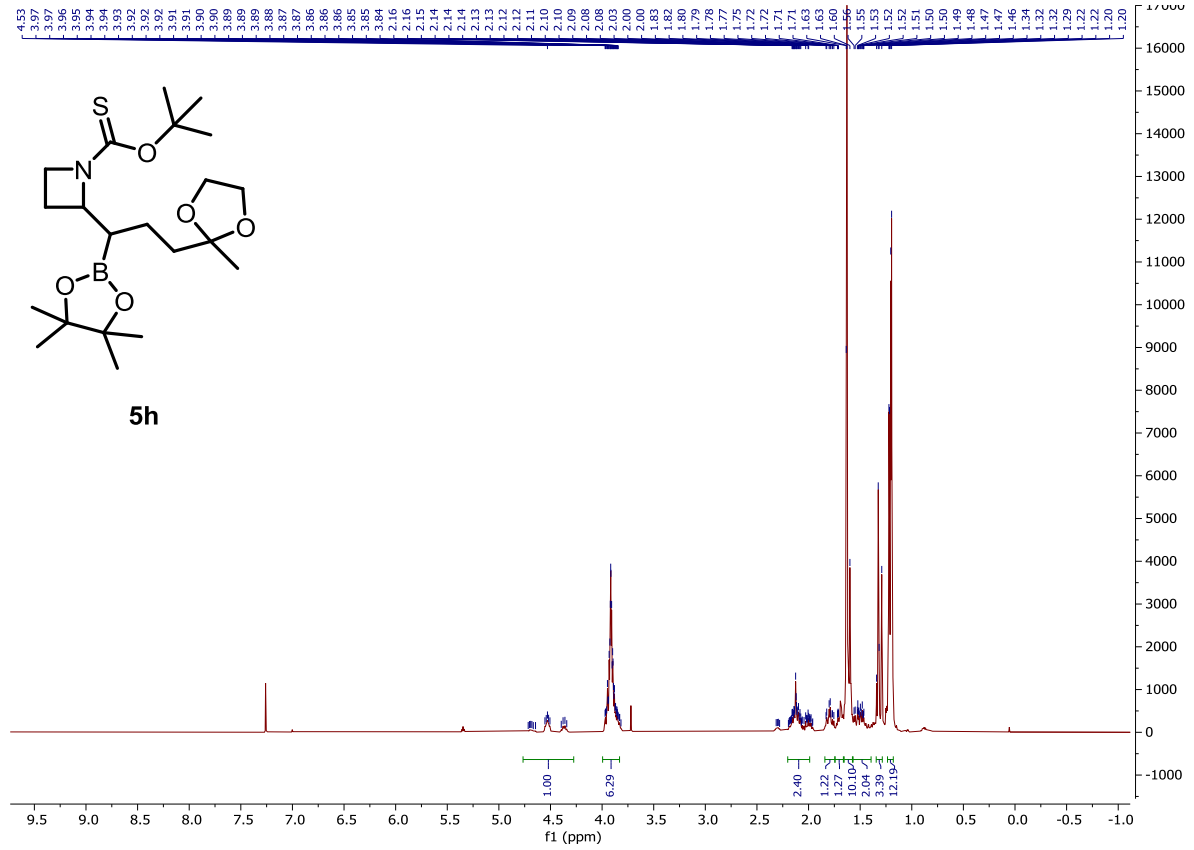
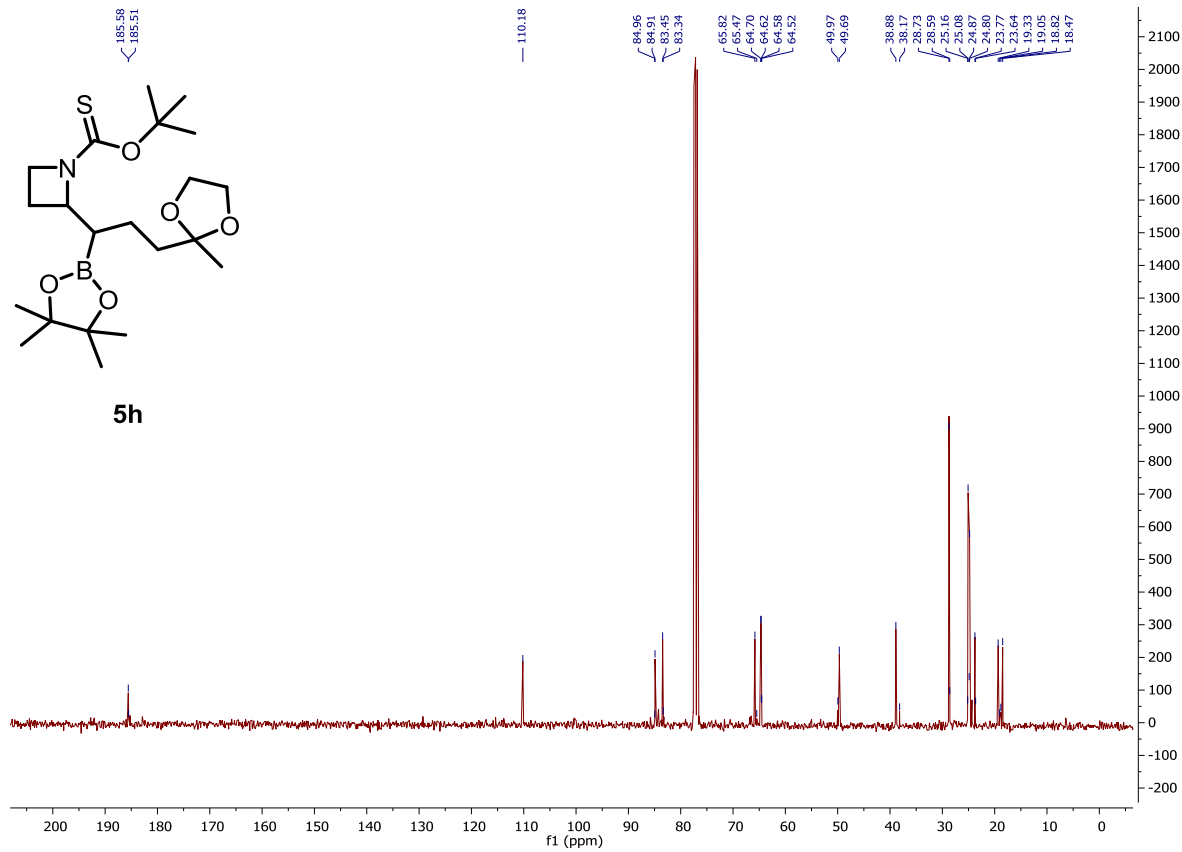
$^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

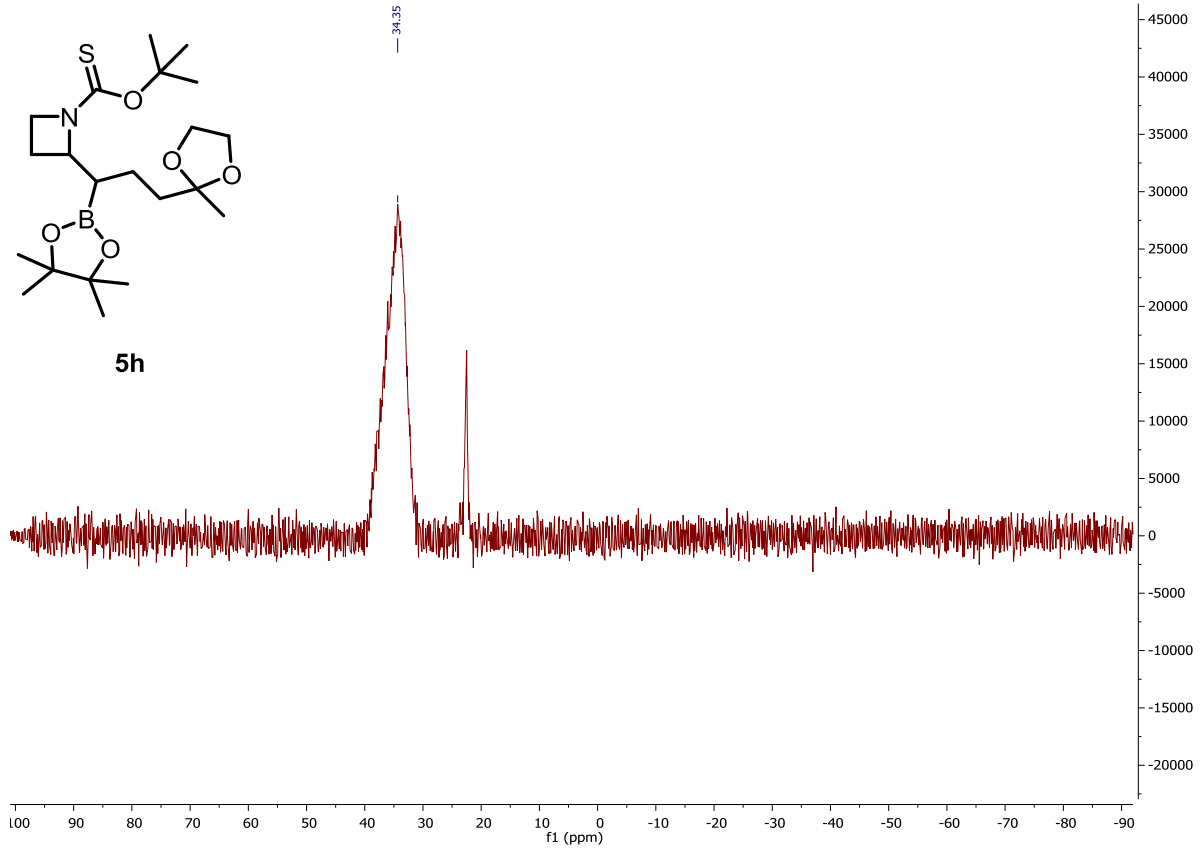
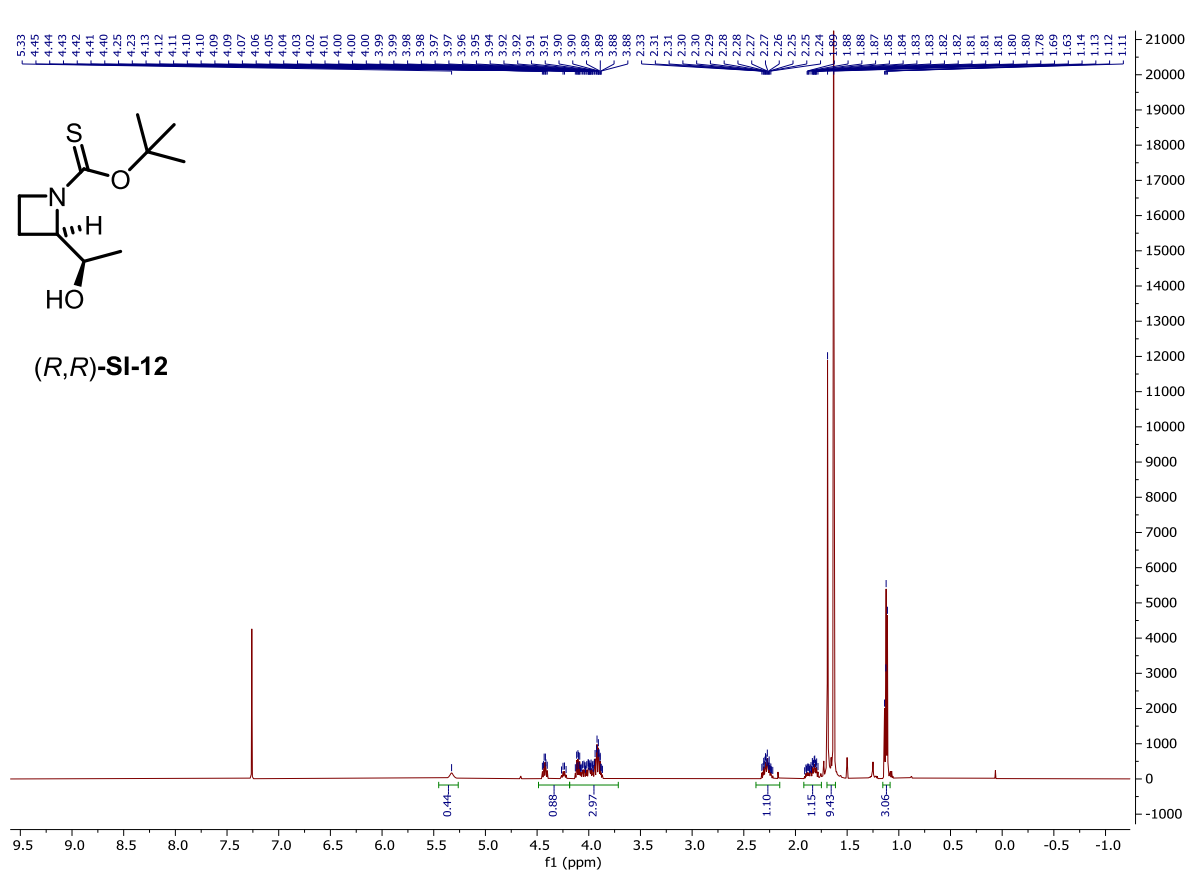
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ )

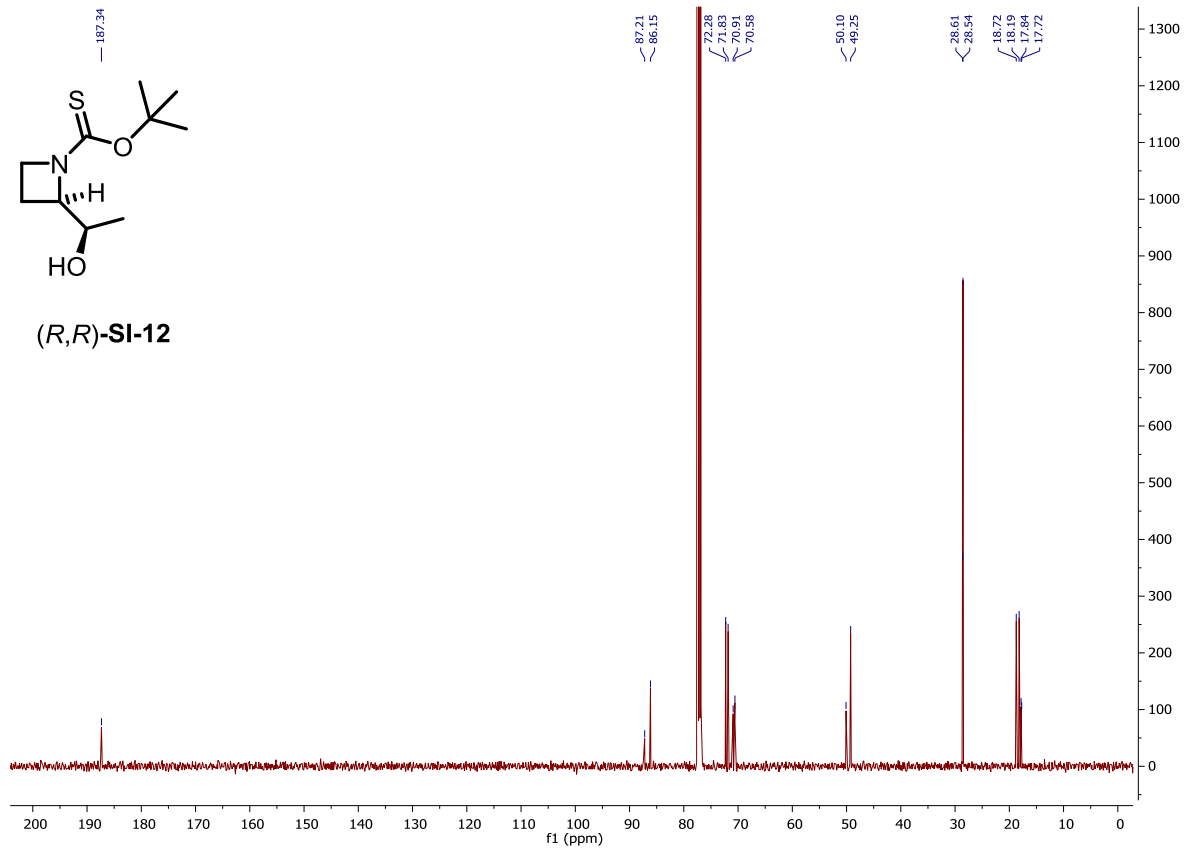
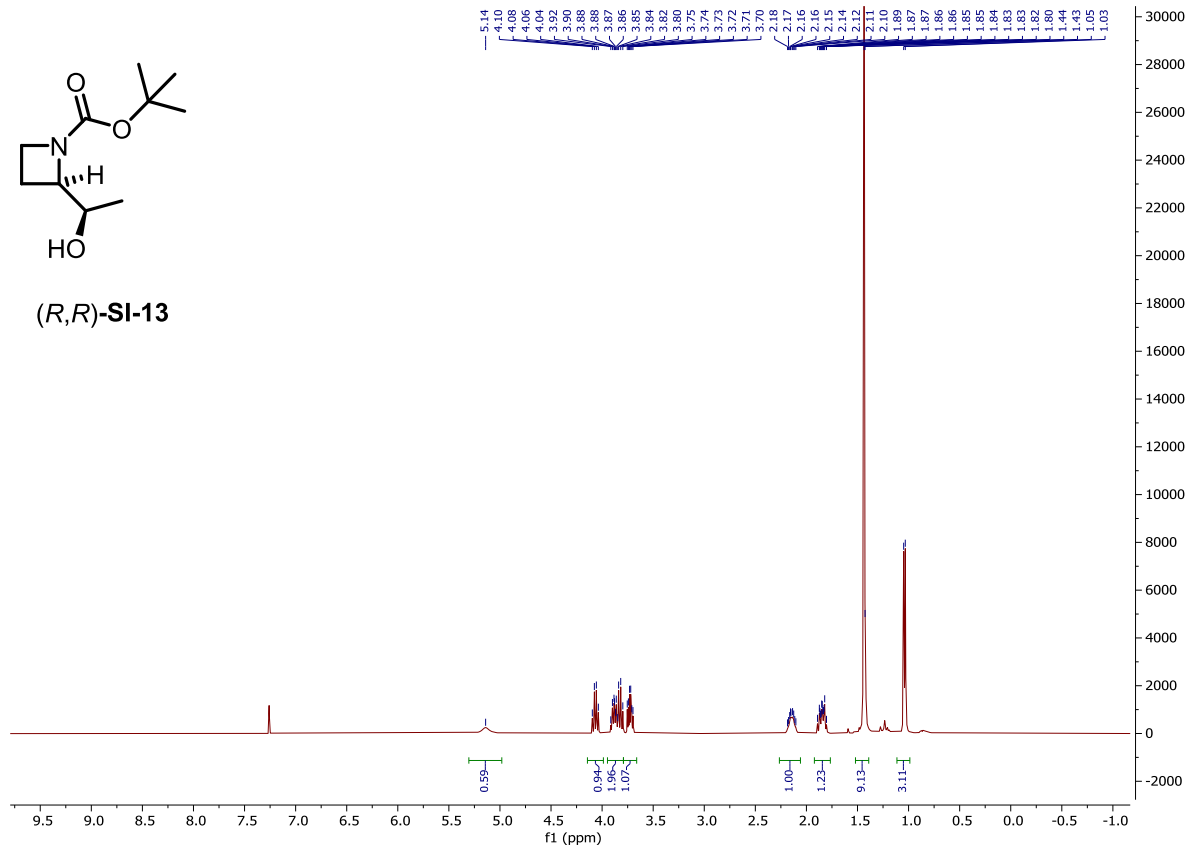
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )

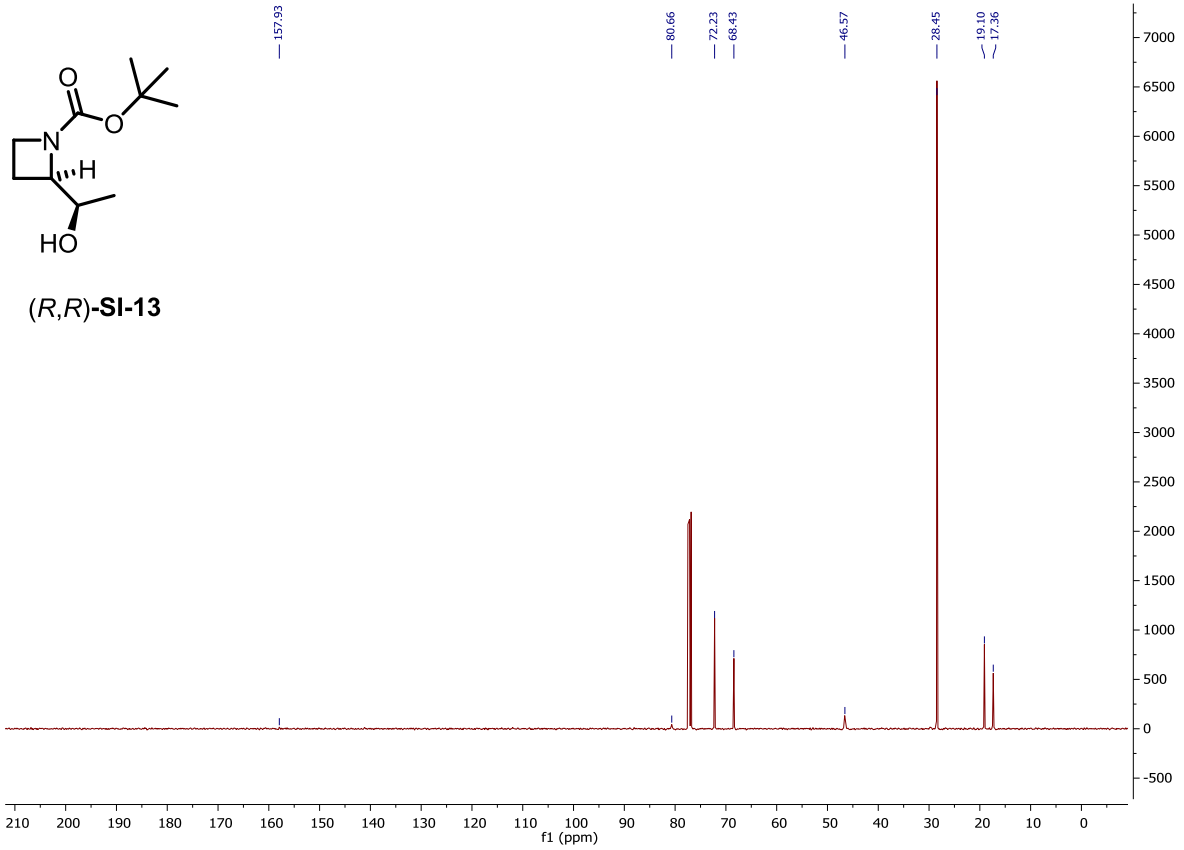
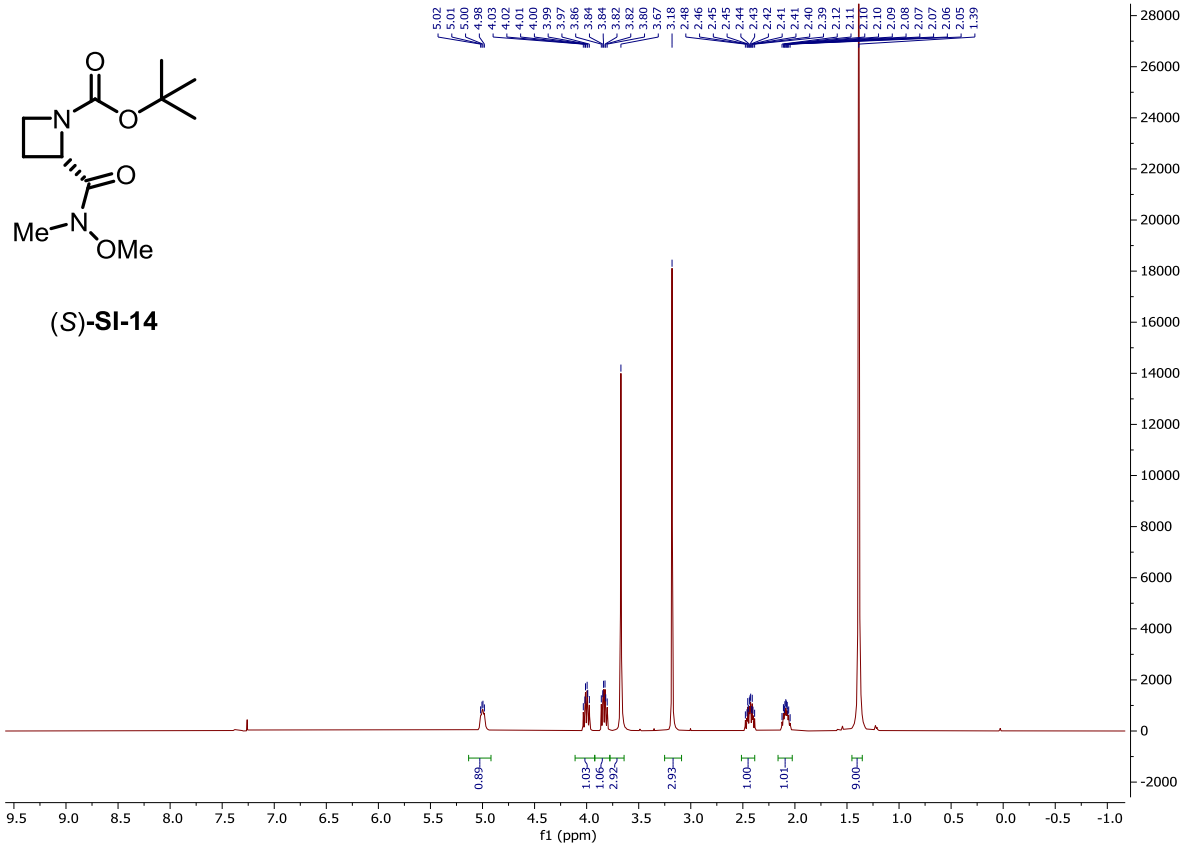
$^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

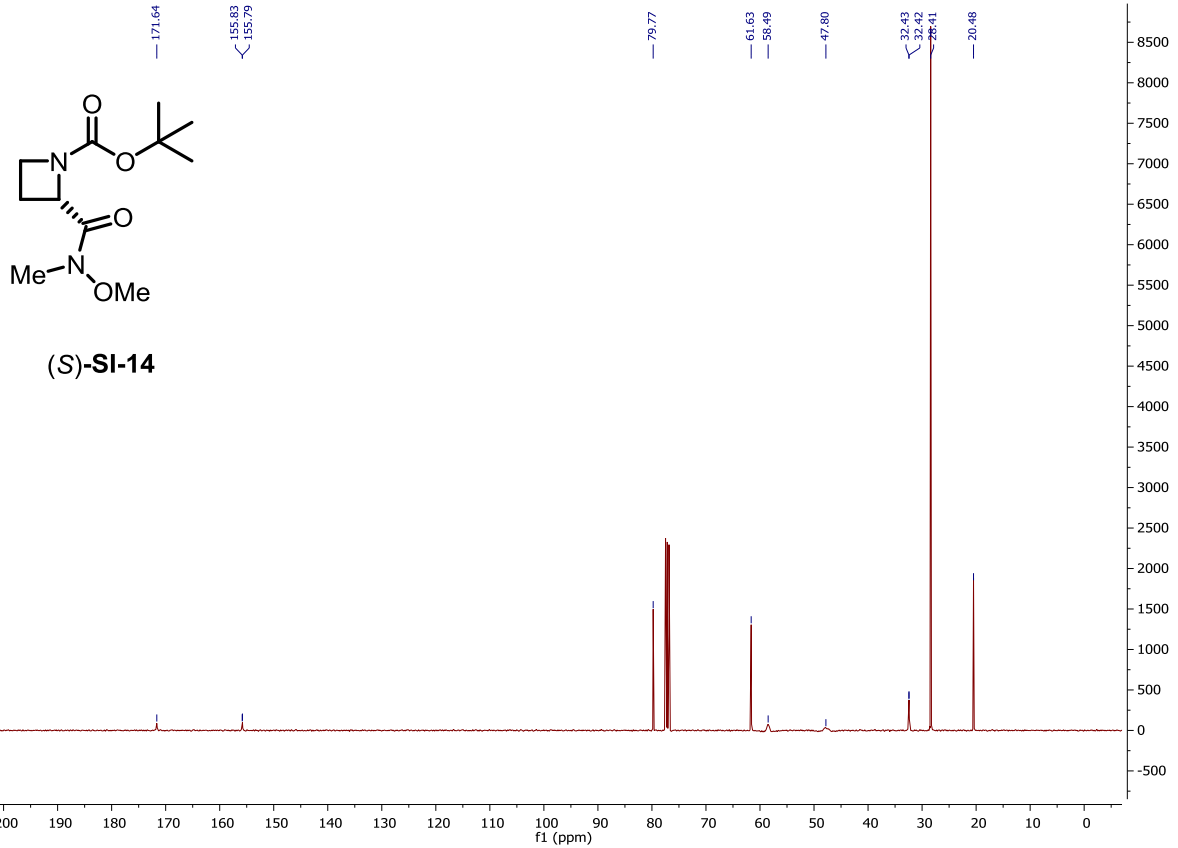
$^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ ) $^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ )

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )

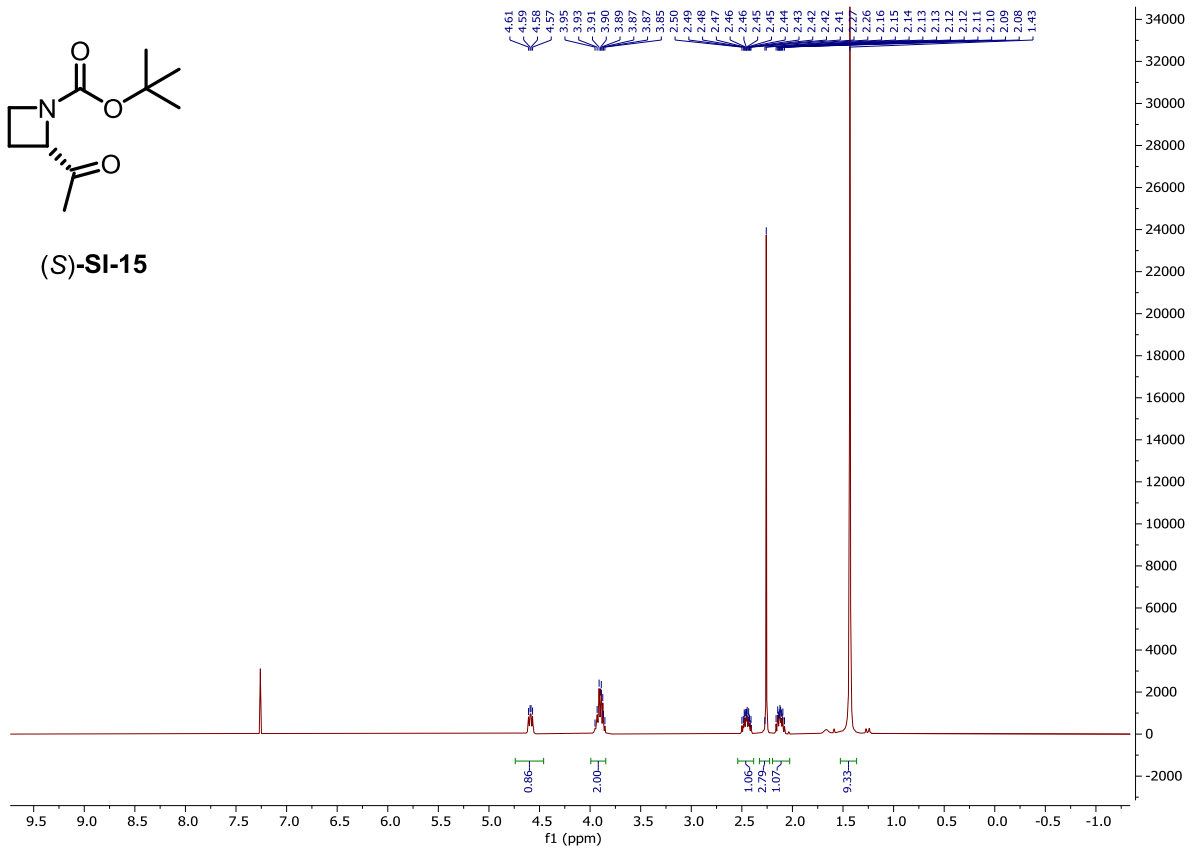
$^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

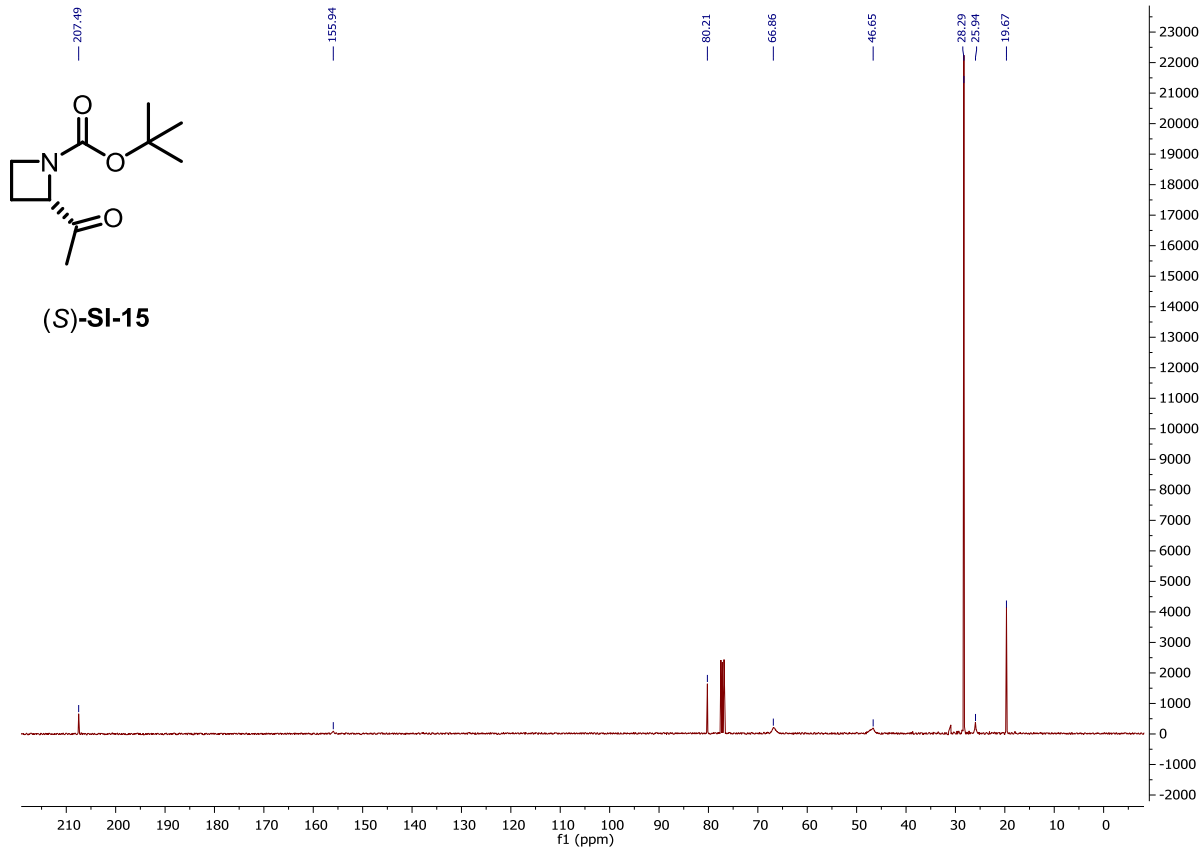
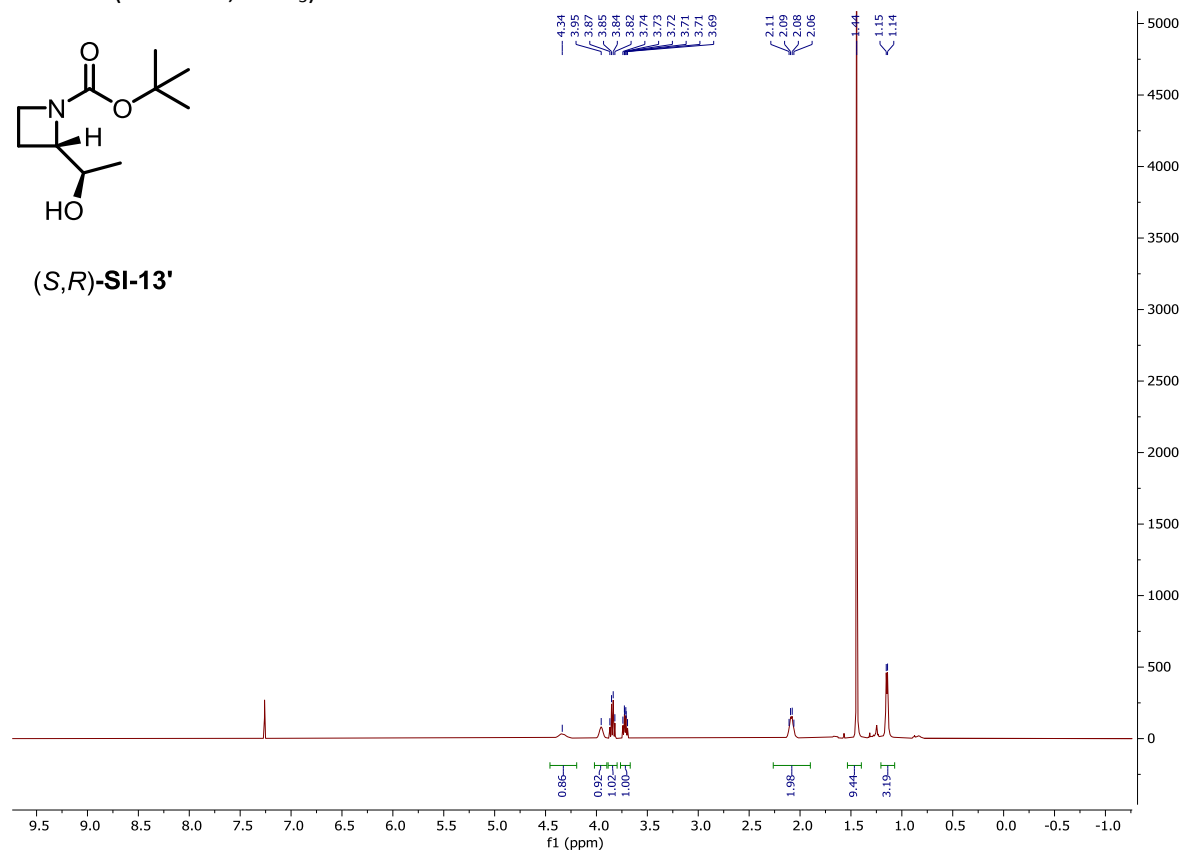
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )

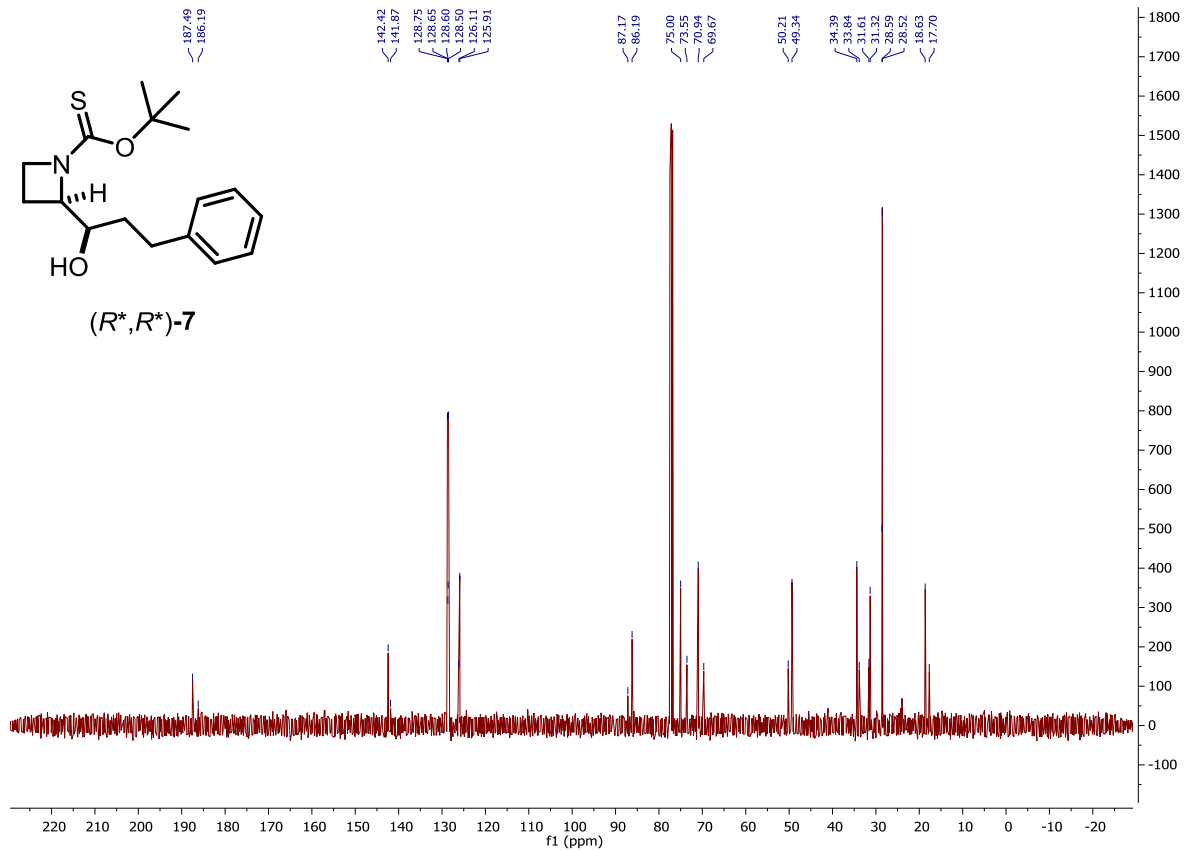
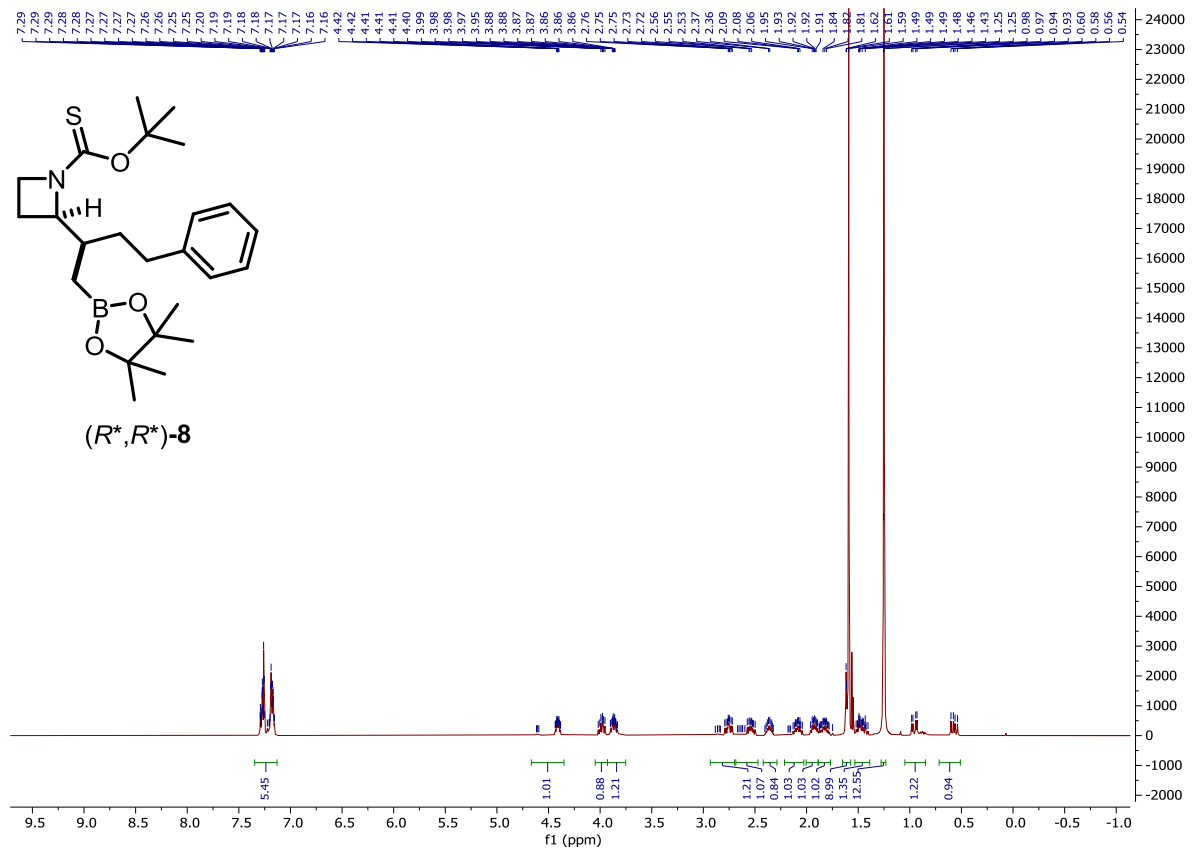
(S)-SI-14

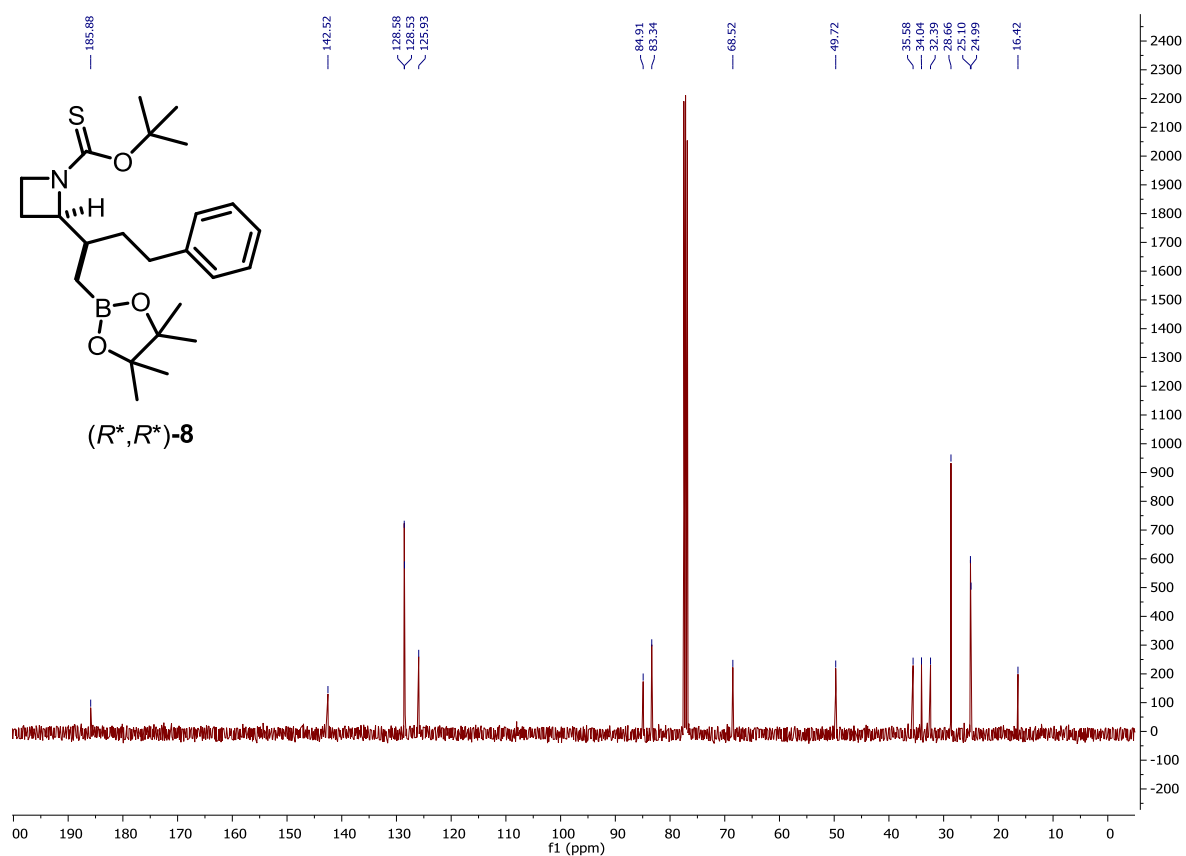
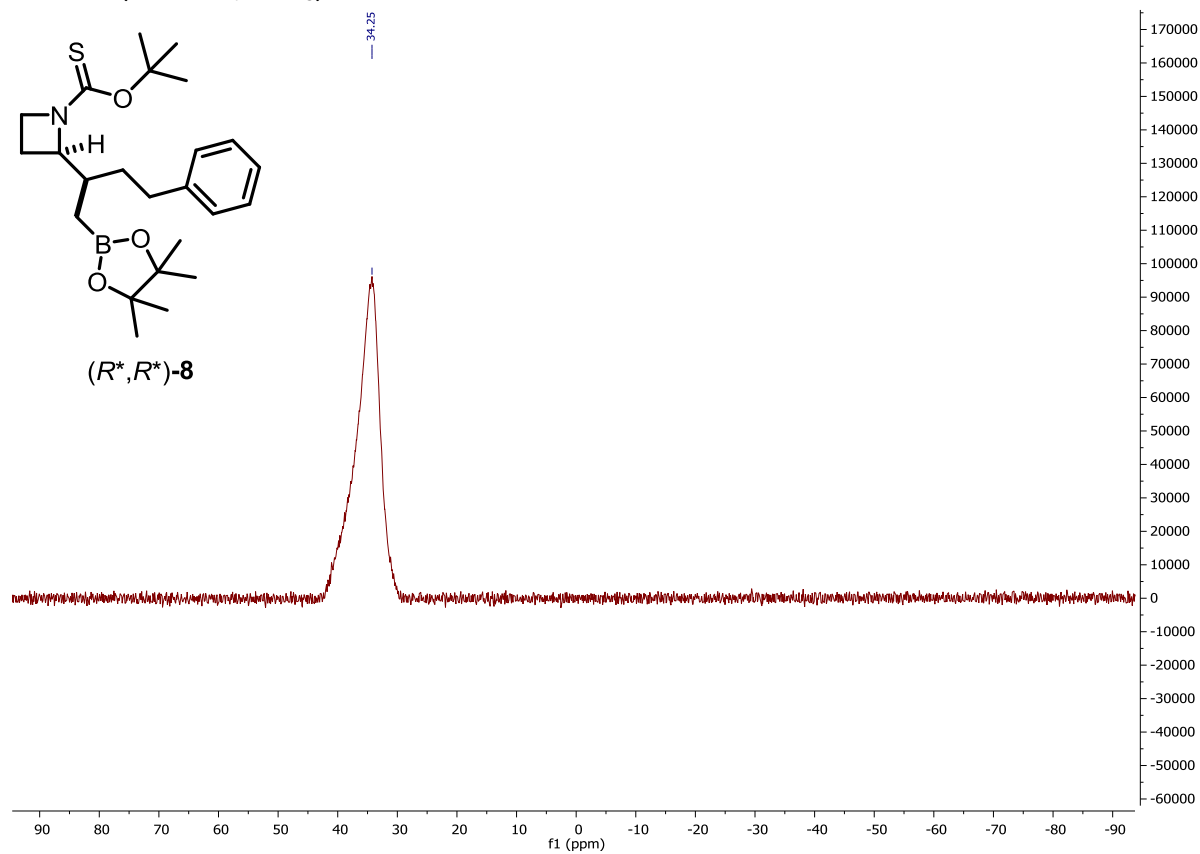
 $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

(S)-SI-15

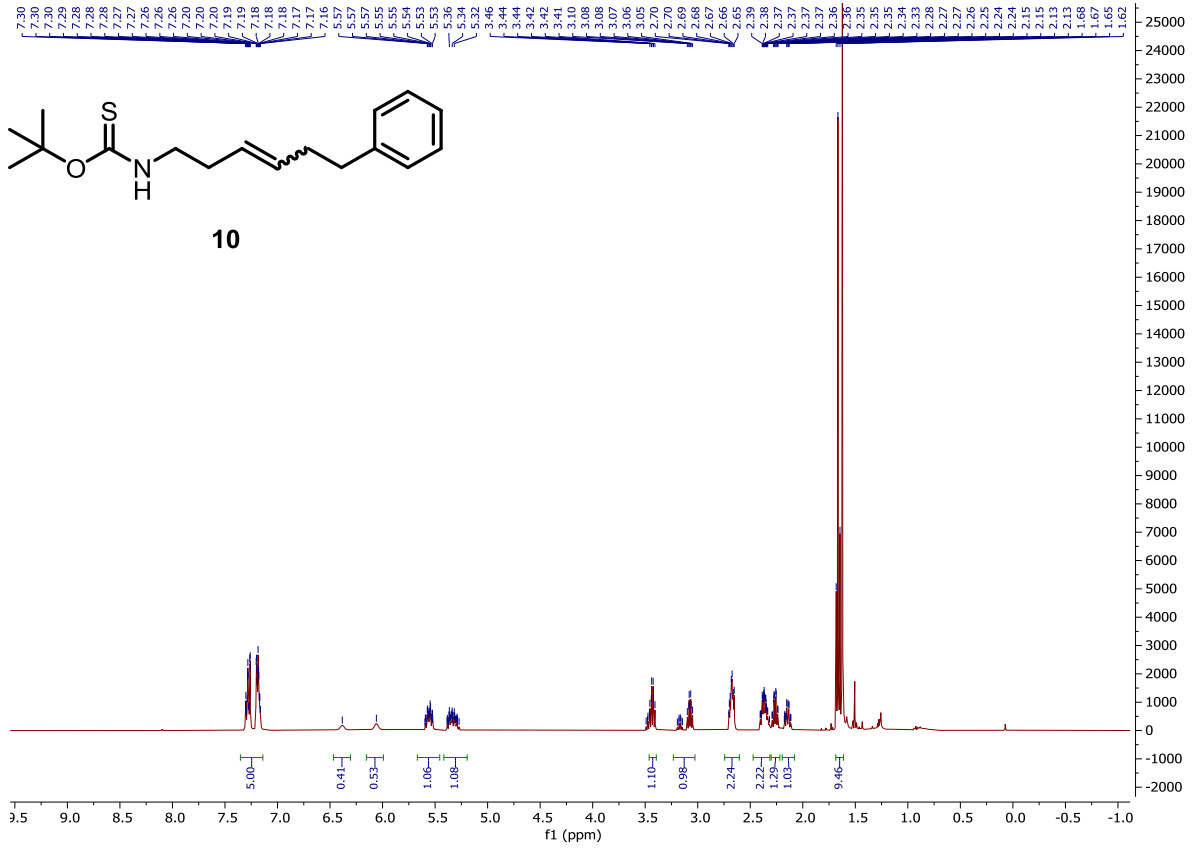
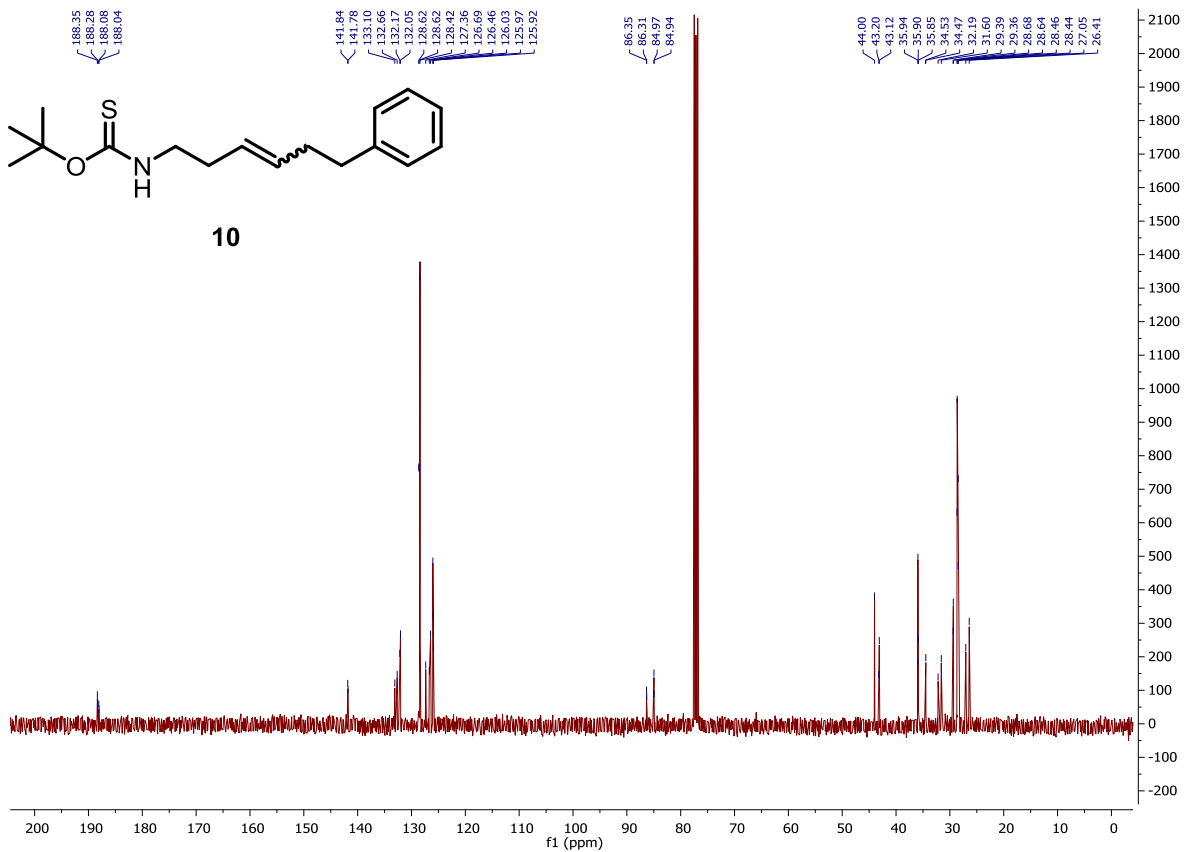
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )**(S)-SI-15** $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )**(S,R)-SI-13'**

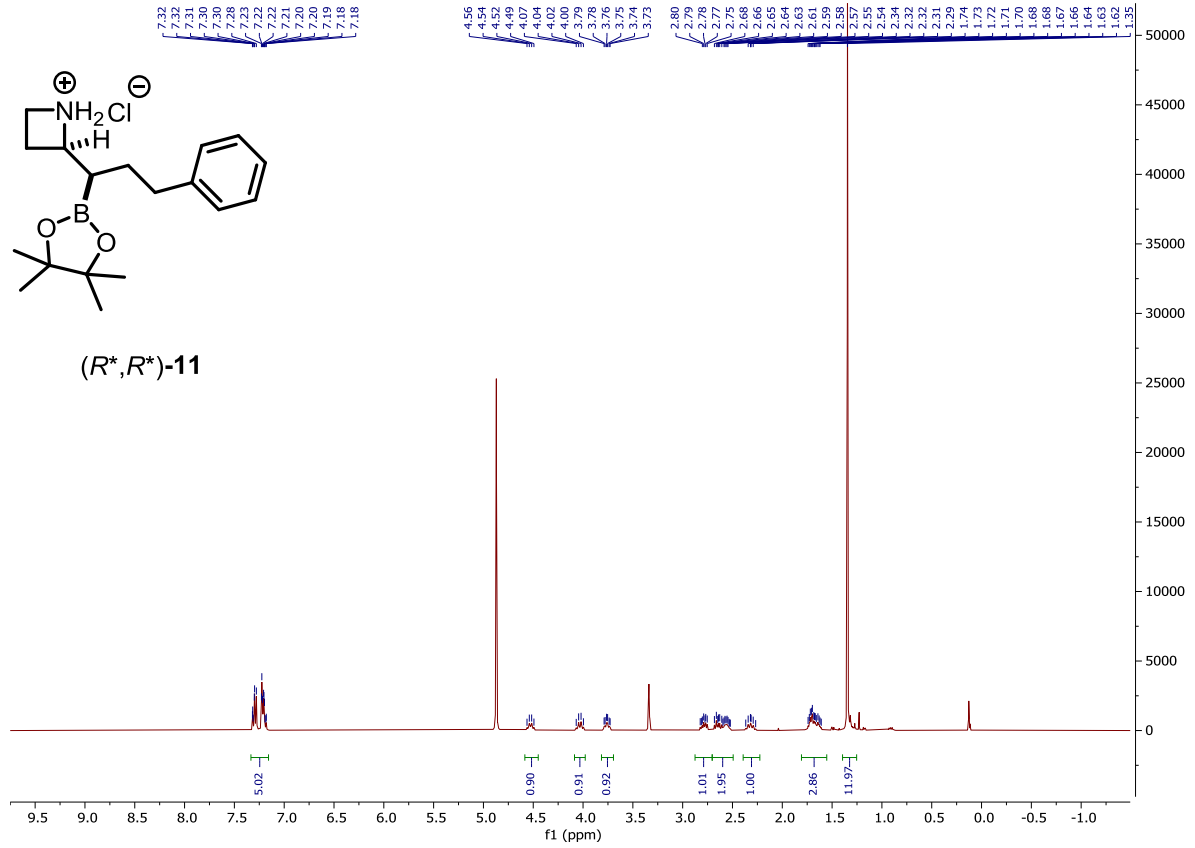
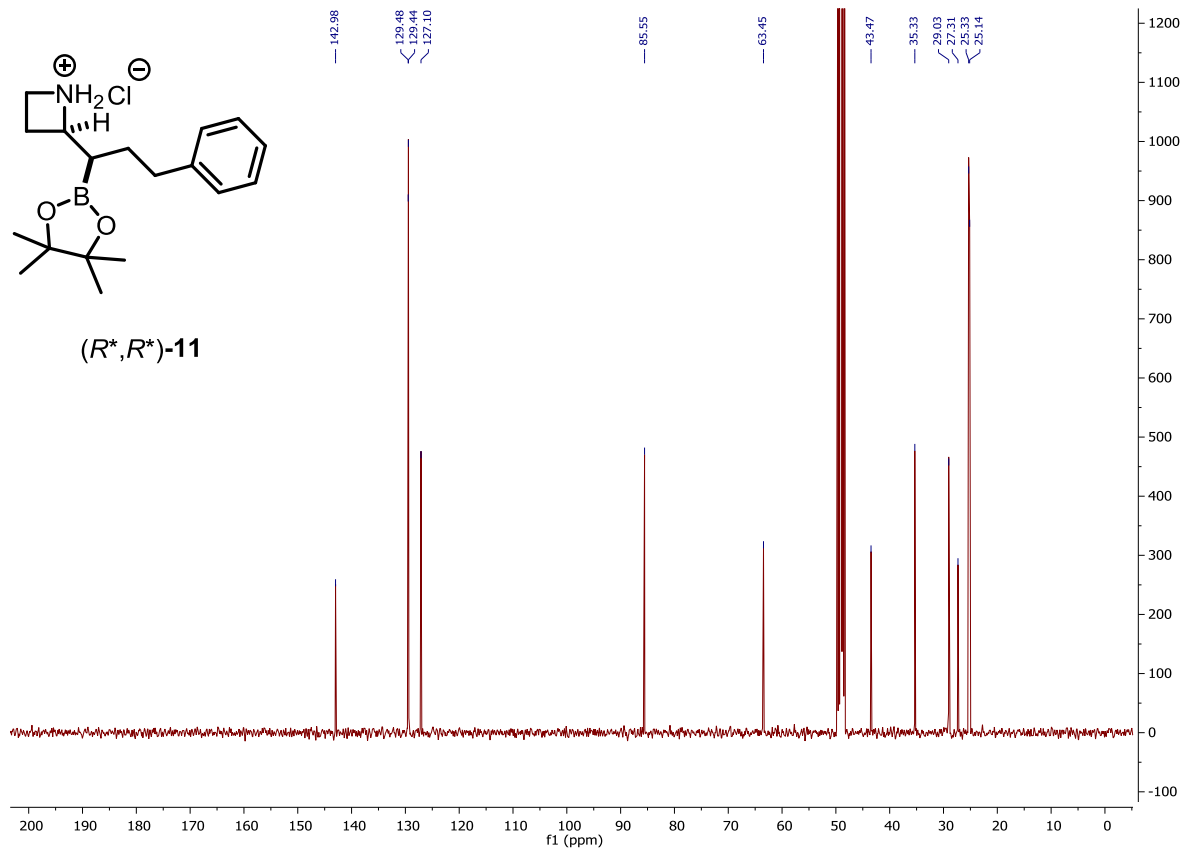


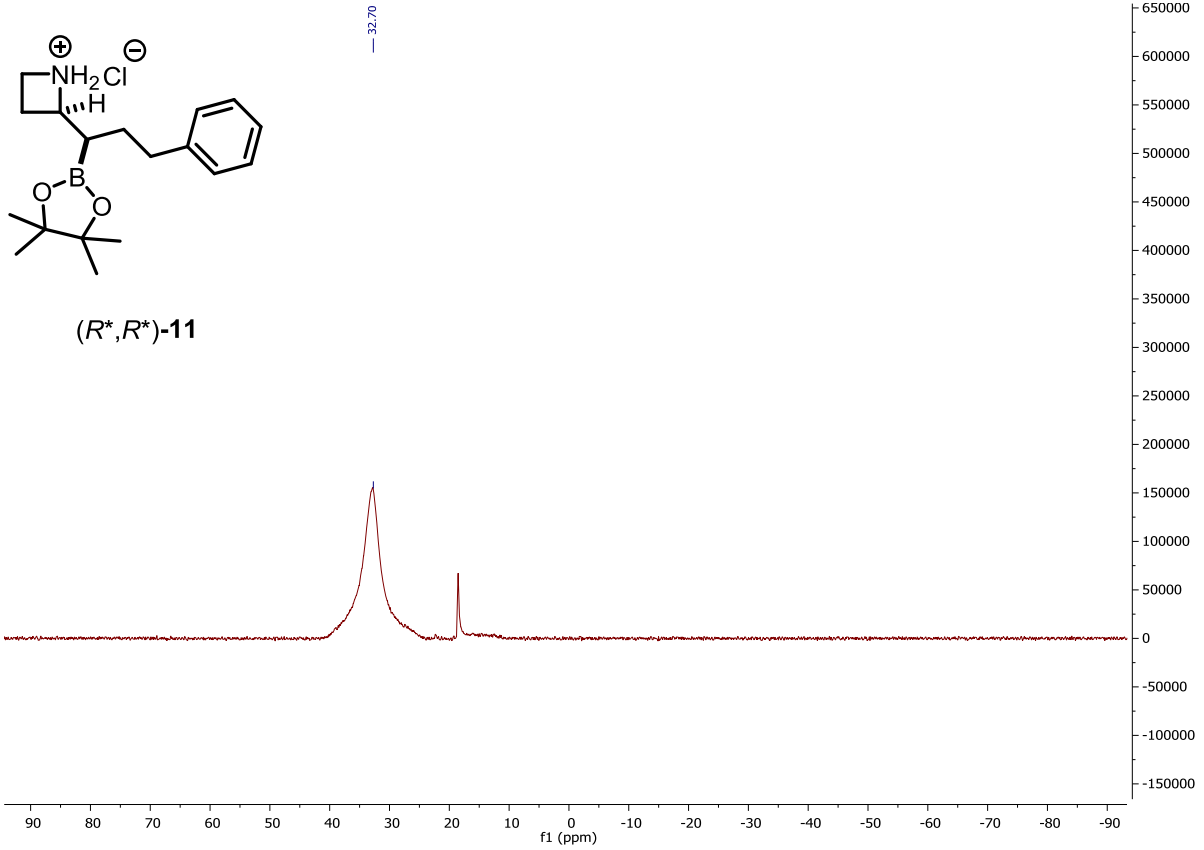
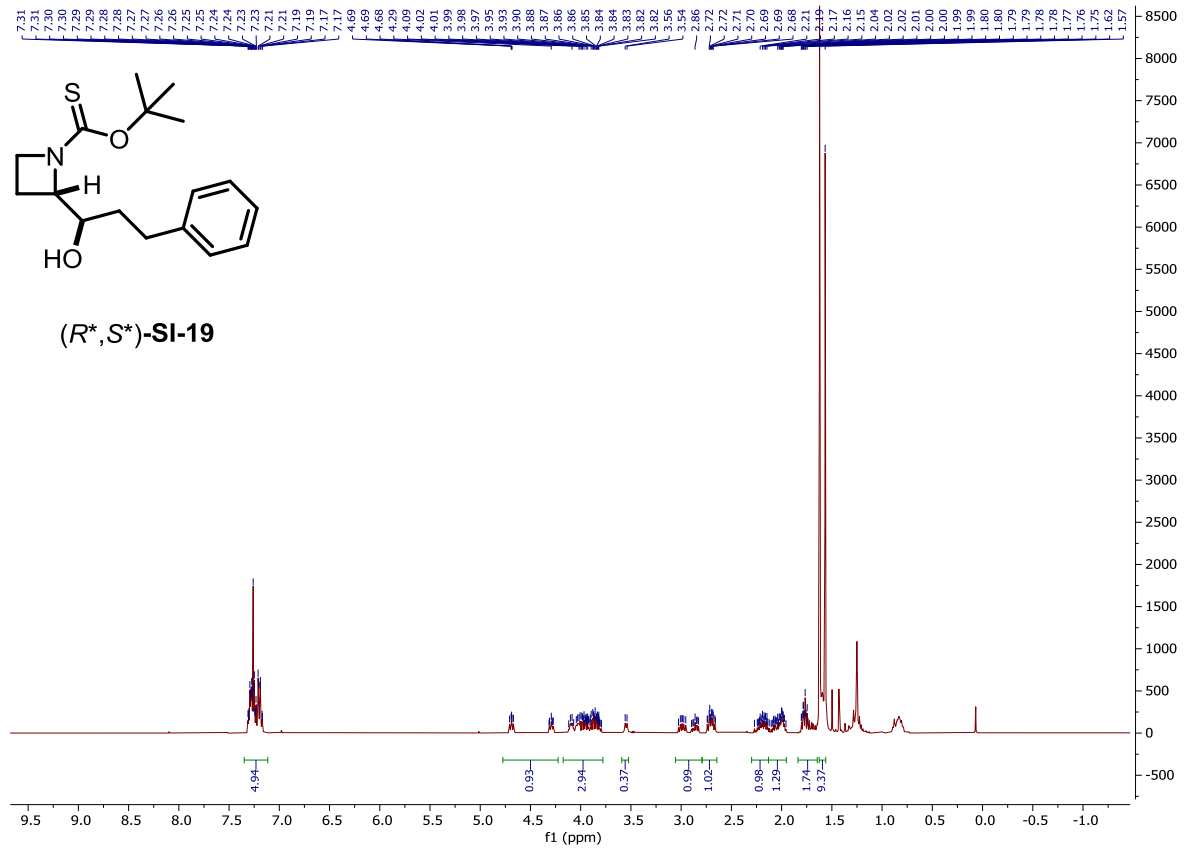
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

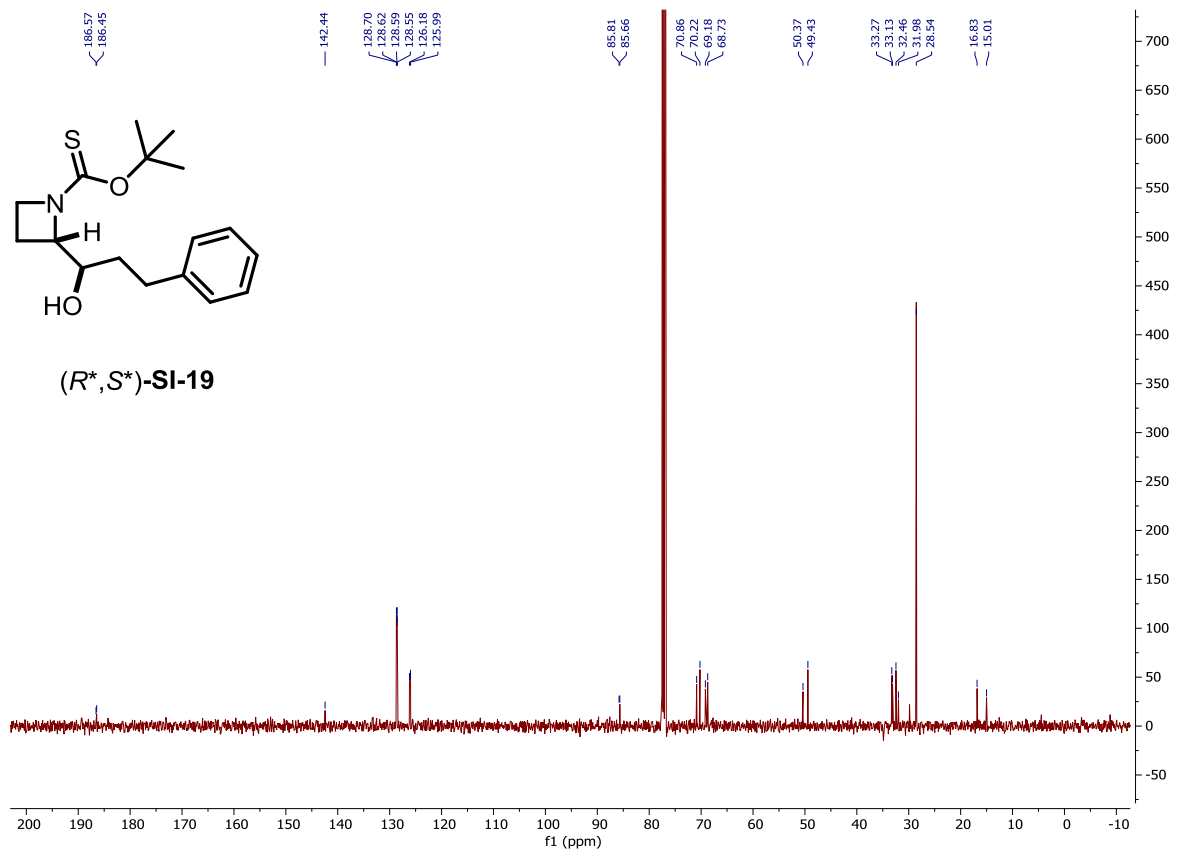
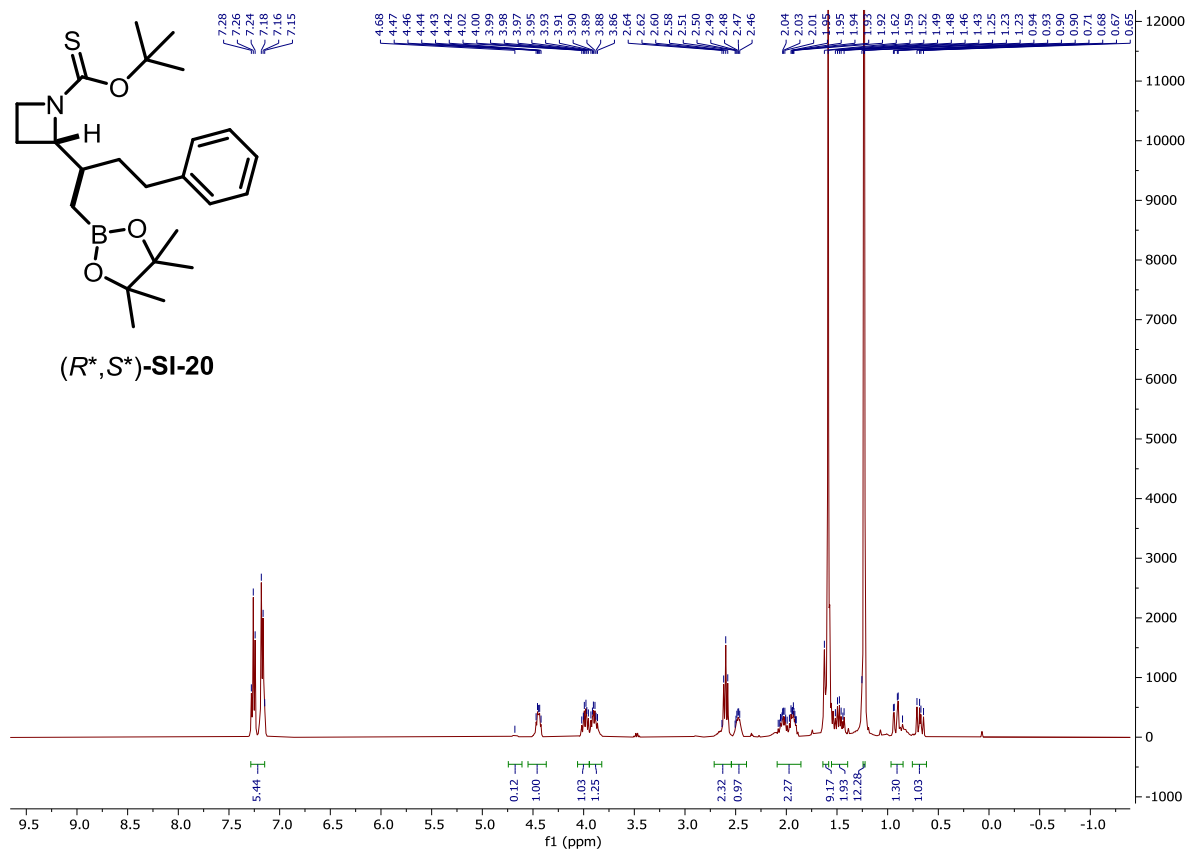
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ )

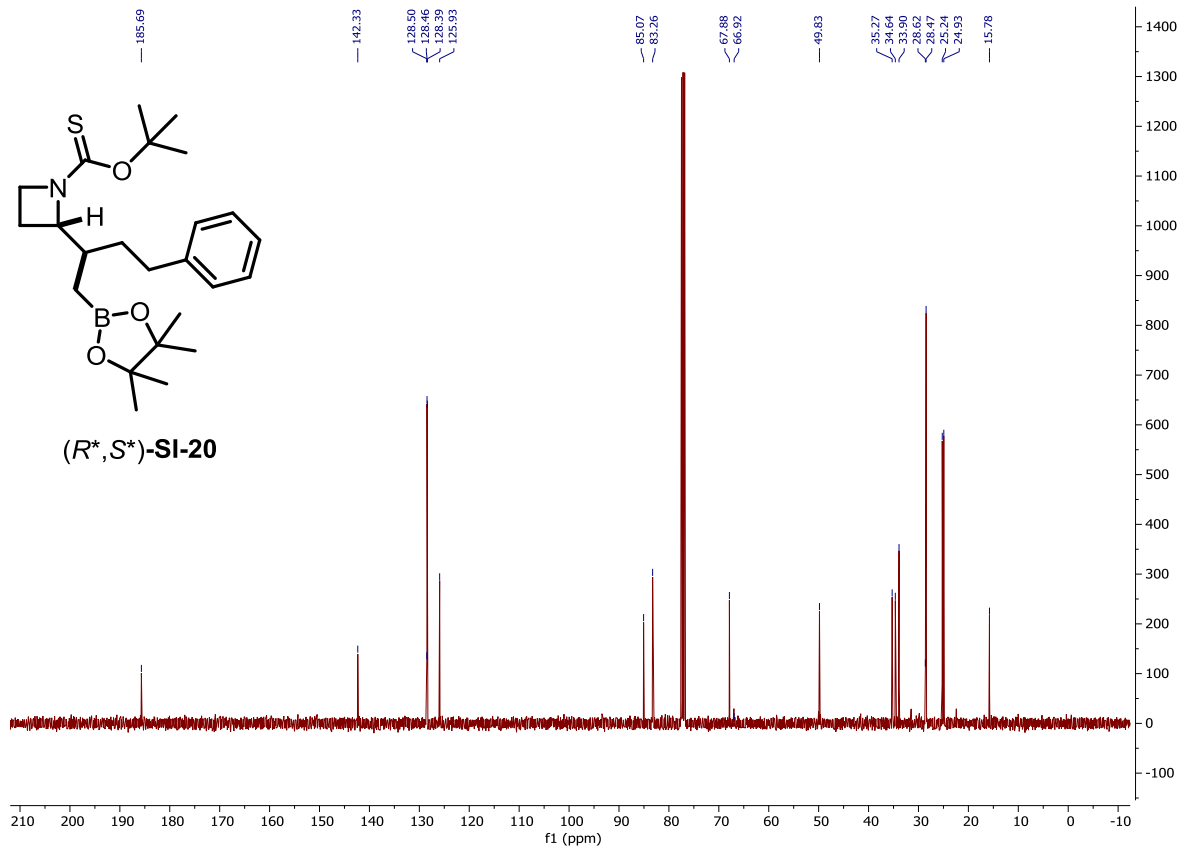
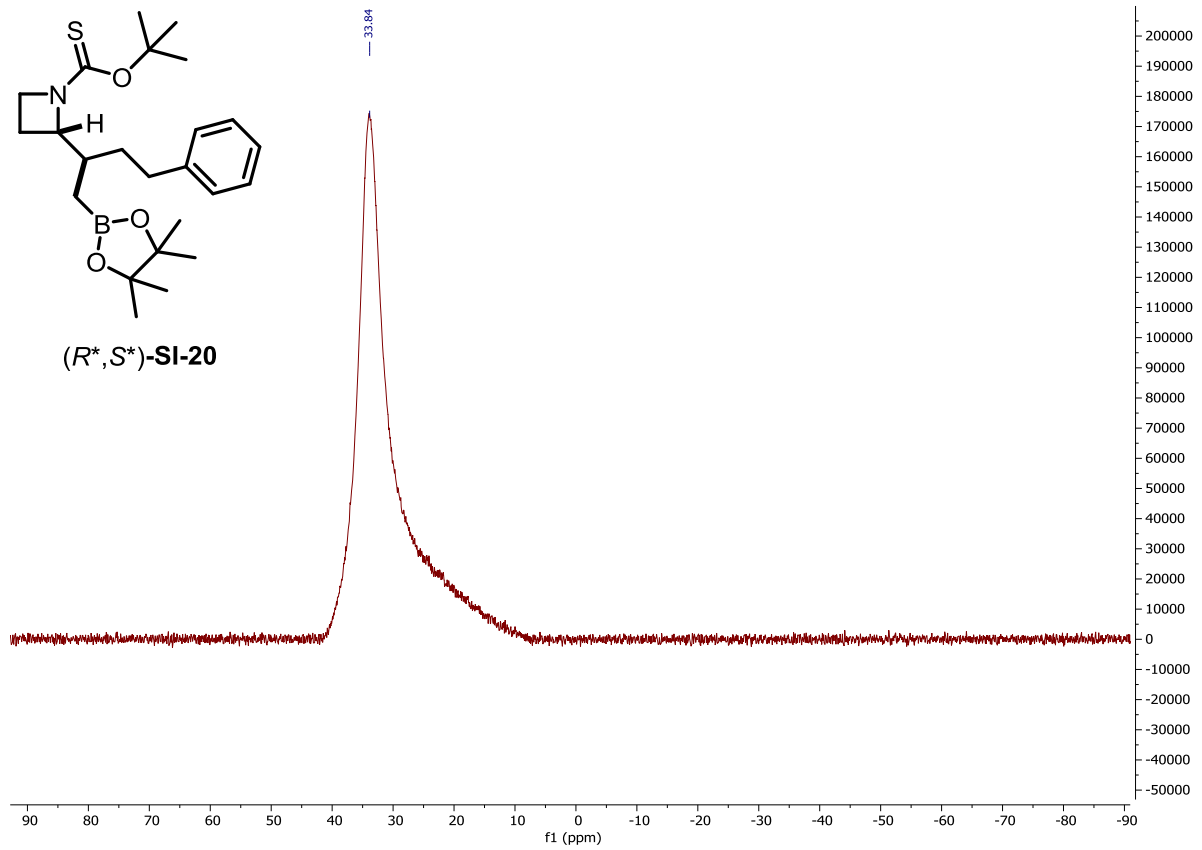


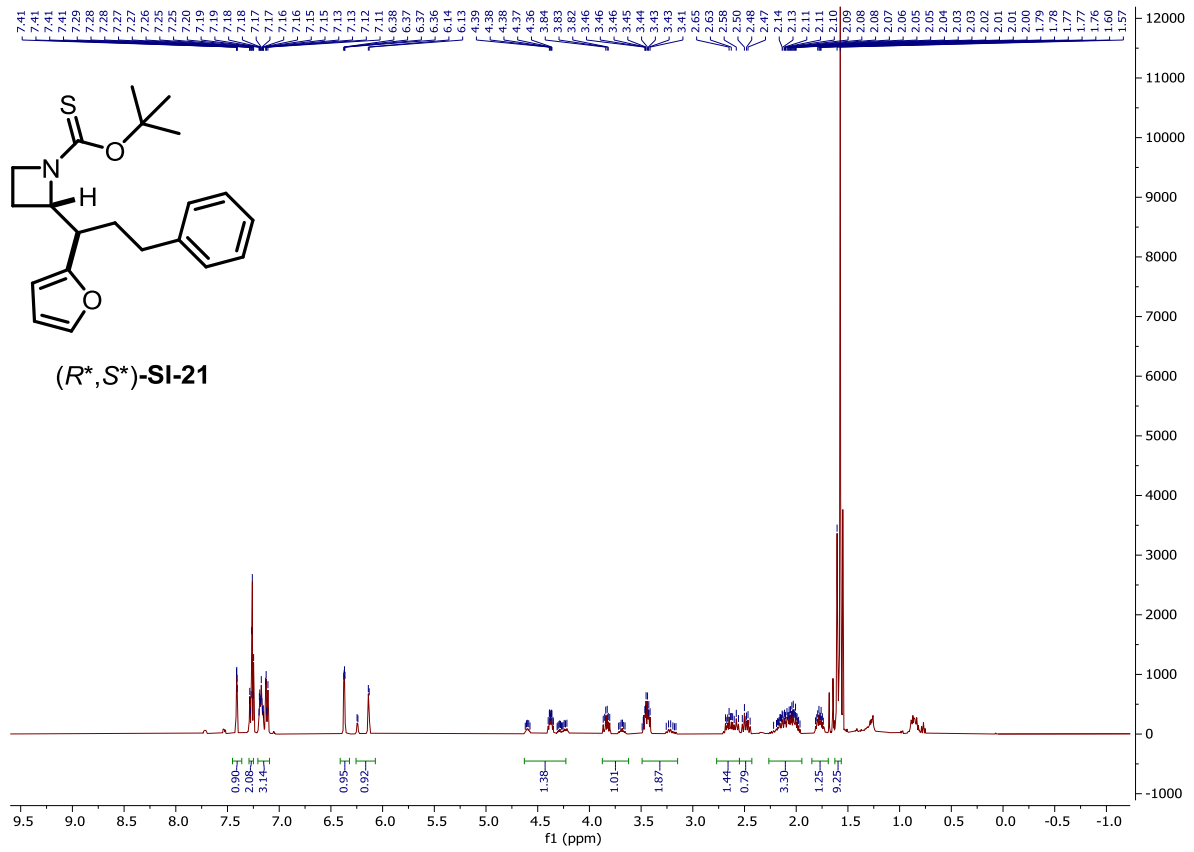
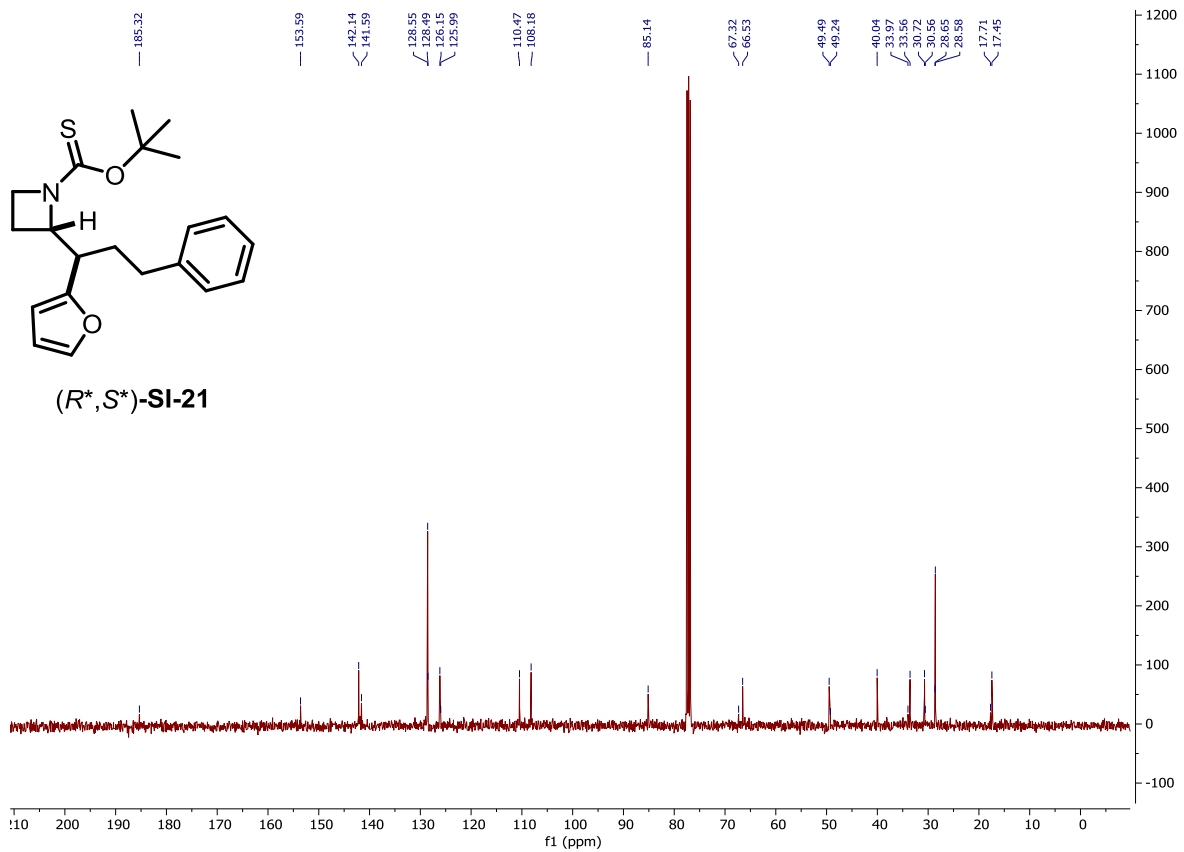
<sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)<sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>)

$^1\text{H}$  NMR (400 MHz,  $\text{CD}_3\text{OD}$ ) $^{13}\text{C}$  NMR (100 MHz,  $\text{CD}_3\text{OD}$ )

$^{11}\text{B}$  NMR (128 MHz,  $\text{CD}_3\text{OD}$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

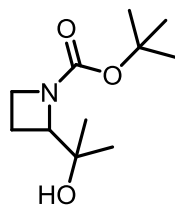
$^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ ) $^{11}\text{B}$  NMR (128 MHz,  $\text{CDCl}_3$ )

$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )

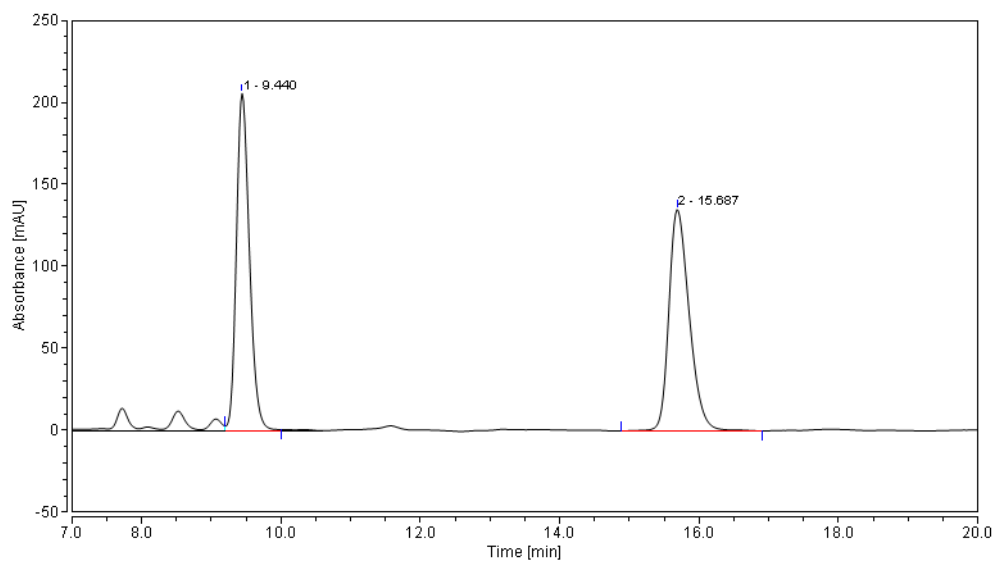
## 7. Chiral HPLC traces

## Racemic

**Chiral HPLC:** (Chiralpak ADH, 5% *i*-PrOH, 95% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 205 nm)  $\tau_R$  (*R*) = 9.4 min,  $\tau_R$  (*S*) = 15.7 min.

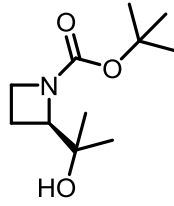
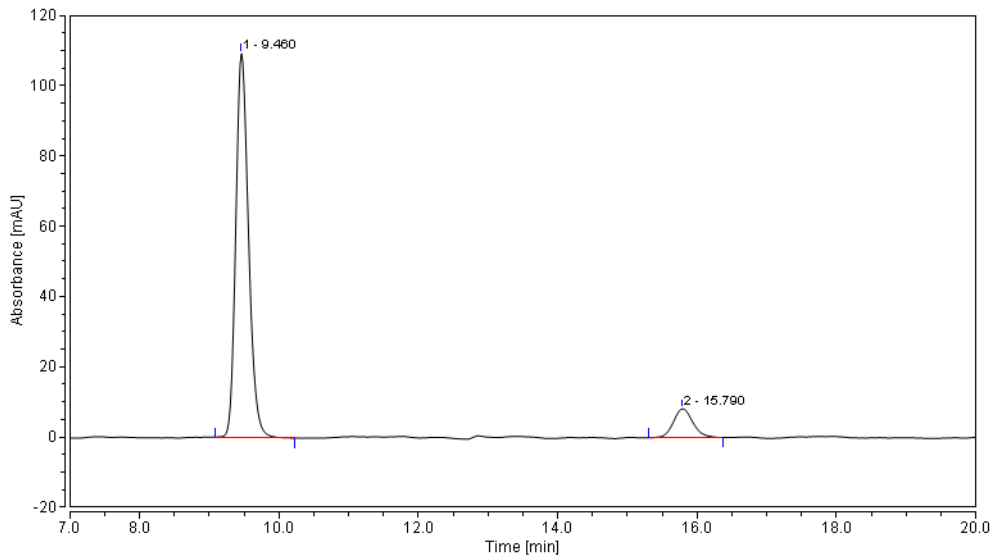


SI-2



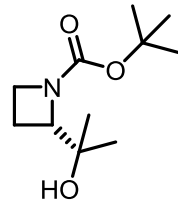
No.	Retention Time	Area	Height	Relative Area
	min	mAU*min	mAU	%
1	9.443	80.502	365.413	48.22
2	15.683	86.429	248.290	51.78
Total:		166.931	613.703	100.00

## Enantioenriched

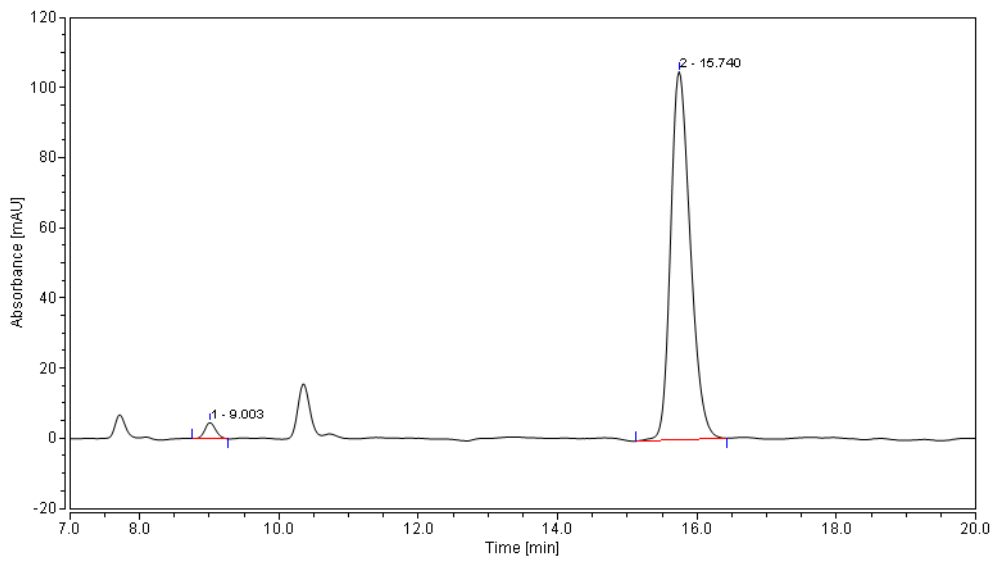
*(R)*-SI-2

No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		9.460	23.115	109.226	89.59
2		15.790	2.686	8.251	10.41
Total:			25.801	117.477	100.00

## Enantioenriched



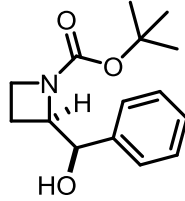
(S)-SI-2



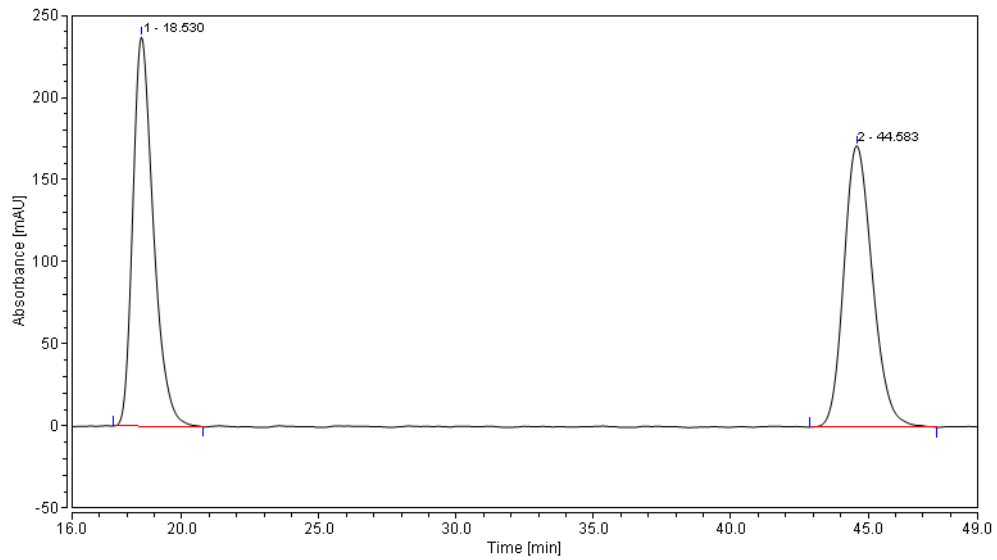
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		9.003	0.834	4.538	2.37
2		15.740	34.402	104.997	97.63
Total:			35.236	109.535	100.00

**Racemic**

**Chiral HPLC:** (Chiralpak ADH, 5% *i*-PrOH, 95% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 203 nm, 5  $\mu$ L injection)  $\tau_R$  (major) = 19.8 min,  $\tau_R$  (minor) = 46.0 min.

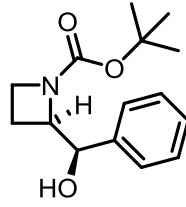
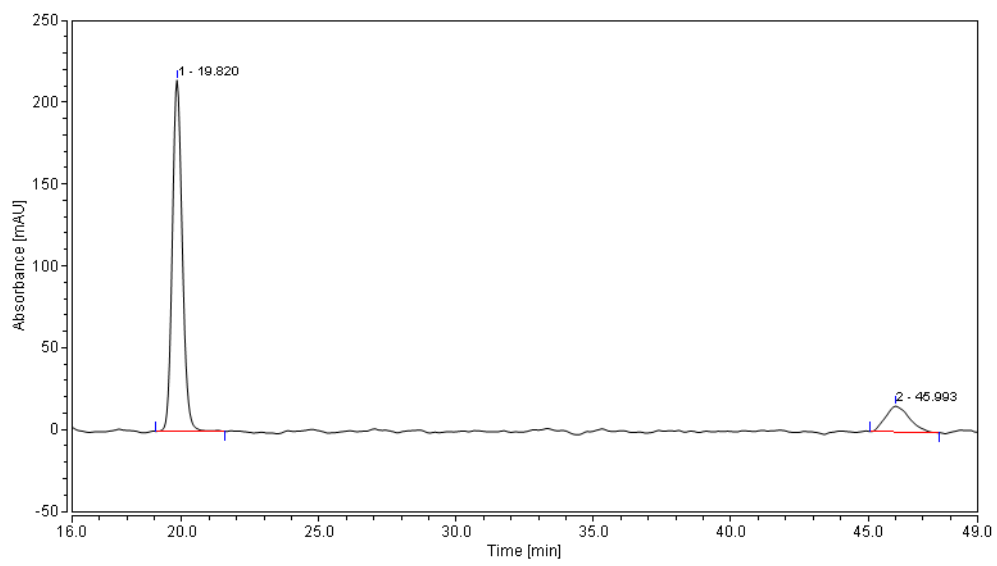


**(*R*<sup>\*</sup>,*R*<sup>\*</sup>)-SI-7**



No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		18.533	243.132	277.402	50.30
2		44.580	240.244	200.625	49.70
Total:			483.376	478.027	100.00

## Enantioenriched

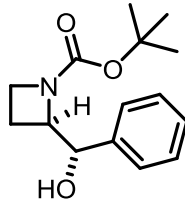
*(R,R)*-SI-7

No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		19.823	90.883	216.159	84.67
2		45.987	16.454	16.139	15.33
Total:			107.337	232.298	100.00

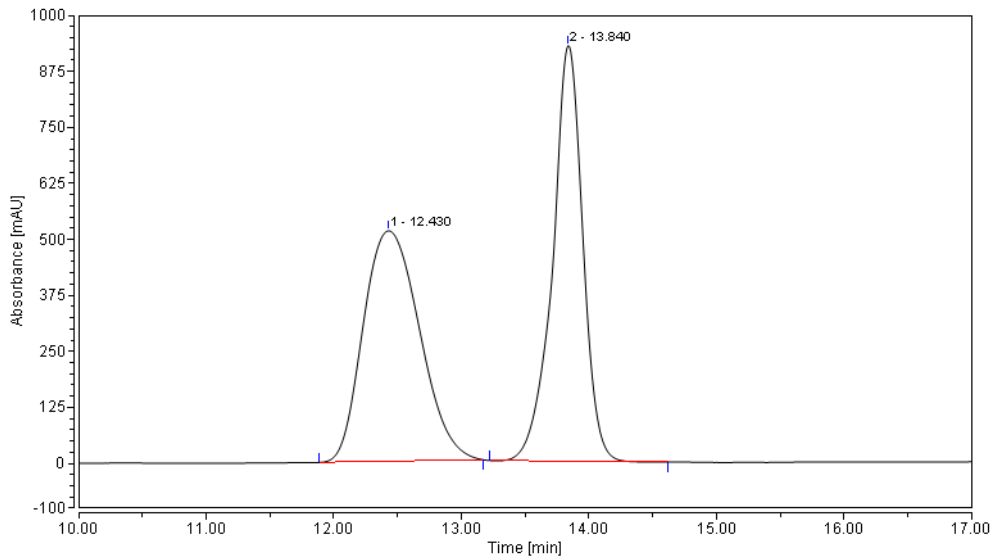
S111

**Racemic**

**Chiral HPLC:** (Chiralpak ADH, 5% *i*-PrOH, 95% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 206 nm, 15  $\mu$ L injection)  $\tau_R$  (major) = 12.3 min,  $\tau_R$  (minor) = 13.8 min.



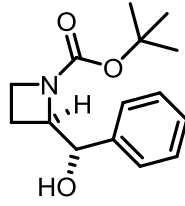
**(*R*\*,*S*\*)-SI-8**



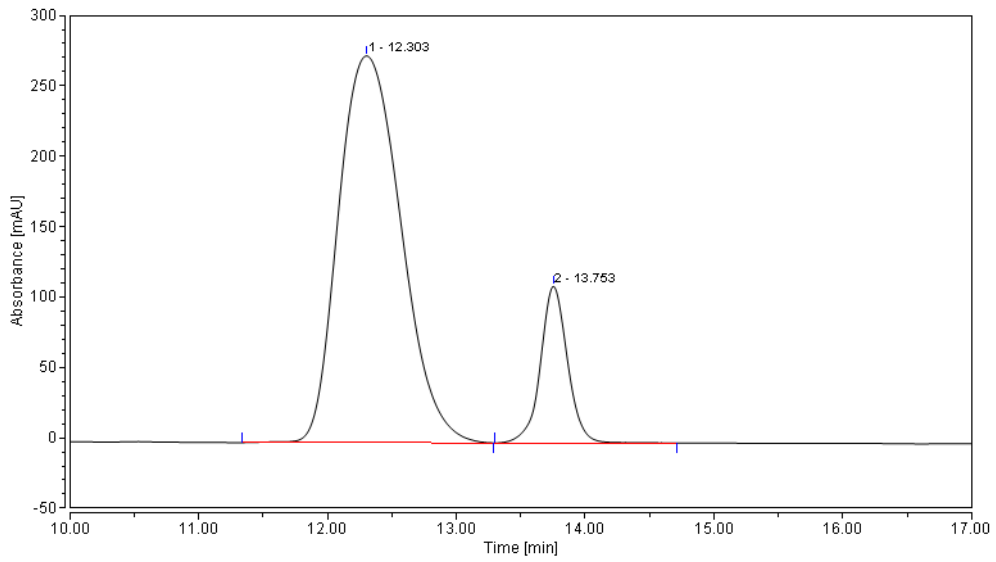
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		12.430	263.034	518.432	50.64
2		13.840	256.353	926.301	49.36
Total:			519.387	1444.733	100.00

S112

**Enantioenriched**



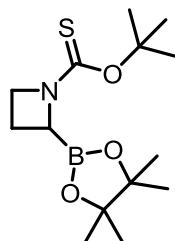
**(R,S)-SI-8**



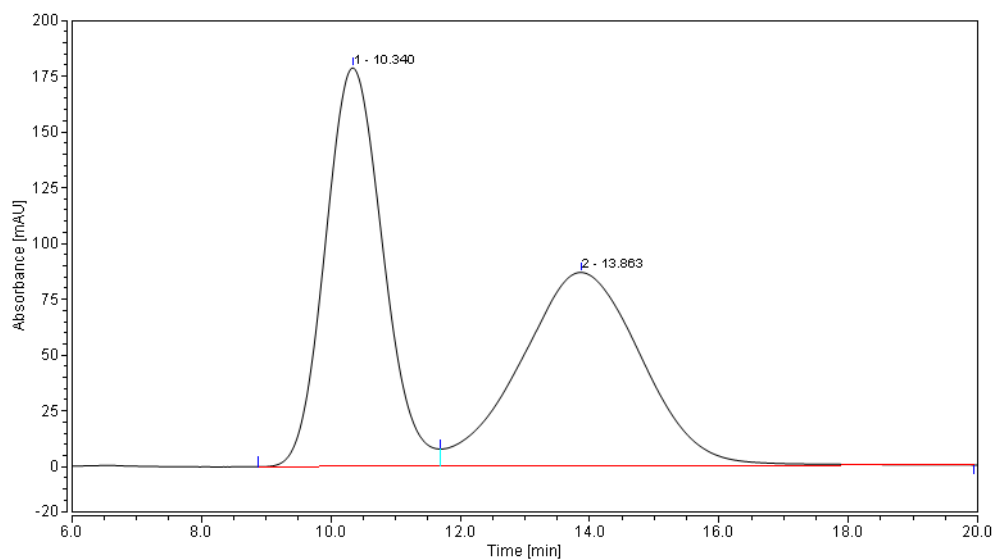
No.	Peak Name	Retention Time min	Area mAU*min	Height mAU	Relative Area %
1		12.303	154.644	274.793	85.09
2		13.753	27.103	111.267	14.91
Total:			181.747	386.061	100.00

## Racemic

**Chiral HPLC:** (Chiralpak ADH, 1% *i*-PrOH, 99% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 260 nm)  $\tau_R$  (major) = 13.9 min,  $\tau_R$  (minor) = 10.3 min.

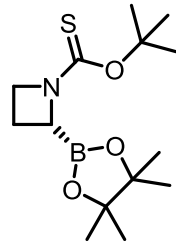


4

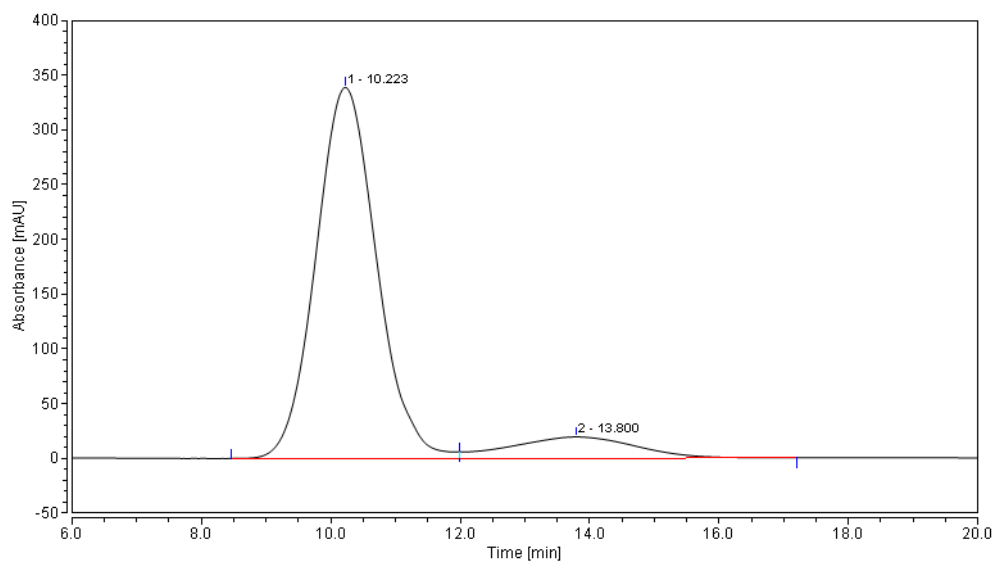


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		10.340	183.857	178.600	49.42
2		13.863	188.154	86.722	50.58
Total:			372.011	265.322	100.00

## Enantioenriched

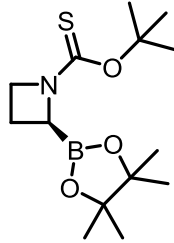


(R)-4

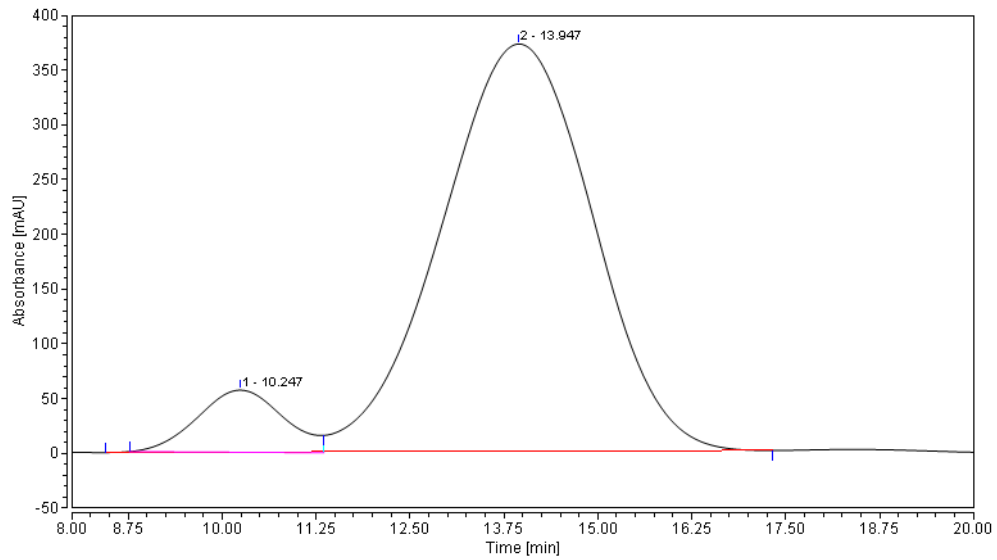


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		10.223	368.089	338.749	89.40
2		13.800	43.662	19.511	10.60
Total:			411.751	358.260	100.00

## Enantioenriched



(S)-4

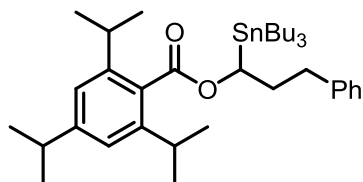


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		10.247	75.596	56.736	8.02
2		13.947	867.108	371.947	91.98
Total:			942.704	428.684	100.00

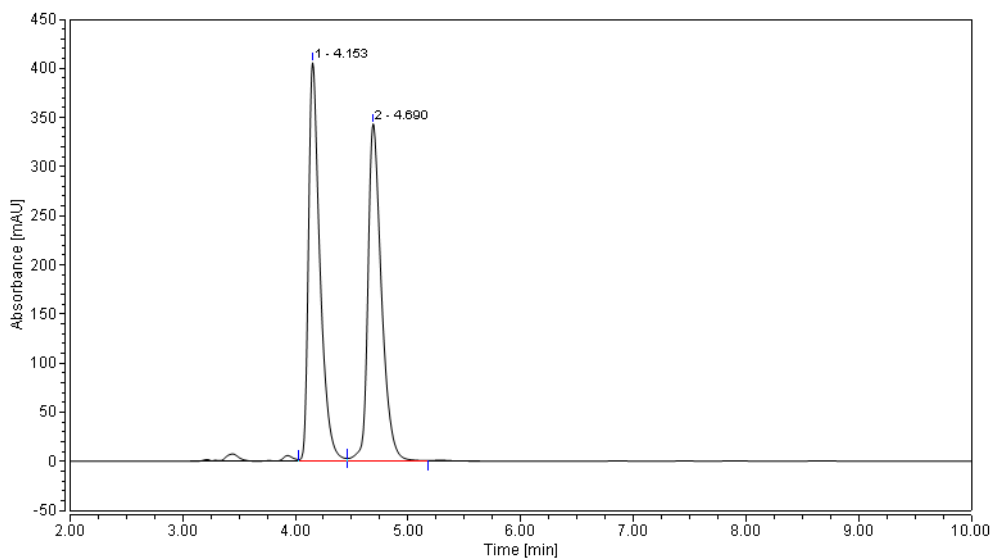
S116

**Racemic**

**Chiral HPLC:** (Chiralpak ODH, 100% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda = 242$  nm)  $\tau_R$  (major) = 4.1 min,  $\tau_R$  (minor) = 4.7 min.

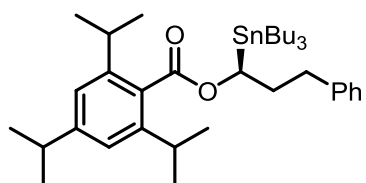


**SI-18**

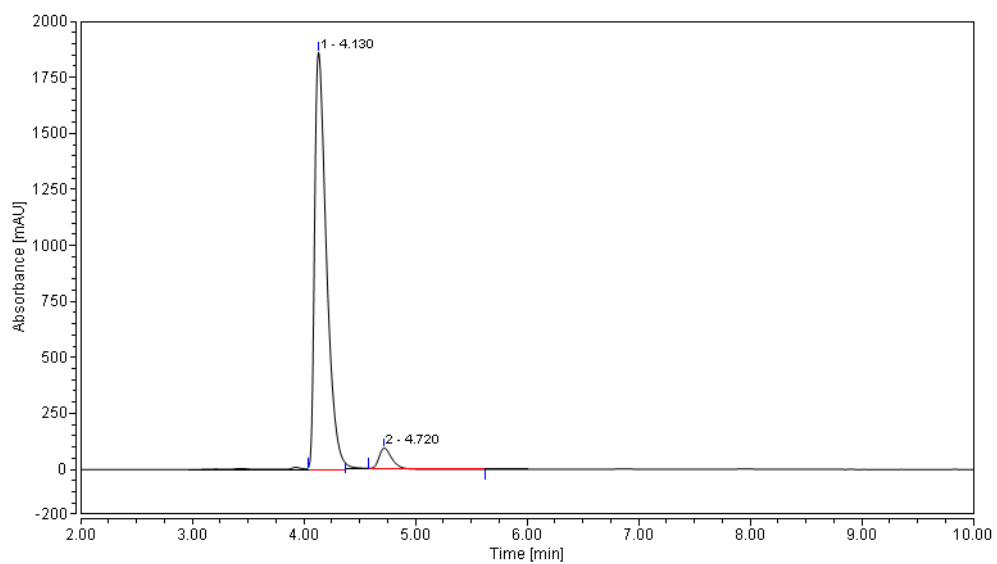


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		4.153	47.720	405.879	49.94
2		4.690	47.837	343.624	50.06
Total:			95.557	749.503	100.00

## Enantioenriched



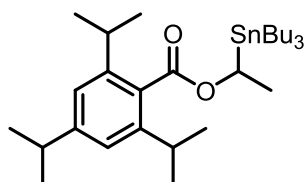
(S)-SI-18



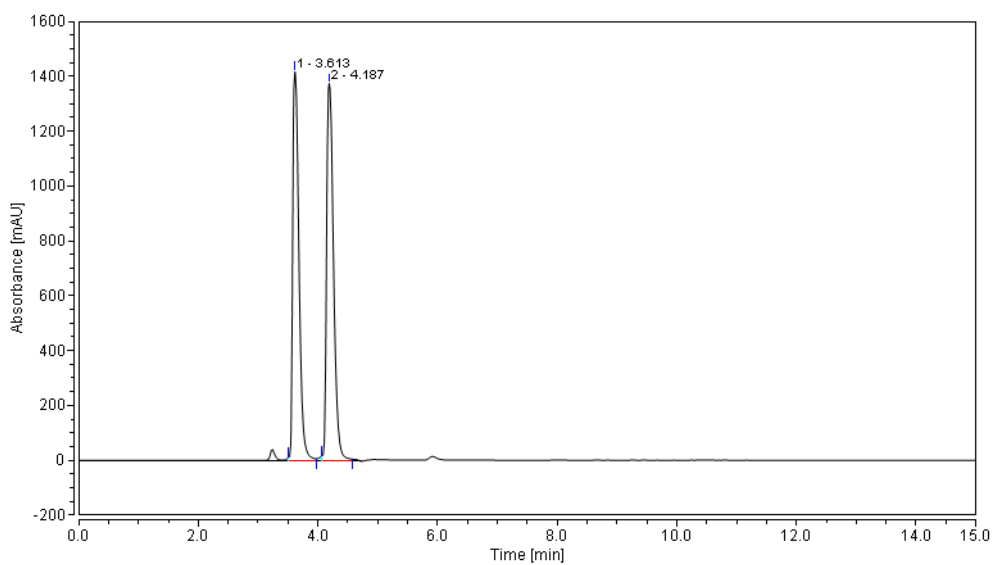
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		4.130	228.240	1861.960	94.39
2		4.720	13.568	95.950	5.61
Total:			241.809	1957.910	100.00

## Racemic

**Chiral HPLC:** (Chiralpak ODH, 100% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 267nm, 25  $\mu$ L injection)  $\tau_R$  (major) = 3.557 min,  $\tau_R$  (minor) = 4.110 min.

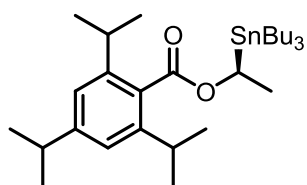


SI-22

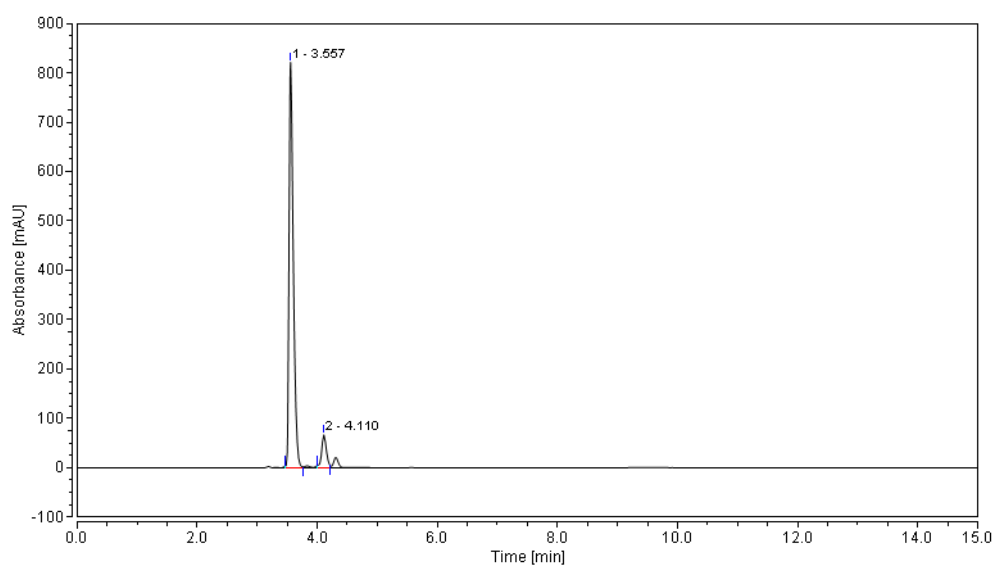


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1	3.613	172.537	1419.342	48.27	50.75
2	4.187	184.878	1377.335	51.73	49.25
Total:			357.414	2796.677	100.00

## Enantioenriched



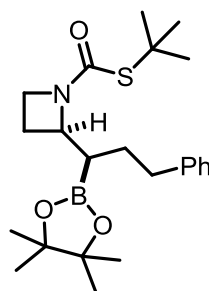
(S)-SI-22



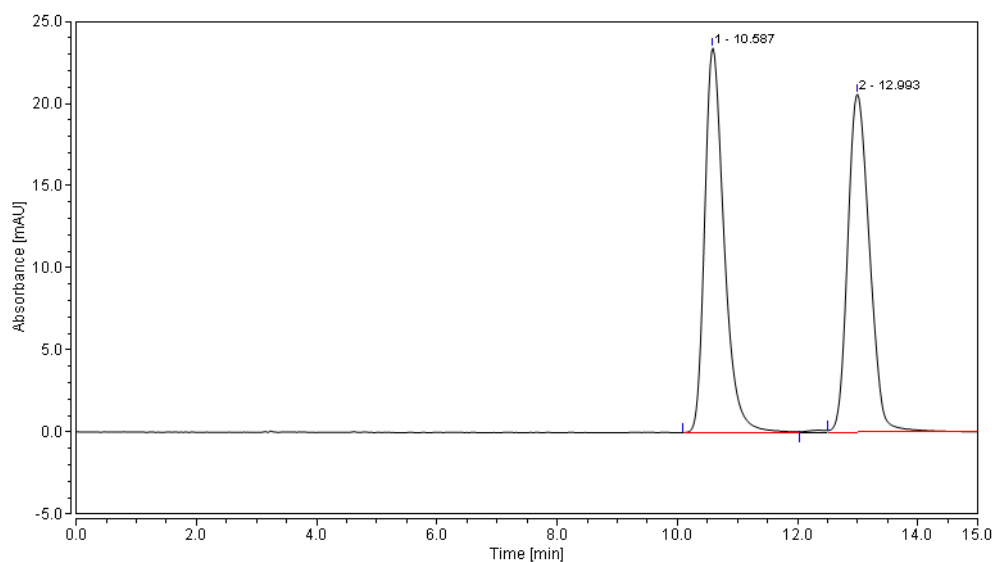
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		3.557	67.660	821.349	91.78
2		4.110	6.063	66.913	8.22
Total:			73.722	888.262	100.00

**Racemic**

**Chiral HPLC:** (Chiralpak ODH, 0.2% *i*-PrOH, 99.8% hexane, 1.0 mL min<sup>-1</sup>, λ = 266nm, 2 μL injection) τ<sub>R</sub> (minor) = 10.587 min, τ<sub>R</sub> (major) = 12.993 min.



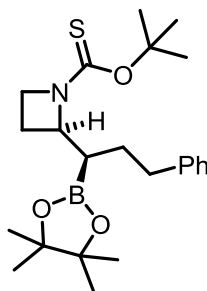
**(*R*<sup>\*</sup>,*R*<sup>\*</sup>)-5a**



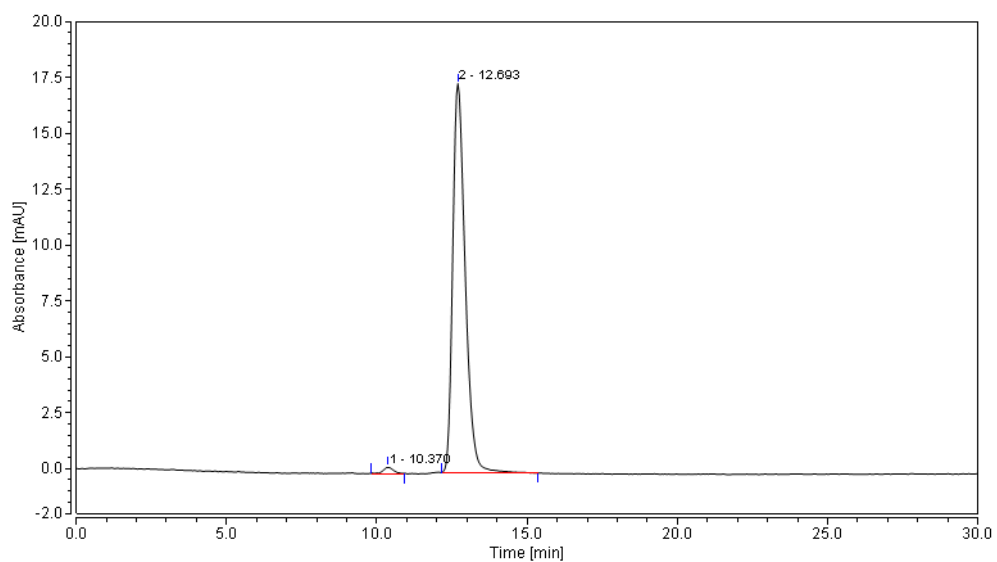
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		10.590	10.246	27.518	50.64
2		12.993	9.985	24.079	49.36
Total:			20.231	51.597	100.00

S121

Enantioenriched



(*R,R*)-5a

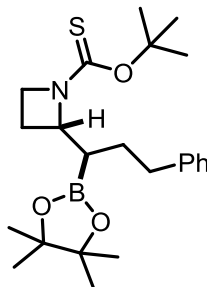


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		10.370	0.124	0.340	1.25
2		12.690	9.800	20.444	98.75
Total:			9.924	20.783	100.00

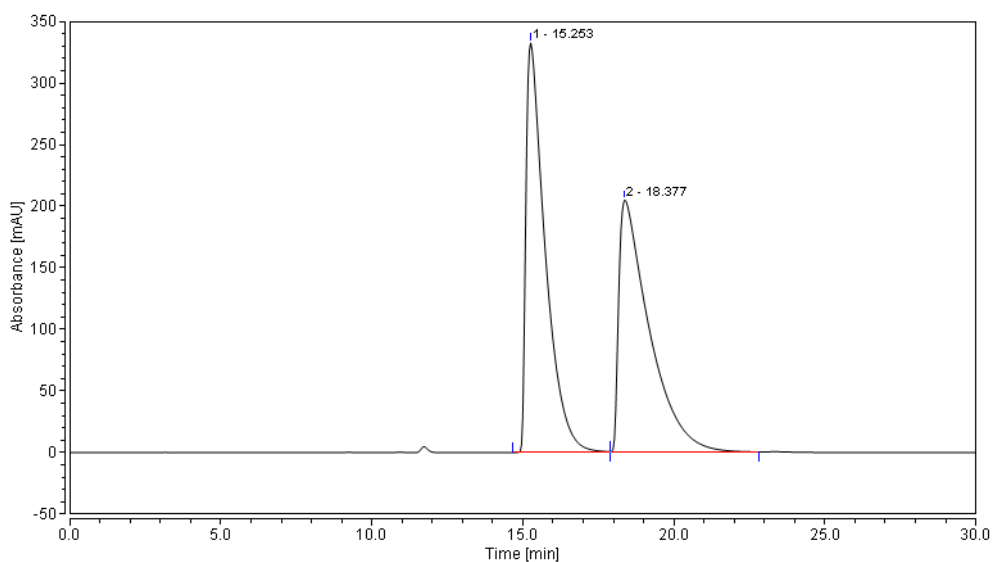
**Racemic**

**Chiral HPLC:** (Chiralpak ODH, 0.1% *i*-PrOH, 99.9% hexane, 1.0 mL min<sup>-1</sup>, λ = 266 nm, 50 μL injection)

τ<sub>R</sub> (minor) = 15.253 min, τ<sub>R</sub> (major) = 18.377 min.



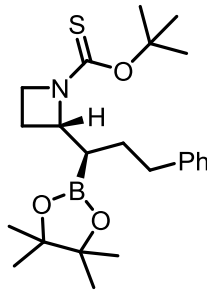
**(*R*\*, *S*\*)-5a'**



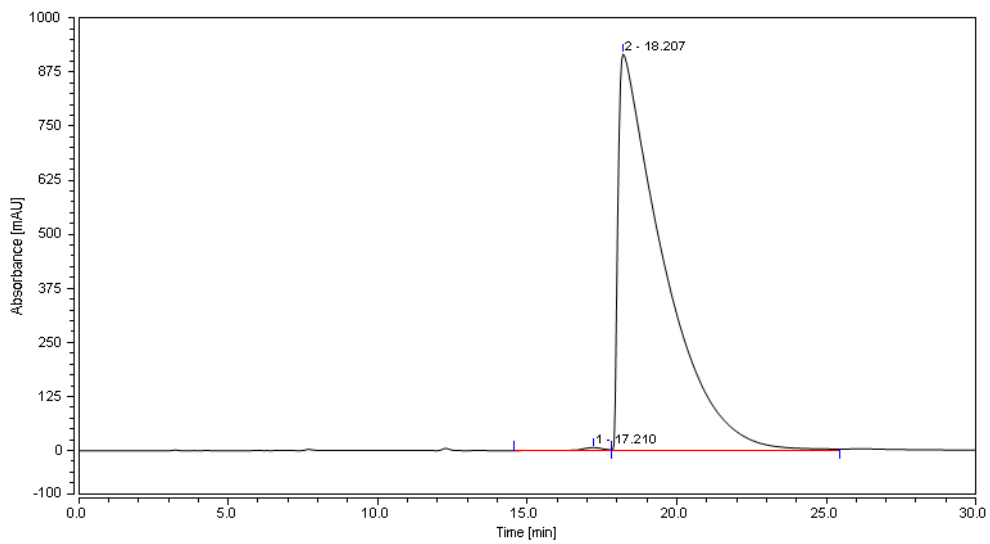
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		15.253	246.885	332.492	50.63
2		18.377	240.752	205.072	49.37
Total:			487.637	537.564	100.00

S123

Enantioenriched



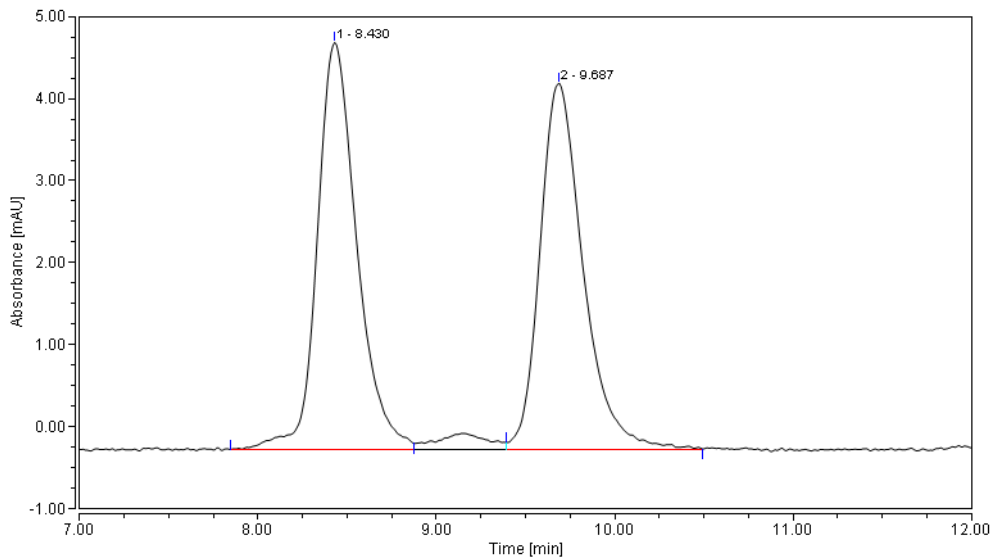
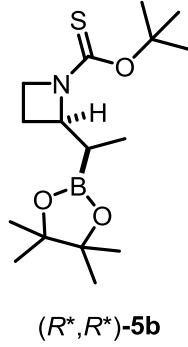
(*S,R*)-5a'



No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		17.210	5.596	6.872	0.35
2		18.207	1591.452	916.535	99.65
Total:			1597.048	923.407	100.00

**Racemic**

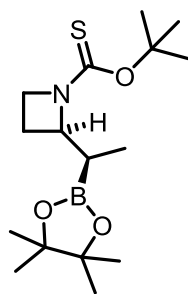
**Chiral HPLC:** (Chiralpak ODH, 0.1% *i*-PrOH, 99.9% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 250m, 5  $\mu$ L injection)  $\tau_R$  (major) = 9.687 min,  $\tau_R$  (minor) = 8.430 min.



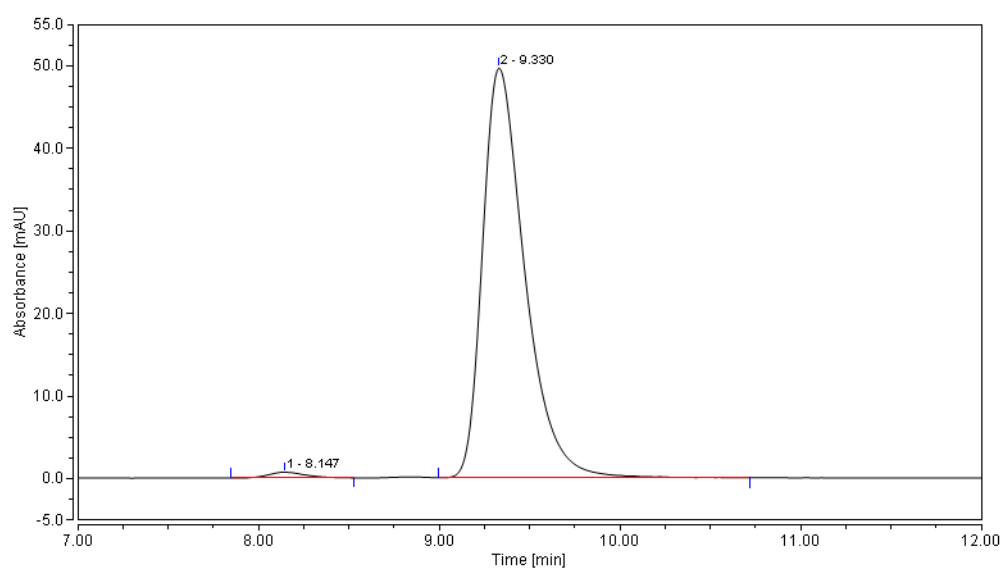
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		8.430	1.273	4.957	50.53
2		9.687	1.246	4.455	49.47
Total:			2.518	9.413	100.00

S125

**Enantioenriched**



**(R,R)-5b**

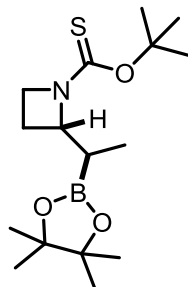


No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		8.147	0.168	0.696	1.24
2		9.330	13.431	49.613	98.76
Total:			13.599	50.309	100.00

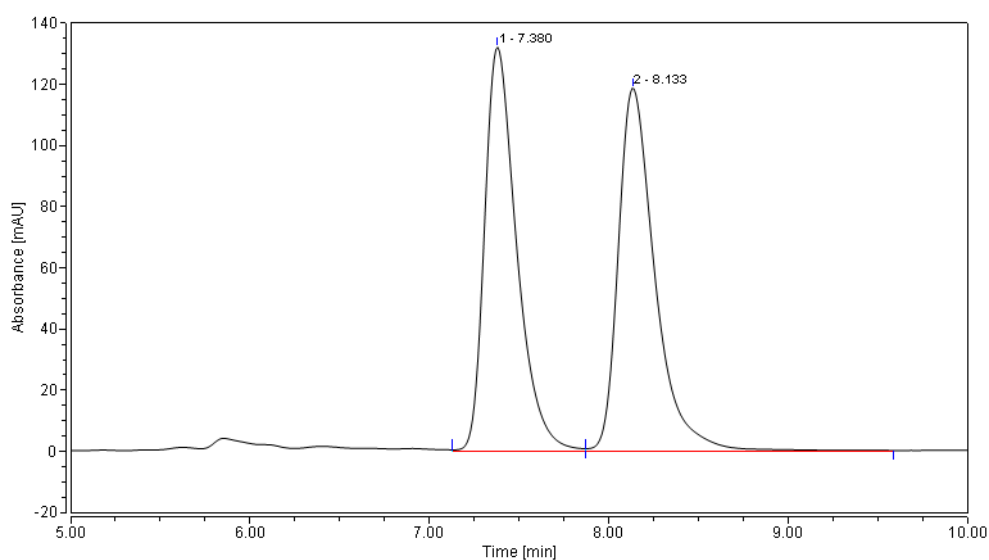
**Racemic**

**Chiral HPLC:** (Chiralpak ODH, 0.1% *i*-PrOH, 99.9% hexane, 1.0 mL min<sup>-1</sup>, λ = 250 nm, 50 μL injection)

τ<sub>R</sub> (major) = 7.360 min, τ<sub>R</sub> (minor) = 8.133 min.



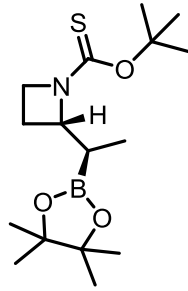
**(*R*<sup>\*</sup>,*S*<sup>\*</sup>)-5b'**



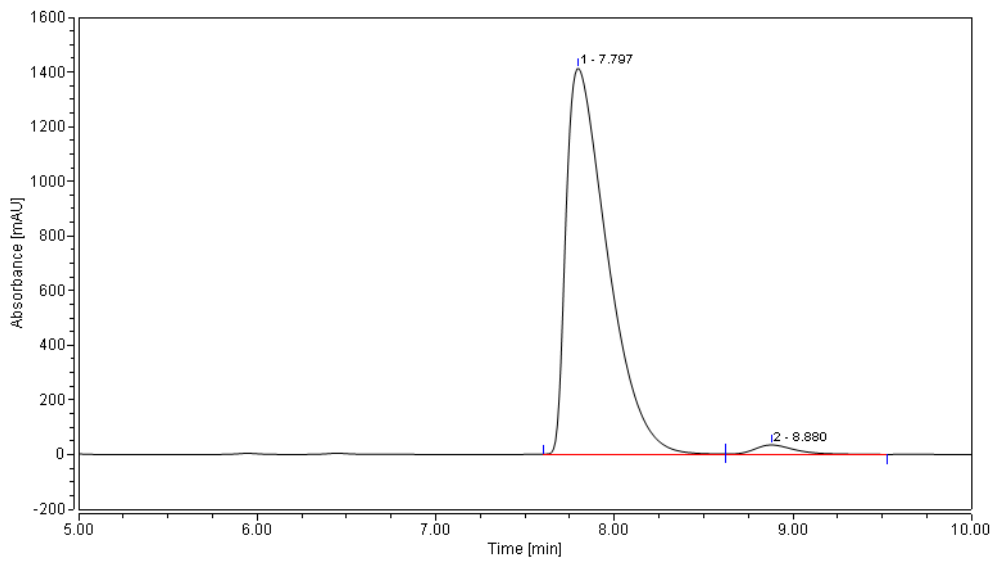
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		7.380	27.308	132.035	49.33
2		8.133	28.047	118.694	50.67
Total:			55.355	250.729	100.00

S127

Enantioenriched



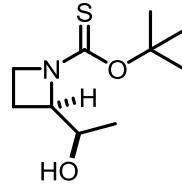
(*S,R*)-**5b'**



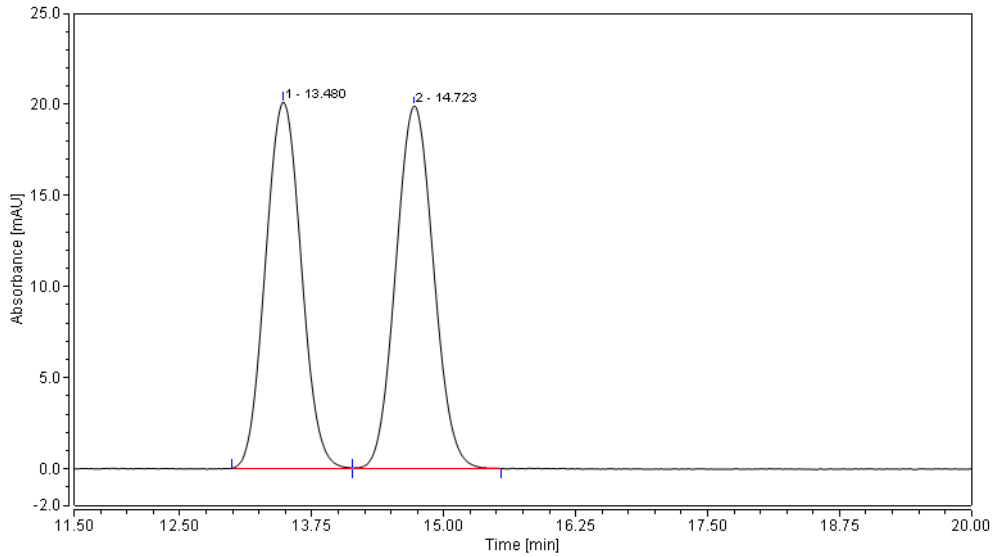
No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		7.797	379.821	1413.818	97.51
2		8.880	9.717	35.201	2.49
Total:			389.539	1449.020	100.00

**Racemic**

**Chiral HPLC:** (Chiralpak ADH, 3% *i*-PrOH, 97% hexane, 1.0 mL min<sup>-1</sup>, λ = 260 nm) τ<sub>R</sub> (major) = 14.7 min, τ<sub>R</sub> (minor) = 13.5 min.

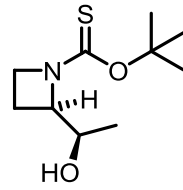
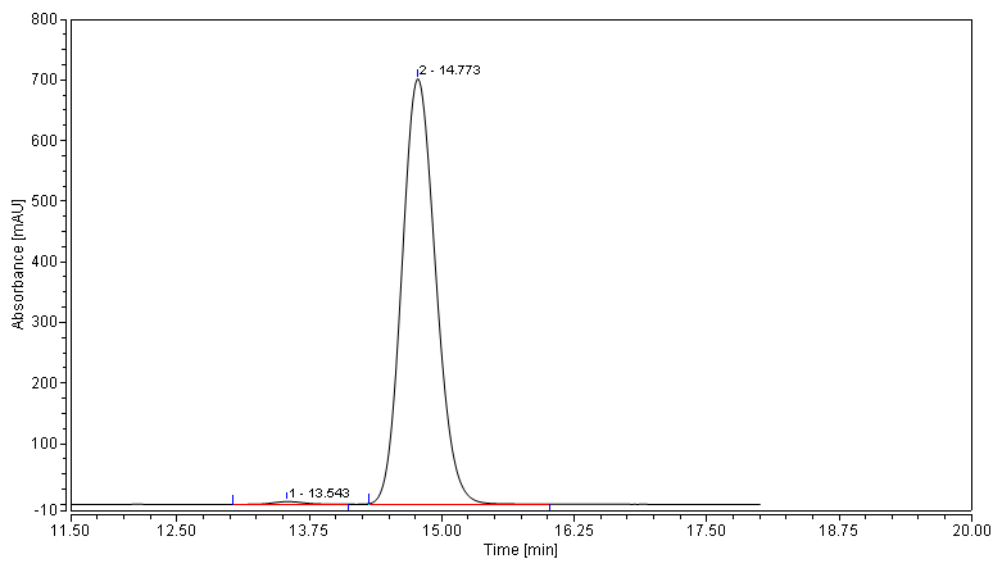


**(*R*<sup>\*</sup>,*R*<sup>\*</sup>)-SI-12**



No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		13.480	7.889	20.117	48.92
2		14.723	8.236	19.899	51.08
Total:			16.126	40.016	100.00

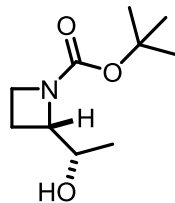
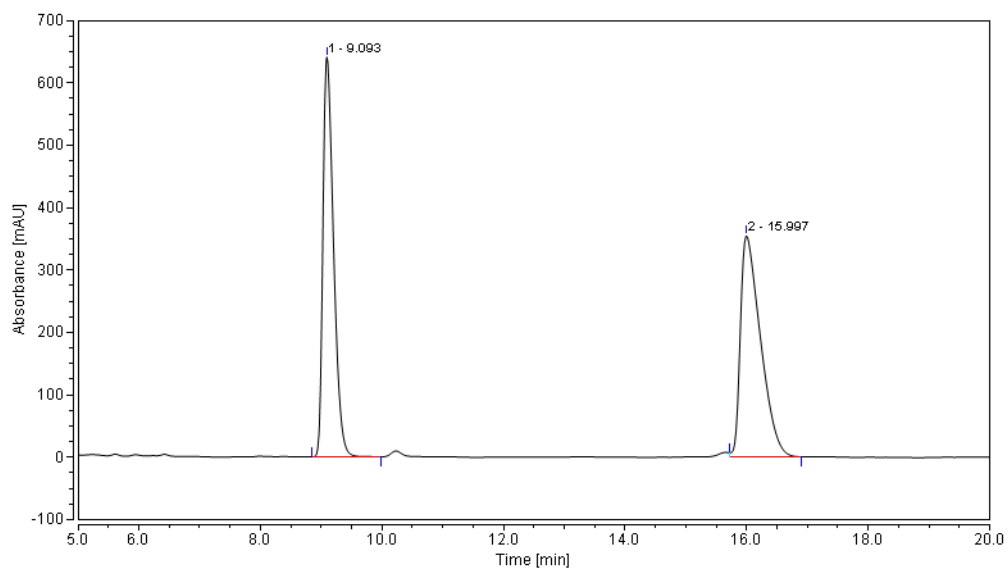
## Enantioenriched

**(R,R)-SI-12**

No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		13.543	1.534	4.539	0.59
2		14.773	258.857	701.866	99.41
Total:			260.391	706.405	100.00

## Racemic

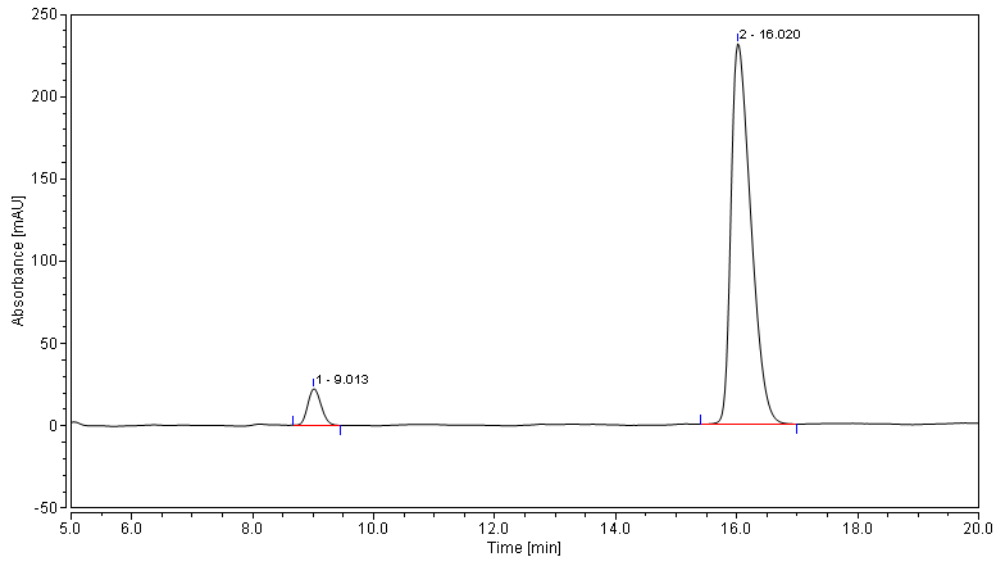
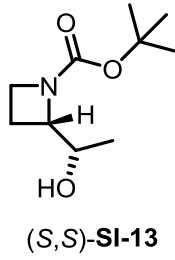
**Chiral HPLC:** (Chiralpak ADH, 5% *i*-PrOH, 95% hexane, 1.0 mL min<sup>-1</sup>,  $\lambda$  = 210nm, 25  $\mu$ L injection)  $\tau_R$  (major) = 9.0 min,  $\tau_R$  (minor) = 16.0 min.

**(*R*<sup>\*</sup>,*R*<sup>\*</sup>)-SI-13**

No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		9.093	129.860	641.077	48.98
2		15.997	135.286	354.724	51.02
Total:			265.146	995.802	100.00

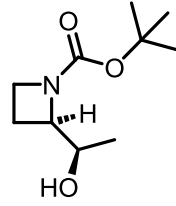
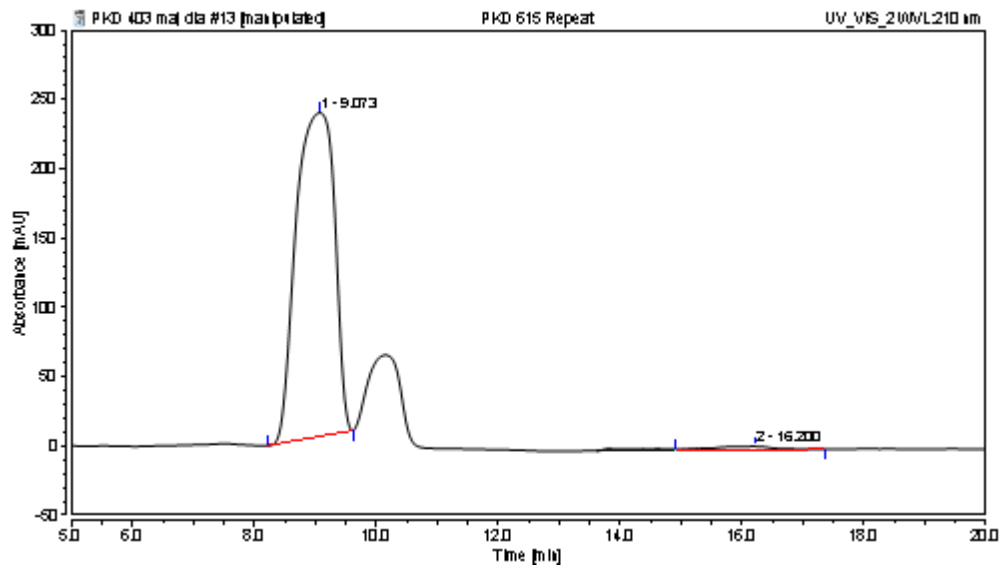
S131

**Enantioenriched**



No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1		9.013	5.684	22.238	6.05
2		16.020	88.332	231.758	93.95
Total:			94.015	253.996	100.00

## Enantioenriched

**(R,R)-SI-13**

No.	Peak Name	Retention Time	Area	Height	Relative Area
		min	mAU*min	mAU	%
1	9.073	170.410	233.504	98.19	98.97
2	16.200	3.142	2.437	1.81	1.03
Total:		173.552	235.941	100.00	100.00