

Supporting information for:

FLP-catalysis meets hydrogen-bond activation

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1 General information

1.1 Synthesis and techniques

Preparation of substrates was carried out in oven dried glassware and, if necessary, under an atmosphere of inert gas (Argon 5.0, AIR LIQUIDE) employing common SCHLENK line techniques. Catalytic reactions were prepared in a GLOVEBOX SYSTEMS inert atmosphere glovebox in Teflon cap sealed J. YOUNG NMR tubes. For high pressure NMR scale experiments a MAN ON THE MOON Millireactor was used. Deuterated solvents were degassed by 3 freeze-pump-thaw cycles and stored over 3 Å molecular sieves. Molecular sieves were activated at 280 °C under vacuum and stored under inert atmosphere. The following abbreviations for solvents were used: Ethyl acetate (EA), cyclohexane (CH).

1.2 Reagents and materials

All commercially available reagents were purchased from SIGMA ALDRICH, ABCR or TCI CHEMICALS and were used as received without further purification unless stated otherwise. $B(C_6F_5)_3$ (**1a**) was purchased from BOULDER SCIENTIFIC COMPANY and used as received. $B(2,4,6-F_3-C_6H_2)_3$ (**1b**) and $B(2,6-F_2-C_6H_3)_3$ (**1c**) were prepared as described earlier^[S11]. The chiral amidine bases (*S*)-*N,N*-bis-(1-phenylethyl)*tert*-butylamidine (**2a**) and (*S*)-*N,N*-bis-(1-phenylethyl)benzamidine (**2b**) were synthesized according to literature procedure^[S12]. Hydrogen 6.0 was provided by AIR LIQUIDE and used without further purification (for high pressure experiments) or purified through JOHNSON MATTHEY Model HIG 35XL gas purifier (for NMR scale experiments).

1.3 Characterization

1H , ^{13}C , ^{19}F and ^{11}B NMR spectra were recorded on a Bruker AV 300 (300 MHz), a Bruker AV 500 (500 MHz) spectrometer or a Bruker Ascend 700 (700 MHz) as solutions. Chemical shifts are expressed in parts per million (ppm, δ) downfield from tetramethylsilane (TMS) and are referenced to the residual solvent signal of C_6D_6 (7.16 ppm for 1H NMR, 128.06 ppm for ^{13}C NMR) or $CDCl_3$ (7.26 ppm for 1H NMR, 77.16 ppm for ^{13}C NMR). ^{11}B NMR and ^{19}F NMR spectra are referenced to $BF_3 \cdot OEt_2$ and $CFCl_3$, respectively. All coupling constants (J) are absolute values and are expressed in Hertz (Hz). The spectra were analyzed according to first order and the descriptions of the signals include: s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, dd = doublet of doublets, etc. Exact assignments of signals were done under consideration of $^1H, ^1H$ -COSY, $^1H, ^{13}C$ -HSQC-, $^1H, ^{13}C$ -HMBC-, and DEPT135-spectra. The

following abbreviations were used: CH₃ = primary (RCH₃), CH₂ = secondary (R₂CH₂), CH = tertiary (R₃CH), Cq = quaternary (R₄C), H_{Ar} = aromatic hydrogen, H_{Alk} = alkyl hydrogen. For analytical HPLC at chiral stationary phase for the determination of enantiomeric excess (ee) a VARIAN 920-LC was used with the following capillary column: CHIRALCEL IA, CHIRALCEL IB. Optical rotation was measured on an Anton Paar MCP5100.

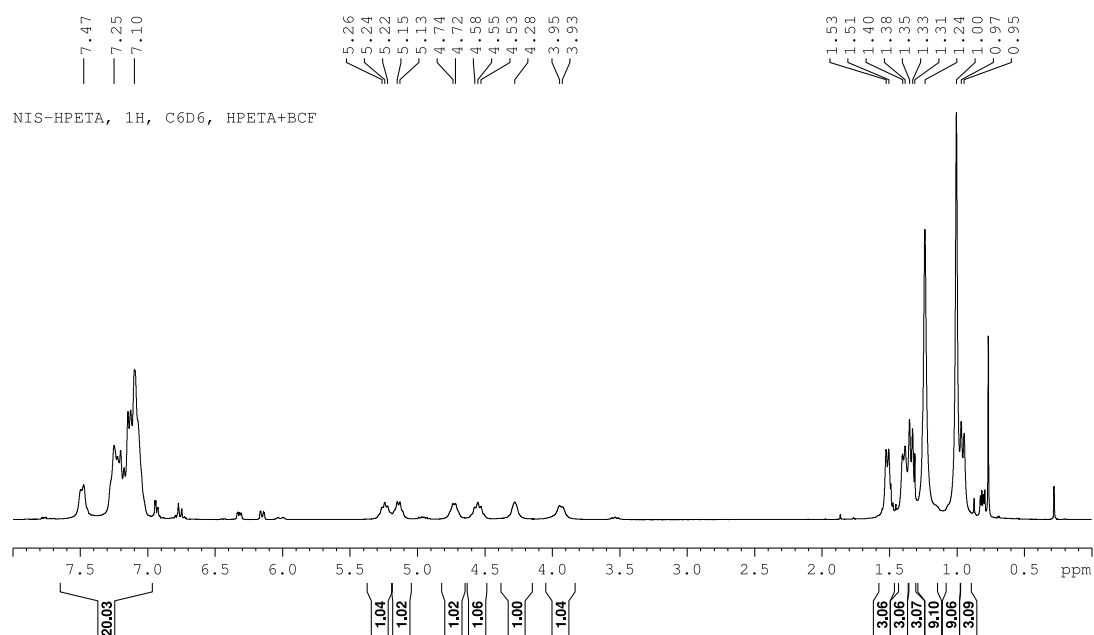
2 Interaction studies

2.1 General procedure

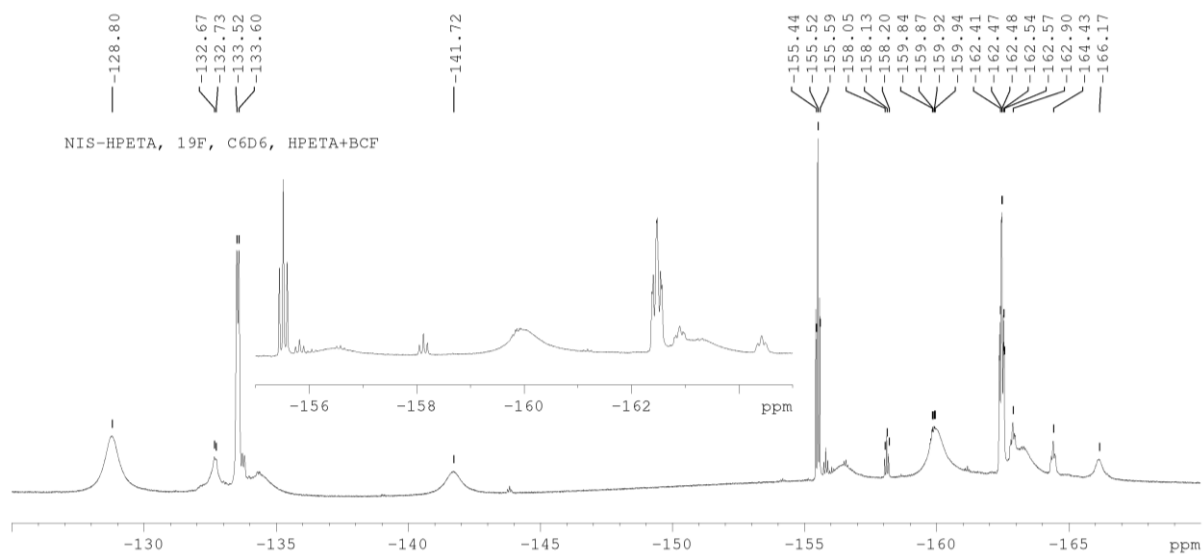
In a glove box chiral amidine base (25.0 μmol, 1.00 equiv.) and borane (25.0 μmol, 1.00 equiv.) were dissolved in 0.6 mL C₆D₆ and transferred to a J. YOUNG NMR tube with teflon tap. The investigation of the interaction was done by ¹H- and ¹¹B-NMR spectroscopy. The sample was then frozen in liquid nitrogen, the headspace was evacuated and the sample was charged with hydrogen at -196 °C. After sealing and thawing, the hydrogen pressure inside the sample reached approximately 4 bar. The sample was then heated to 90 °C on a shaking plate to ensure hydrogen exchange. After 18 h the NMR tube was cooled to room temperature and the reaction mixture was analyzed by ¹H- and ¹¹B-NMR spectroscopy.

2.2 Borane/amidine Lewis pair 1a/2a

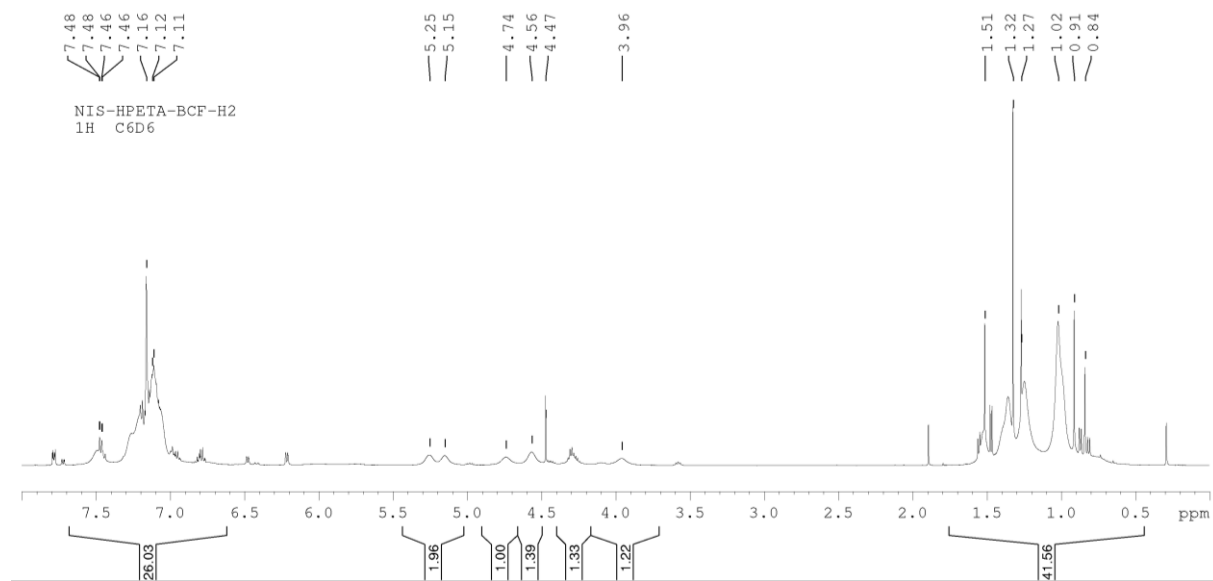
¹H-NMR (300 MHz, 298 K, C₆D₆) before applying 4 bar H₂-pressure:



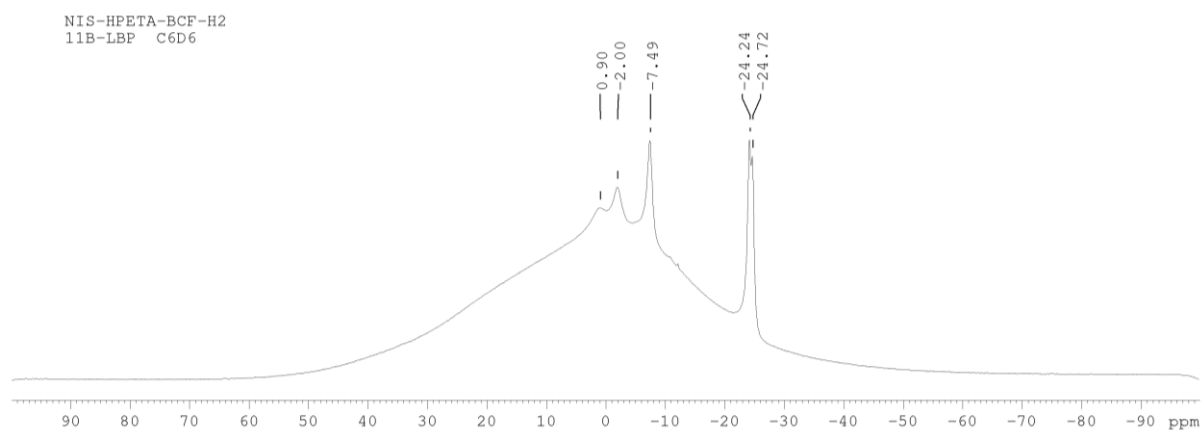
^{19}F -NMR (282 MHz, 298 K, C_6D_6) before applying 4 bar H_2 -pressure:



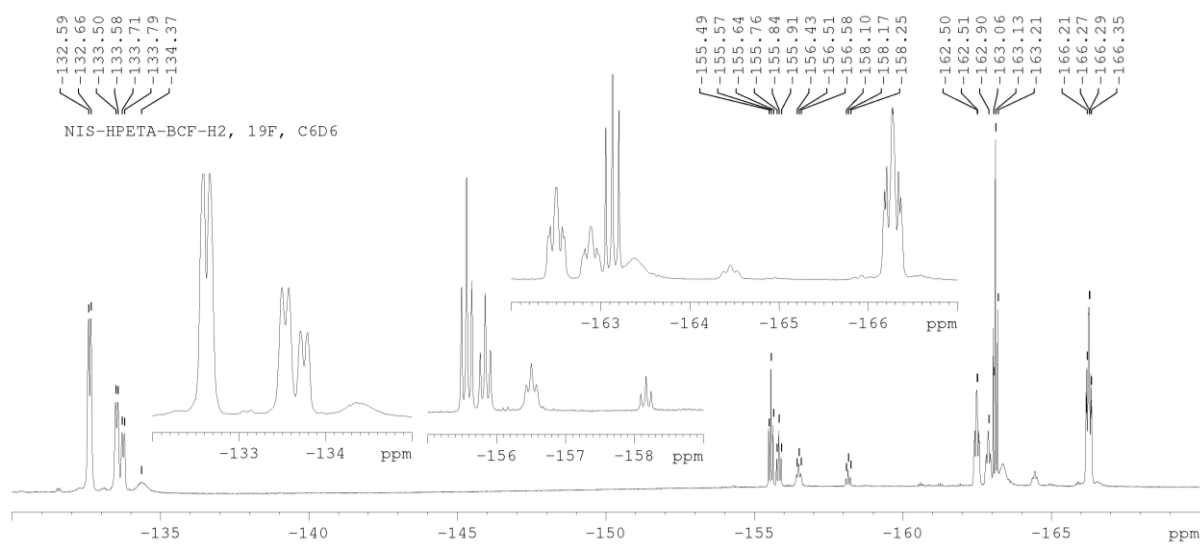
^1H -NMR (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:



^{11}B -NMR (160 MHz, 303 K, C_6D_6) after 18 h at 90 °C:

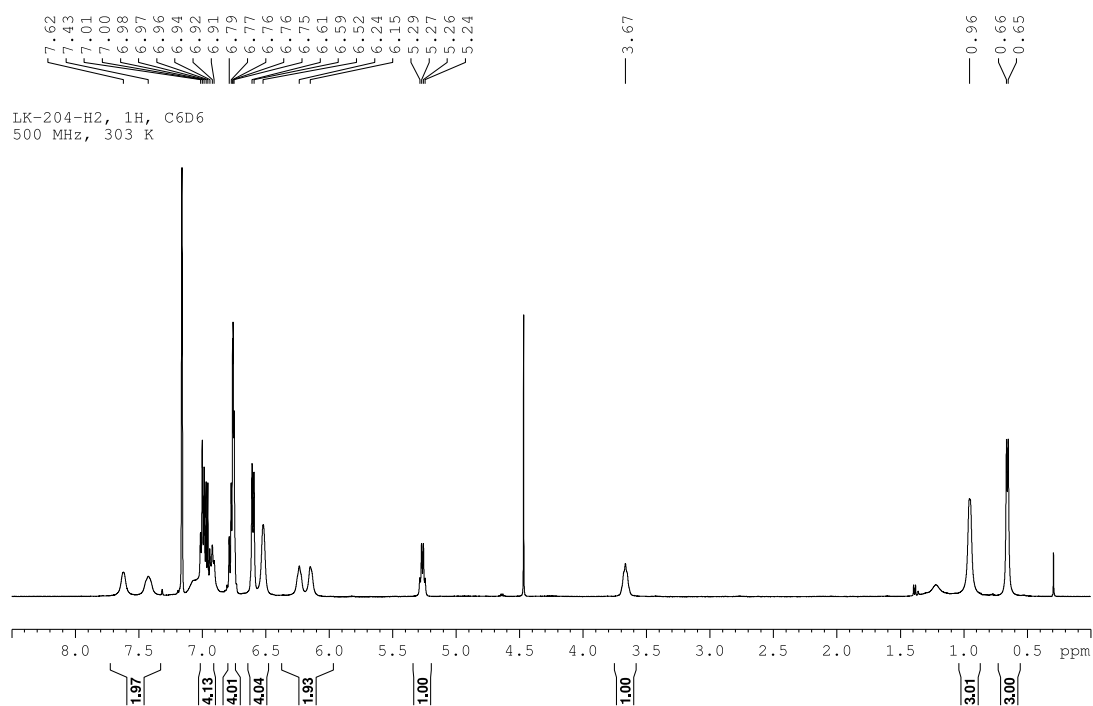


^{19}F -NMR (282 MHz, 298 K, C_6D_6) after 18 h at 90 °C:

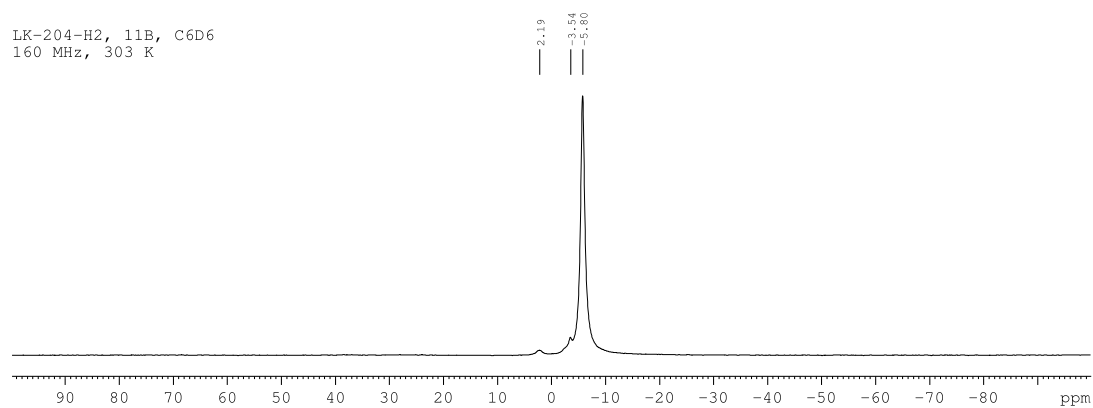


2.3 Borane/amidine Lewis pair 1a/2b

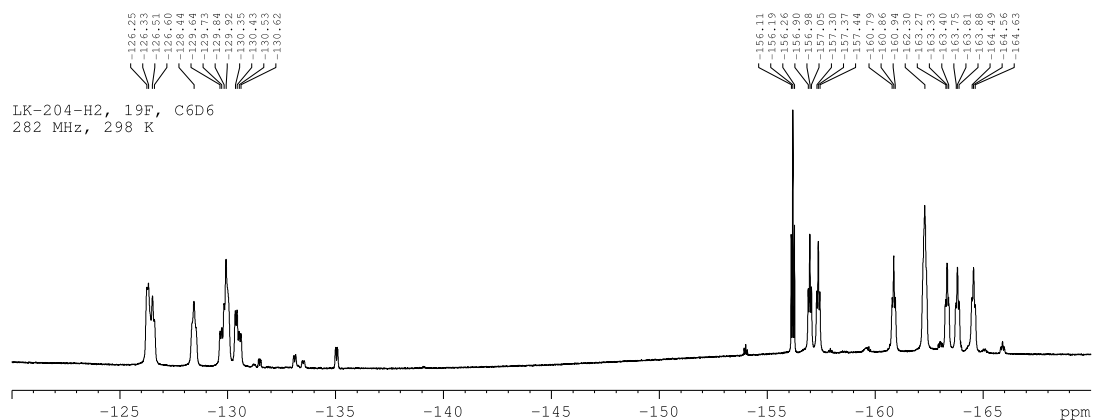
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after applying 4 bar H_2 -pressure:



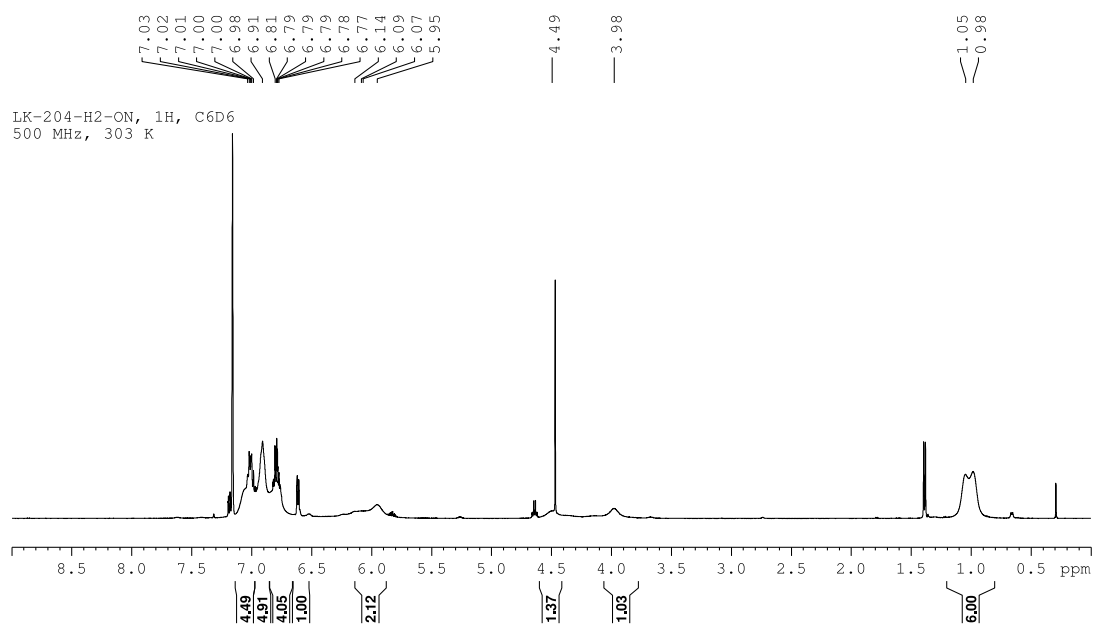
$^{11}\text{B-NMR}$ (160 MHz, 303 K, C_6D_6) after applying 4 bar H_2 -pressure:



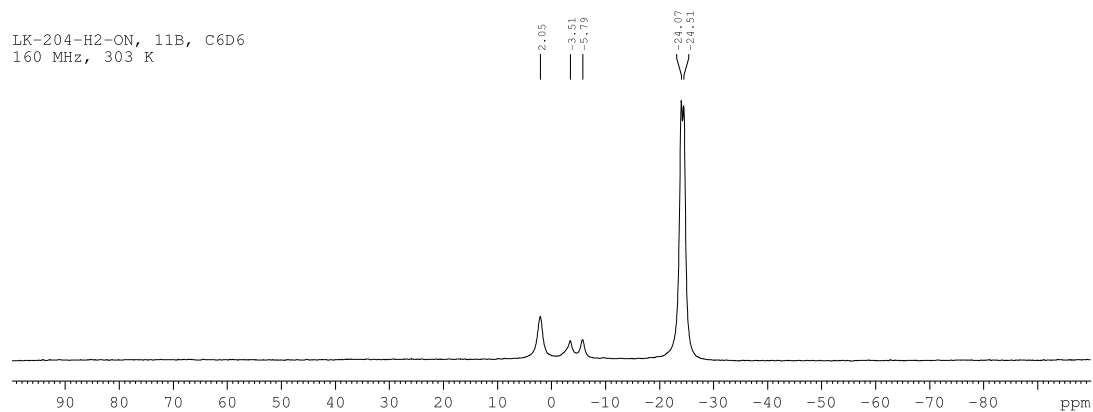
¹⁹F-NMR (282 MHz, 298 K, C₆D₆) after applying 4 bar H₂-pressure:



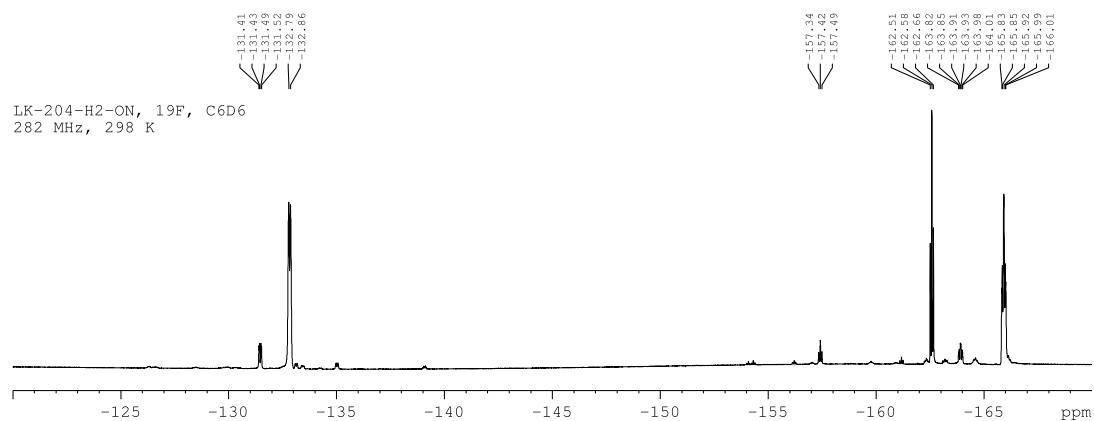
¹H-NMR (500 MHz, 303 K, C₆D₆) after 18 h at 90 °C:



¹¹B-NMR (160 MHz, 303 K, C₆D₆) after 18 h at 90 °C:

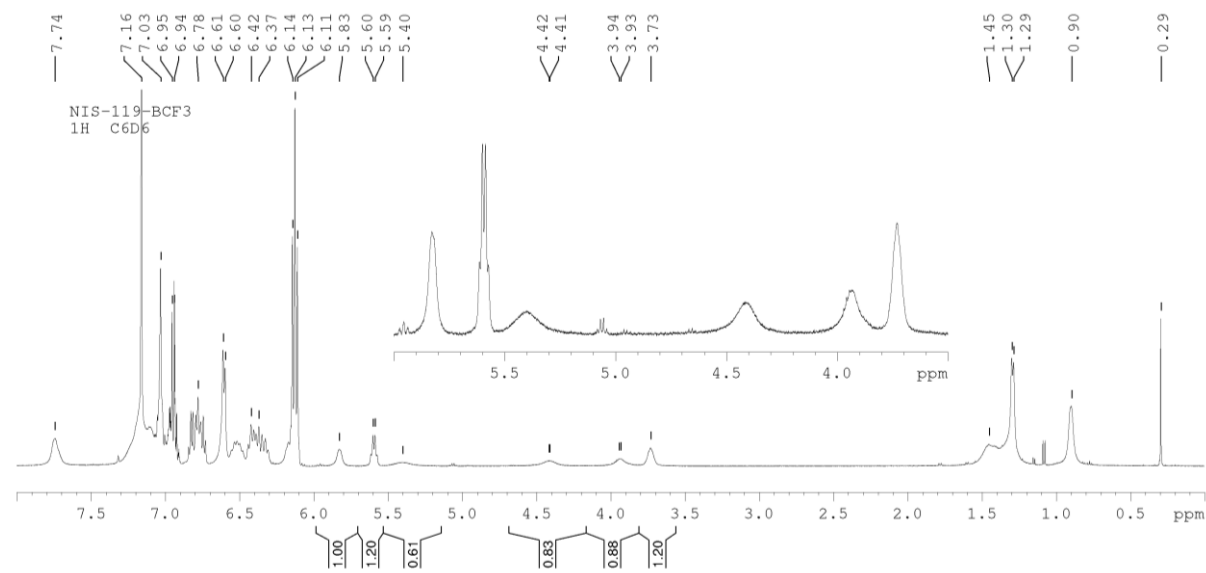


^{19}F -NMR (282 MHz, 298 K, C_6D_6) after 18 h at 90 °C:

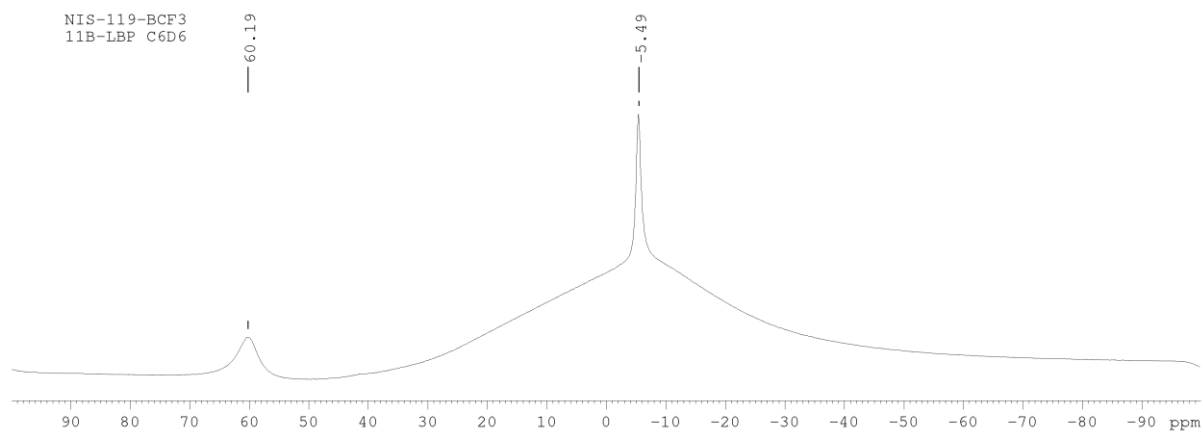


2.4 Borane/amidine Lewis pair **1b/2b**

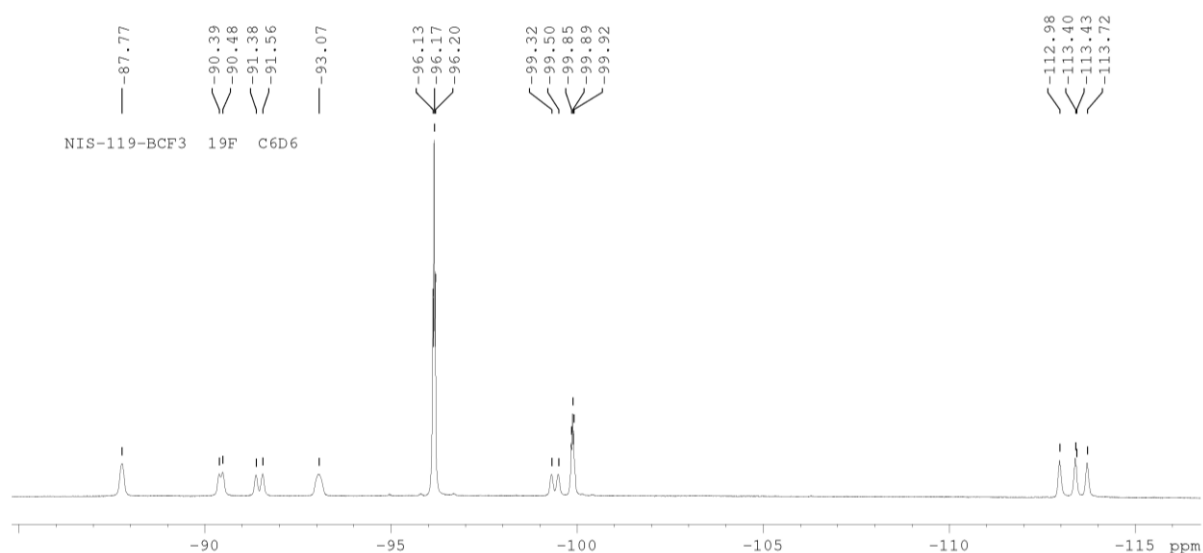
^1H -NMR (500 MHz, 303 K, C_6D_6) before applying 4 bar H_2 -pressure:



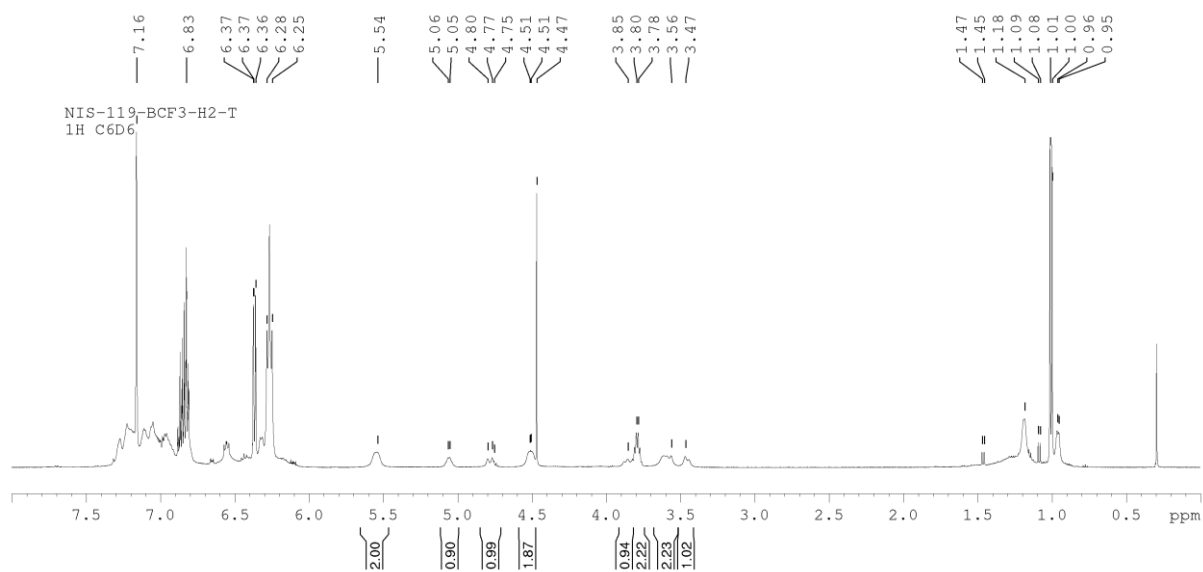
^{11}B -NMR (160 MHz, 303 K, C_6D_6) before applying 4 bar H_2 -pressure:



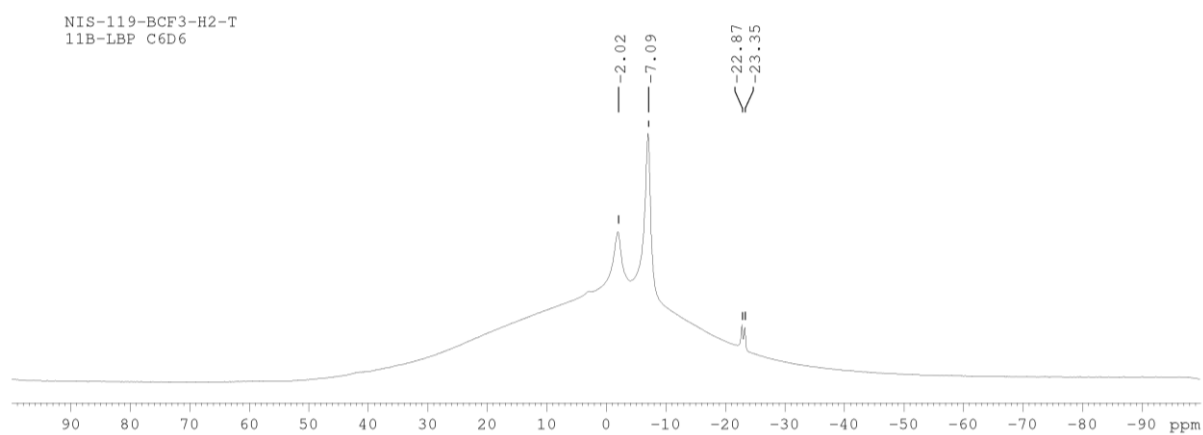
^{19}F -NMR (282 MHz, 298 K, C_6D_6) before applying 4 bar H_2 -pressure:



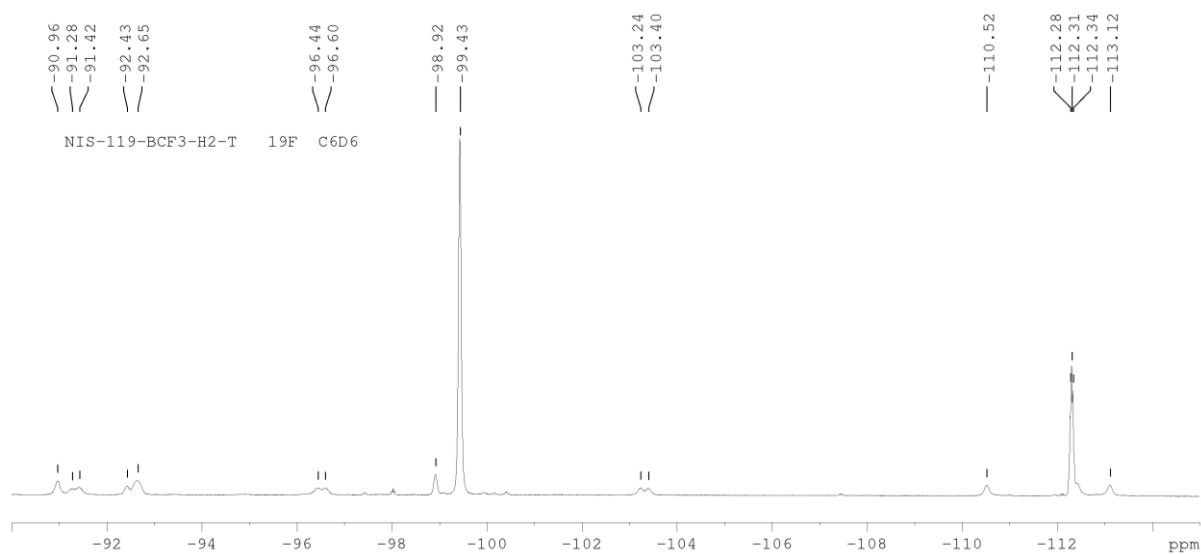
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:



$^{11}\text{B-NMR}$ (160 MHz, 303 K, C_6D_6) after 18 h at 90 °C:

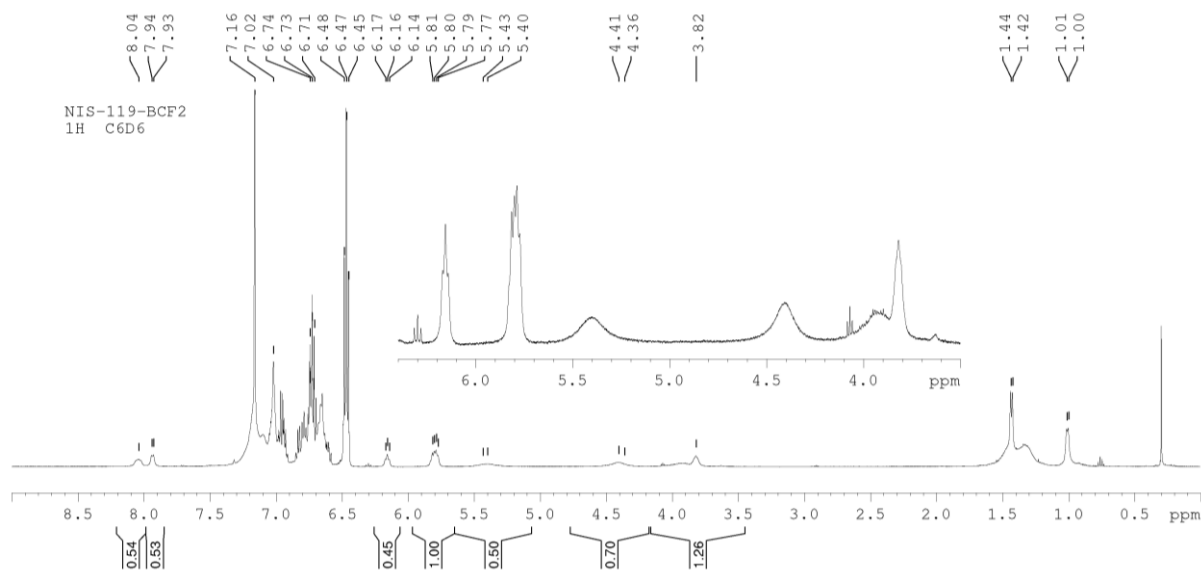


^{19}F -NMR (282 MHz, 298 K, C_6D_6) after 18 h at 90 °C:

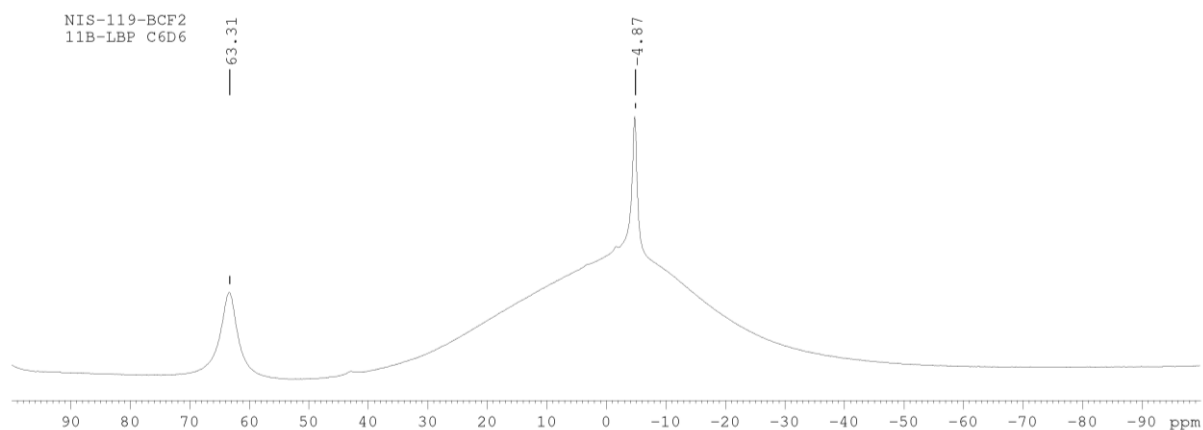


2.5 Borane/amidine Lewis pair 1c/2b

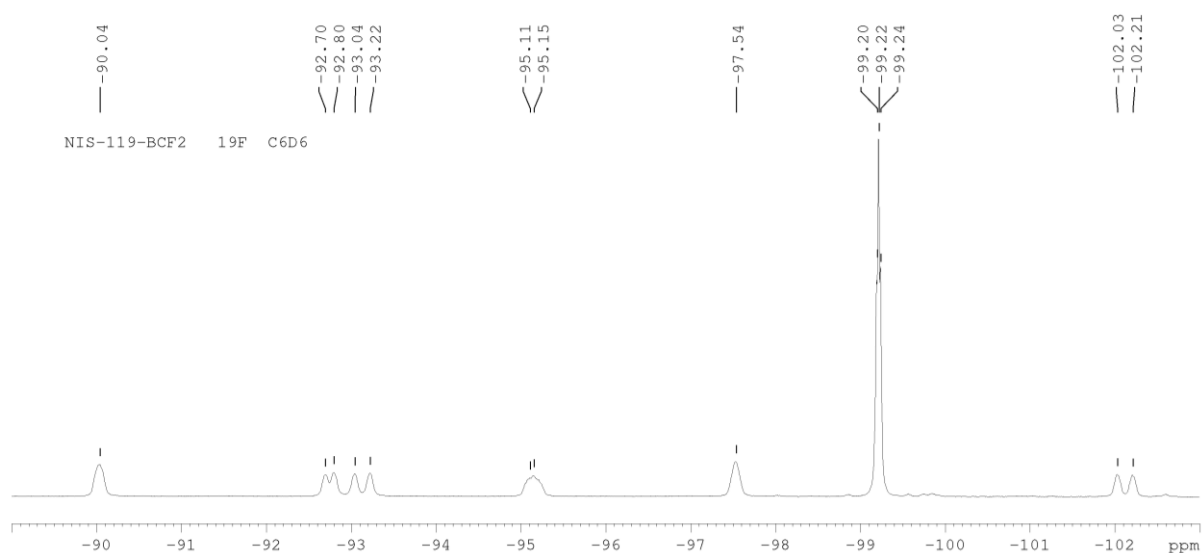
^1H -NMR (500 MHz, 303 K, C_6D_6) before applying 4 bar H_2 -pressure:



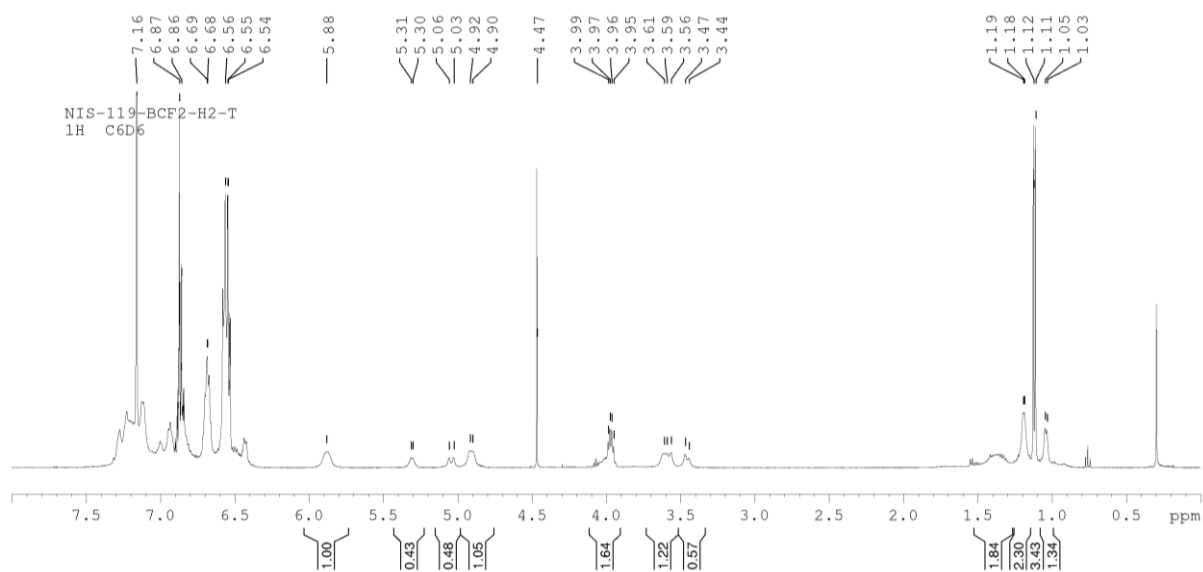
^{11}B -NMR (160 MHz, 303 K, C_6D_6) before applying 4 bar H_2 -pressure:



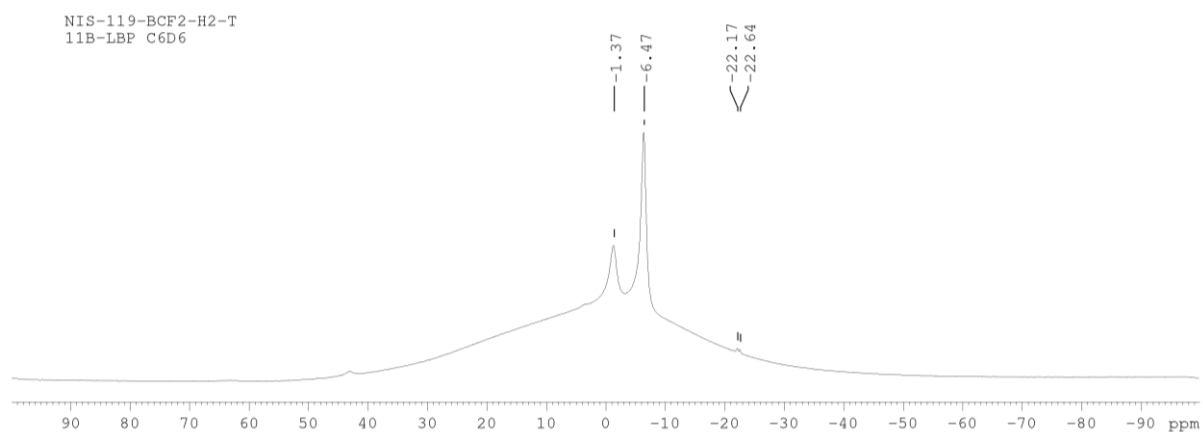
^{19}F -NMR (282 MHz, 298 K, C_6D_6) before applying 4 bar H_2 -pressure:



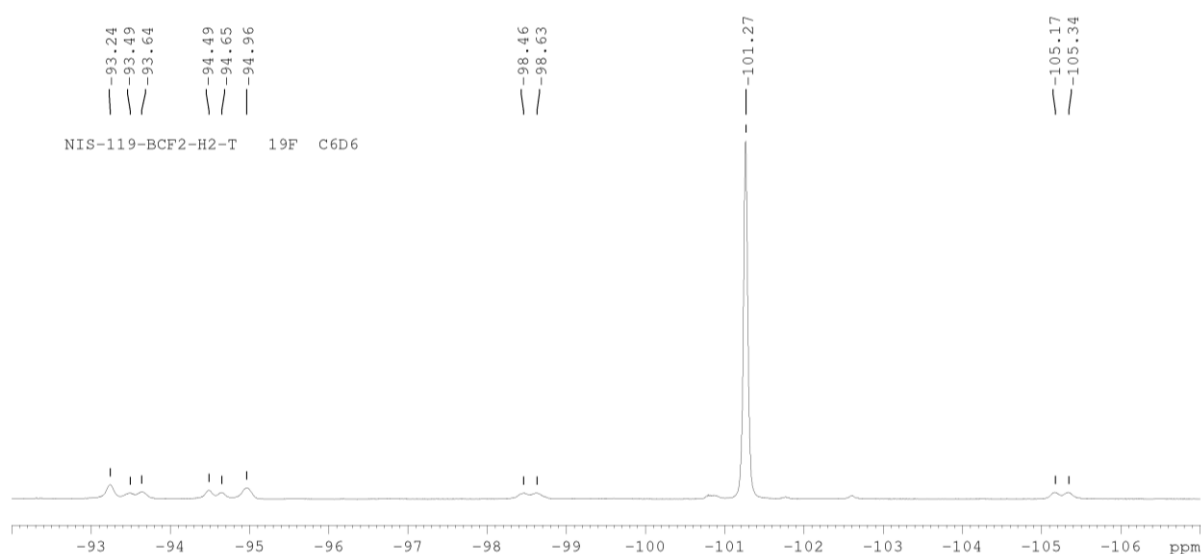
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:



$^{11}\text{B-NMR}$ (160 MHz, 303 K, C_6D_6) after 18 h at 90 °C:

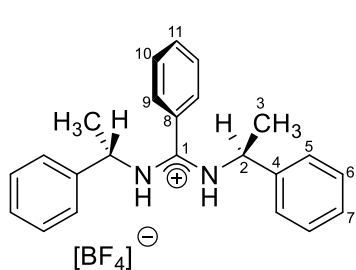


^{19}F -NMR (282 MHz, 298 K, C_6D_6) after 18 h at 90 °C:

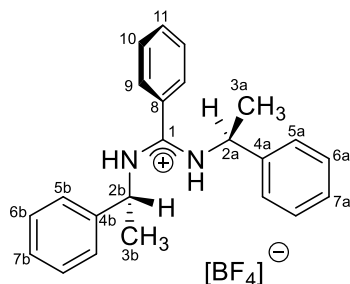


2.6 Reaction of amidine **2b** with HBF_4

The amidine **2b** (8.2 mg, 25 μmol , 1.0 equiv.) was dissolved in 0.6 ml C_6D_6 and $\text{HBF}_4 \cdot \text{OEt}_2$ (55%, 50 μmol , 2.0 equiv.) was added. The formation of the corresponding $[\text{H-2b}][\text{BF}_4]$ was confirmed by NMR spectroscopy. The solvent was evaporated and the residue was dried *in vacuo*. The ether-free sample was analyzed by 1D and 2D NMR spectroscopy. The *trans/trans* and the *cis/trans* amidinium cation in a ratio of 1:1.1 were observed.



trans/trans- $[\text{H-2b}][\text{BF}_4]$



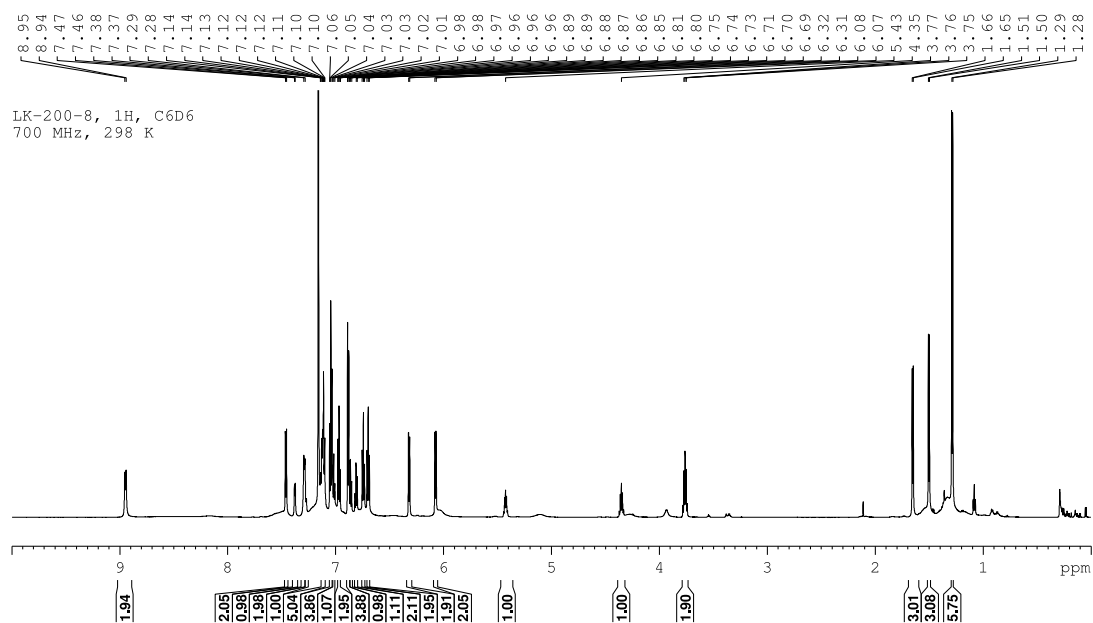
cis/trans- $[\text{H-2b}][\text{BF}_4]$

^1H -NMR (700 MHz, 298 K, C_6D_6)

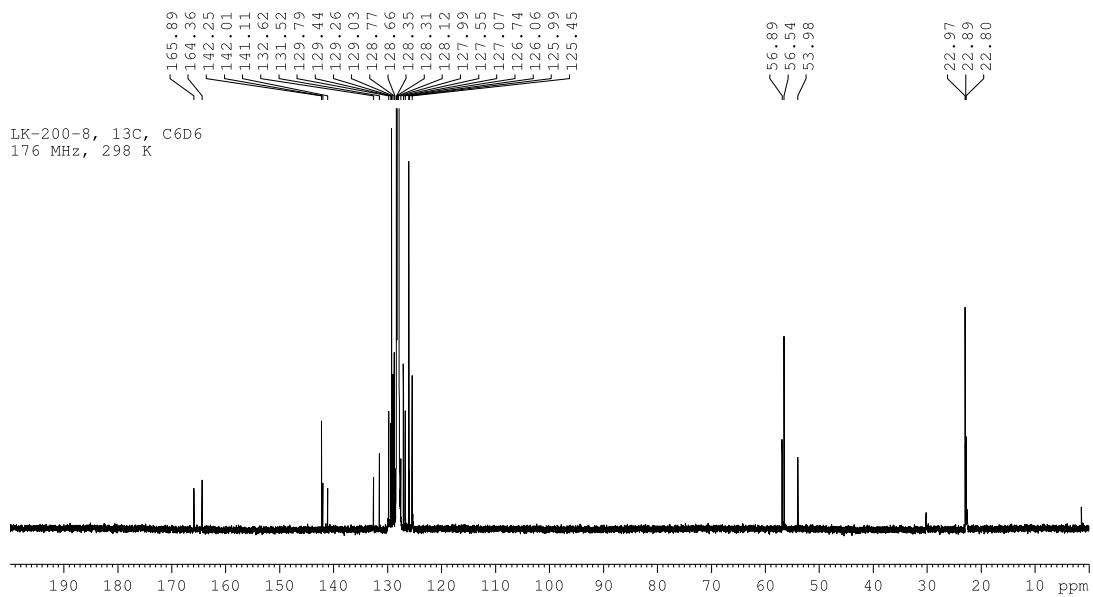
δ = 8.95 (br, 2H, *trans/trans*-NH),
 7.47 – 7.46 (m, 2H, *cis/trans*- $\text{H}_{\text{Ar},5\text{a}}$),
 7.38 (br, 1H, *cis/trans*- $\text{NHC}^{2\text{a}}\text{H}$),
 7.29 – 7.28 (m, 2H, *cis/trans*- $\text{H}_{\text{Ar},9}$),
 7.28 (br, 1H, *cis/trans*- $\text{NHC}^{2\text{b}}\text{H}$),
 7.14 – 7.10 (m,

5H, *cis/trans*- $\text{H}_{\text{Ar},6\text{a}/10/11}$),
 7.06-7.03 (m, 4H, *trans/trans*- $\text{H}_{\text{Ar},6}$),
 7.03 – 7.01 (m, 1H, *cis/trans*- $\text{H}_{\text{Ar},7\text{a}}$),
 6.98 – 6.96 (m, 2H, *trans/trans*- $\text{H}_{\text{Ar},7}$),
 6.89 – 6.87 (m, 4H, *trans/trans*- $\text{H}_{\text{Ar},5}$),
 6.86 – 6.85 (m, 1H, *trans/trans*- $\text{H}_{\text{Ar},11}$),
 6.82 – 6.80 (m, 1H, *cis/trans*- $\text{H}_{\text{Ar},7\text{b}}$),
 6.75 – 6.73 (m, 2H, *cis/trans*- $\text{H}_{\text{Ar},6\text{b}}$),
 6.71 – 6.69 (m, 2H, *trans/trans*- $\text{H}_{\text{Ar},10}$),
 6.32 – 6.31 (m, 2H, *trans/trans*- $\text{H}_{\text{Ar},9}$),
 6.08 – 6.07 (m, 2H, *cis/trans*- $\text{H}_{\text{Ar},5\text{b}}$),
 5.43 (qd, $^3J_{\text{HH}} = 6.5$ Hz, $^3J_{\text{HH}} = 6.3$ Hz, 1H, *cis/trans*- $\text{NC}^{2\text{a}}\text{H}$),
 4.35 (qd, $^3J_{\text{HH}} = 7.1$ Hz, $^3J_{\text{HH}} = 6.8$ Hz, 1H, *cis/trans*- $\text{NC}^{2\text{b}}\text{H}$),
 3.76 (qd, $^3J_{\text{HH}} = 7.2$ Hz, $^3J_{\text{HH}} = 7.0$ Hz, 1H,

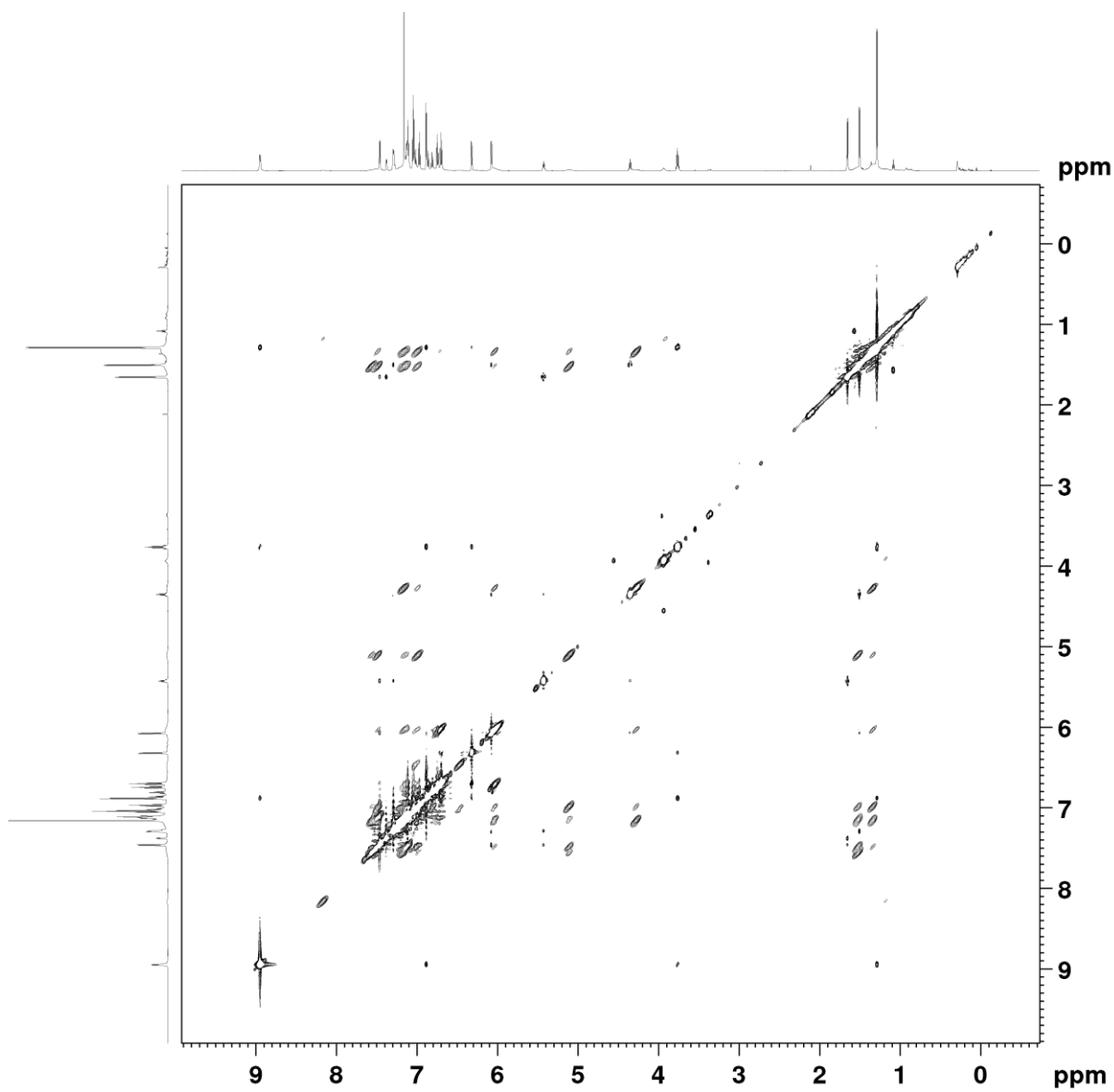
trans/trans-NC²H), 1.65 (d, $^3J_{\text{HH}} = 6.6$ Hz, 3H, *cis/trans-C^{3a}H₃*), 1.50 (d, $^3J_{\text{HH}} = 7.1$ Hz, 3H, *cis/trans-C^{3b}H₃*), 1.29 (d, $^3J_{\text{HH}} = 7.1$ Hz, 3H, *trans/trans-C³H₃*).



¹³C-NMR (176 MHz, 298 K, C₆D₆) $\delta = 165.9$ (*trans/trans-C¹*), 164.4 (*cis/trans-C¹*), 142.2 (*trans/trans-C⁴*), 142.0 (*cis/trans-C^{4b}*), 141.1 (*cis/trans-C^{4a}*), 132.6 (*cis/trans-C¹¹*), 131.5 (*trans/trans-C¹¹*), 129.8 (*cis/trans-C^{6a}*), 129.4 (*cis/trans-C¹⁰*), 129.3 (*trans/trans-C⁶*), 129.0 (*trans/trans-C¹⁰*), 128.8 (*cis/trans-C^{6b}*), 128.7 (*cis/trans-C^{7a}*), 128.3 (*cis/trans-C⁸*), 128.1 (*trans/trans-C⁷*), 128.0 (*cis/trans-C⁹*), 127.5 (*cis/trans-C^{7b}*), 127.1 (*trans/trans-C⁹*), 126.7 (*cis/trans-C^{5a}*), 126.1 (*trans/trans-C⁵*), 126.0 (*trans/trans-C⁸*), 125.5 (*cis/trans-C^{5b}*), 56.9 (*cis/trans-C^{2b}*), 56.5 (*trans/trans-C²*), 54.0 (*cis/trans-C^{2a}*), 23.0 (*trans/trans-C³*), 22.9 (*cis/trans-C^{3a}*), 22.8 (*cis/trans-C^{3b}*).



¹H-¹H NOESY (700 MHz, 298 K, C₆D₆)



2.7 Epimerization study of amidine **2b**

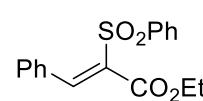
The amidine **2b** (49.3 mg, 150 μmol , 1.00 equiv.) and the borane **1c** (5.3 mg, 15 μmol , 10 mol%) were dissolved in 3.6 ml benzene. The resulting solution was heated to 90 °C over night. Purification of the amidine was accomplished by flash chromatography (silica, CH/EA/Et₃N: 2/1/0.01, R_f = 0.1). Optical rotation of the amidine was measured before and after treatment with the borane.

$[\alpha]_{\text{D}}^{20} = -60.6$ (c = 0.20, THF) for amidine **2b**; $[\alpha]_{\text{D}}^{20} = -60.6$ (c = 0.20, THF) for amidine **2b** after heating with borane **1c** to 90 °C.

Chiral amidine **2b** does not undergo epimerization under the reaction conditions of hydrogenation.

3 Substrate synthesis

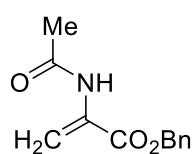
3.1 Synthesis of 3-phenyl-2-(phenylsulfonyl)ethylacrylate (**4b**)

 In a round-bottomed flask was α -(phenylsulfonyl)ethylacetate (2.28 g, 10.0 mmol, 1.00 equiv.) dissolved in benzene (8 mL). Benzaldehyde (1.06 g, 10.0 mmol, 1.00 equiv.), piperidine (0.05 mL) and acetic acid (0.15 mL) was added and the reaction mixture was heated for 3 h, while the water was removed by a Dean–Stark apparatus. The reaction was monitored by TLC (silica, CH/EA: 5/1, R_f = 0.3). The reaction mixture was then cooled to room temperature and washed with aqueous HCl (2 M) and water. The organic phase was dried over Na₂SO₄ and the volatiles were removed under reduced pressure, yielding the crude product (clear yellow oil). Purification was accomplished by flash chromatography (silica, CH/EA: 5/1). The product was obtained as highly viscous, colorless oil. Yield: 74% (2.33 g, 7.36 mmol).

¹H-NMR (500 MHz, 303 K, CDCl₃) δ = 7.99-7.94 (m, 3H, H_{Ar}), 7.66-7.61 (m, 1H, PhCH), 7.58-7.52 (m, 2H, H_{Ar}), 7.47-7.41 (m, 3H, H_{Ar}), 7.41-7.36 (m, 2H, H_{Ar}), 4.22 (q, ³J_{HH} = 7.1 Hz, 2H, OCH₂), 1.14 (t, ³J_{HH} = 7.1 Hz, 6H, OCH₂CH₃).

NMR spectroscopic data was in good agreement with the literature.^[S14]

3.2 Synthesis of *N*-acetyl-*O*-benzyl-1,2-didehydroalanine (**7**)



N-Acetyl-1,2-didehydroalanine (775 mg, 6.00 mmol, 1.07 equiv.) was placed in a round-bottomed flask covered in tin foil and dissolved in dimethylacetamide (DMA) (10 mL). Potassium carbonate (774 mg, 5.60 mmol, 1.00 equiv.) was added and the resulting suspension was stirred for a few minutes. Benzylbromide (0.67 mL, 5.60 mmol, 1.00 equiv.) was added and the reaction mixture was stirred at room temperature over night. The reaction mixture was subsequently diluted with diethyl ether and water. The phases were separated and the aqueous phase was extracted twice with diethyl ether. The combined organic phases were washed with sat. aq. NaHCO₃ and the volatiles were carefully and in darkness removed under reduced pressure. The product was obtained as a colorless oil, which was stored in the freezer. Yield: 85% (1.04 g, 4.74 mmol).

¹H-NMR (500 MHz, 303 K, CDCl₃) δ = 7.71 (br, 1H, NH), 7.42-7.32 (m, 5H, H_{Ar}), 6.61 (s, 1H, NHCCH₂), 5.94 (d, ²J_{HH} = 1.5 Hz, 1H, NHCCH₂), 5.27 (s, 2H, PhCH₂), 2.12 (s, 3H, (CO)CH₃).

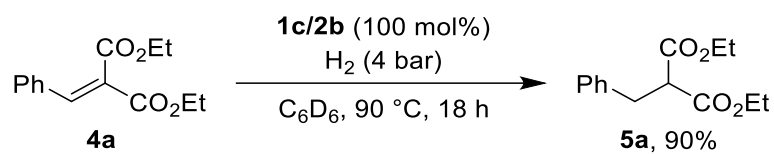
NMR spectroscopic data was in good agreement with the literature.^[S15]

4 FLP-catalyzed hydrogenations

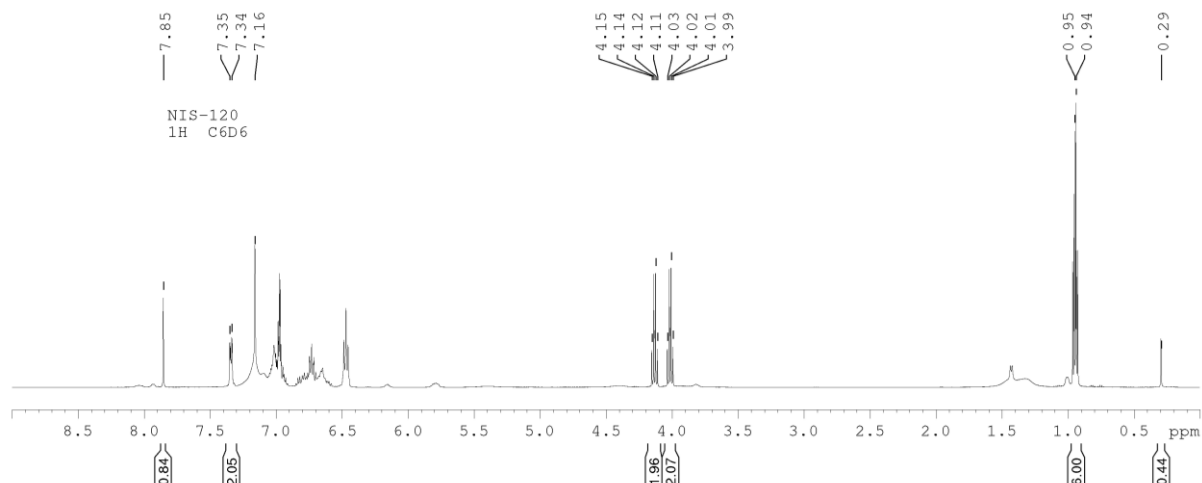
4.1 General procedure A for NMR-scale hydrogenations

In a glove box borane **1c** (7.0-35 mg, 20-100 μmol, 20-100 mol%) or borane **1b** (8.1 mg, 20 μmol, 20 mol%), amidine **2b** (6.6-32.8 mg, 20-100 μmol, 20-100 mol%) and substrate **4a** (24.8 mg, 100 μmol, 1.00 equiv.) or substrate **4b** (31.6 mg, 100 μmol, 1.00 equiv.) were dissolved in 0.6 mL C₆D₆ and transferred to a J. YOUNG NMR tube with teflon tap. The sample was then frozen in liquid nitrogen, the headspace was evacuated and the sample was charged with hydrogen at -196 °C. After sealing and thawing, the hydrogen pressure inside the sample reached approximately 4 bar. The sample was then heated to 90 °C on a shaking plate to ensure hydrogen exchange. After 18 h the NMR tube was cooled to room temperature and the crude reaction mixture was analyzed by ¹H-NMR spectroscopy.

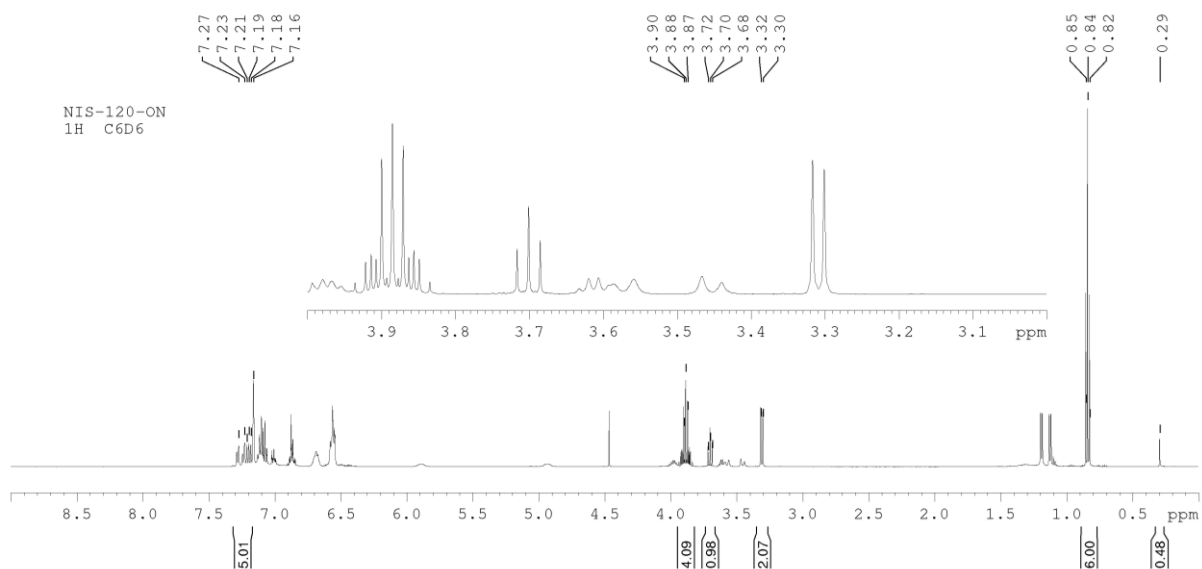
4.2 Hydrogenation of substrate 4a



$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) before applying 4 bar H_2 -pressure:



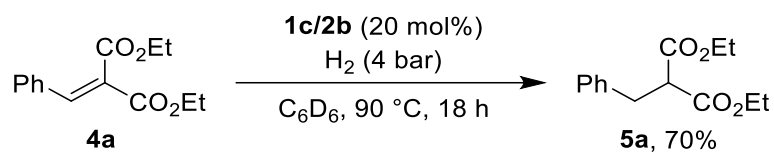
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:



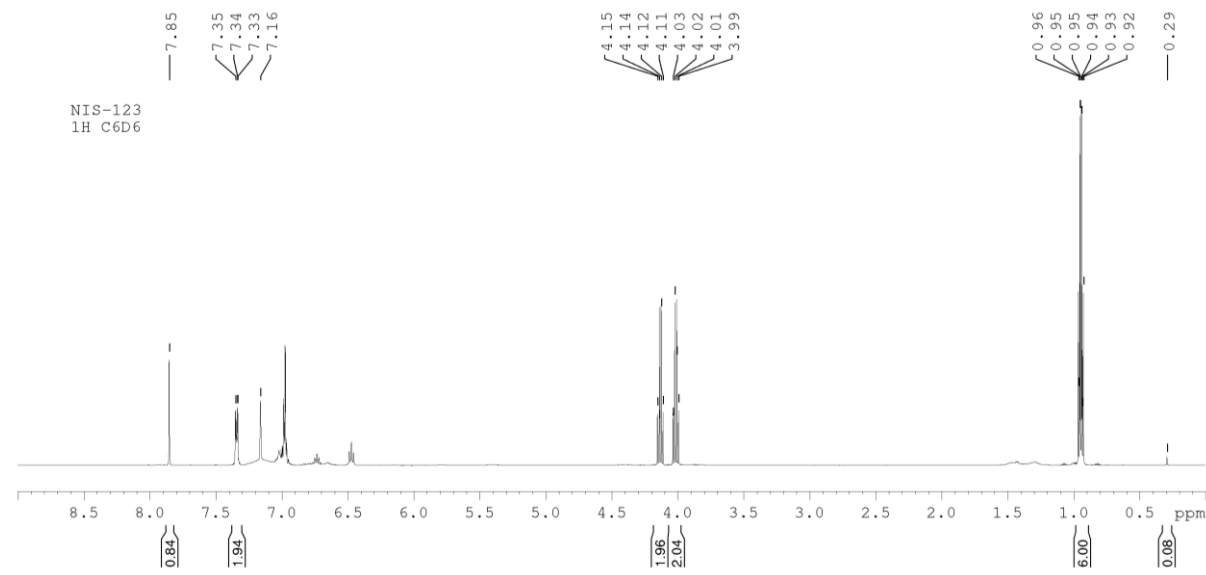
NMR-Yield: 90%

$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) δ = 7.31-7.17 (m, 4H, H_{Ar}), 3.94-3.83 (m, 4H, OCH_2) 3.70 (t, $^3J_{\text{HH}}$ = 7.9 Hz, 1H, PhCH_2CH), 3.31 (d, 2H, PhCH_2), 0.84 (t, $^3J_{\text{HH}}$ = 7.1 Hz, 6H, OCH_2CH_3).

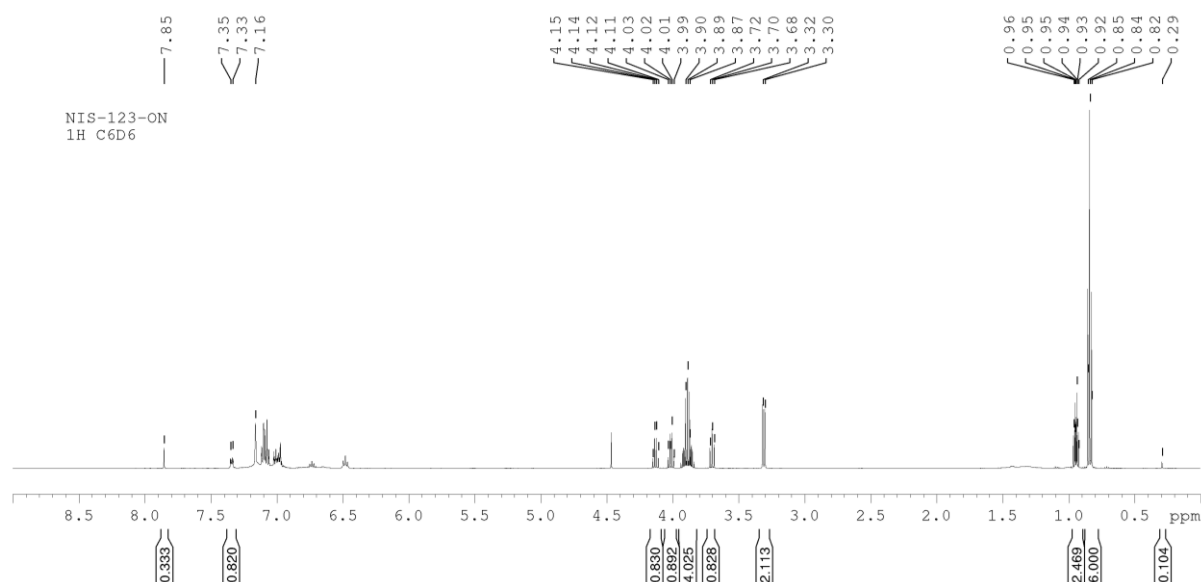
NMR spectroscopic data was in good agreement with the literature.^[S13]



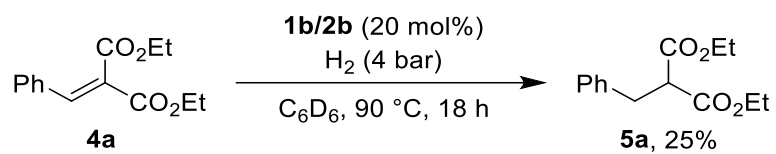
¹H-NMR (500 MHz, 303 K, C₆D₆) before applying 4 bar H₂-pressure:



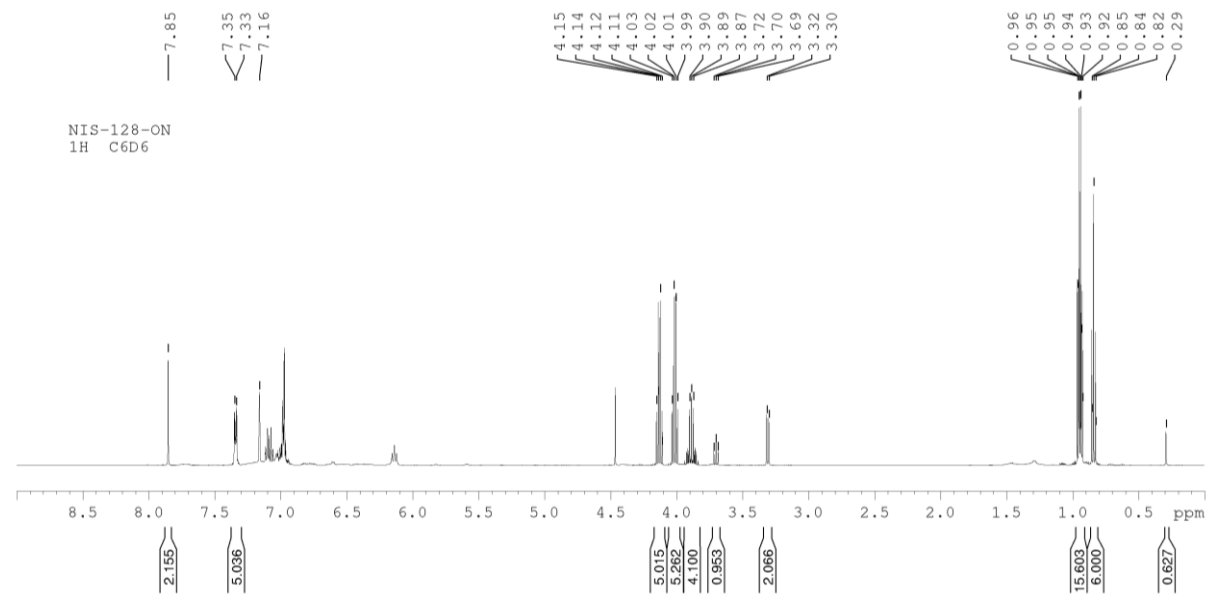
¹H-NMR (500 MHz, 303 K, C₆D₆) after 18 h at 90 °C:



NMR-Yield: 70%

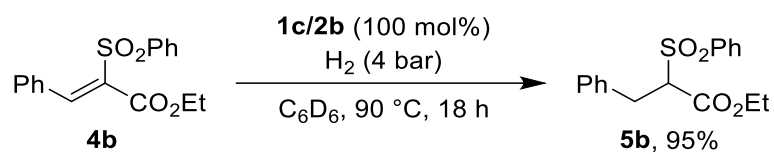


¹H-NMR (500 MHz, 303 K, C₆D₆) after 18 h at 90 °C:

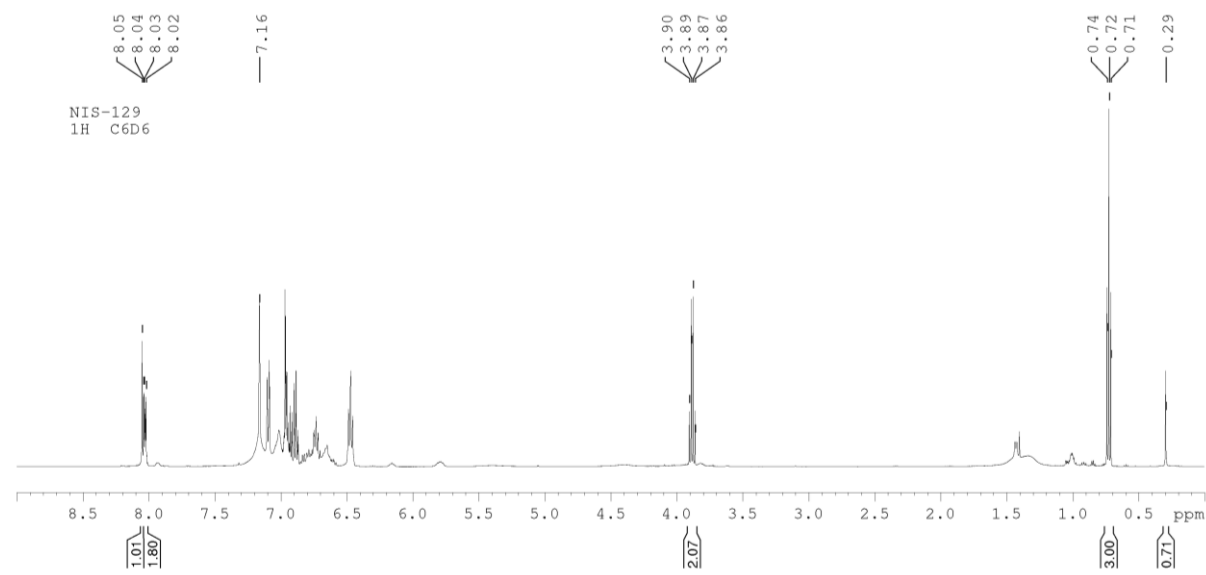


NMR-Yield: 25%

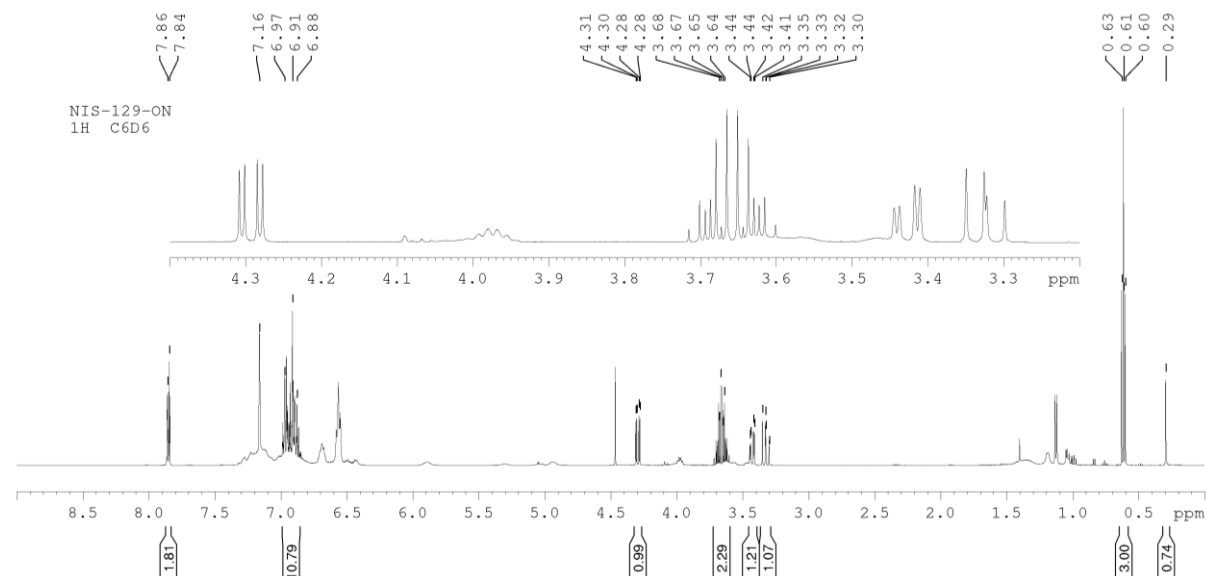
4.3 Hydrogenation of substrate 4b



$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) before applying 4 bar H_2 -pressure:



$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:

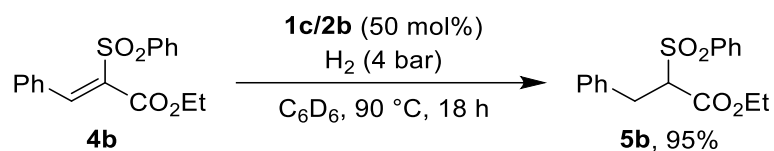


NMR-Yield: 95%

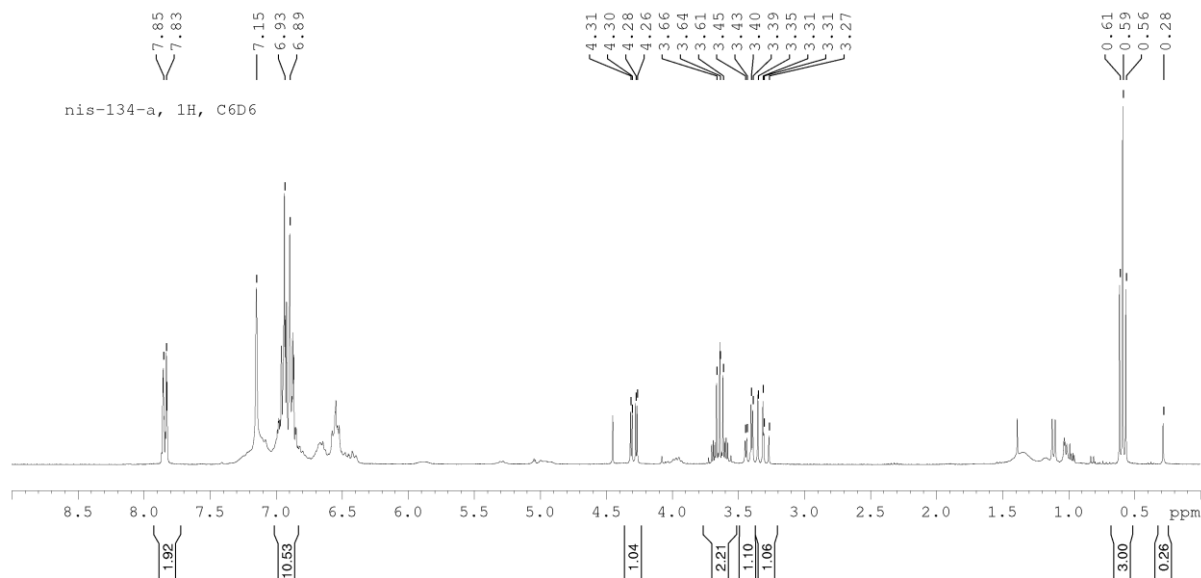
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) $\delta = 7.87\text{-}7.83$ (m, 2H, H_{Ar}), $6.99\text{-}6.85$ (m, 6H, H_{Ar}), 4.29 (dd, $^3J_{\text{HH}} = 11.9$ Hz, 3.8 Hz, 1H, PhCH_2CH), $3.72\text{-}3.60$ (m, 2H, OCH_2) 3.43 (dd, $^2J_{\text{HH}} = 13.6$ Hz, $^3J_{\text{HH}} =$

3.5 Hz, 1H, PhCH₂), 3.32 (dd, ²J_{HH} = 13.6 Hz, ³J_{HH} = 11.7 Hz, 1H, PhCH₂), 0.61 (t, ³J_{HH} = 7.1 Hz, 3H, OCH₂CH₃).

NMR spectroscopic data was in good agreement with the literature.^[S14]



¹H-NMR (300 MHz, 298 K, C₆D₆) after 18 h at 90 °C:

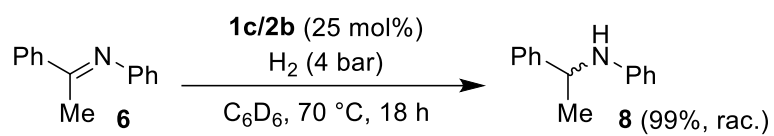


NMR-Yield: 95%

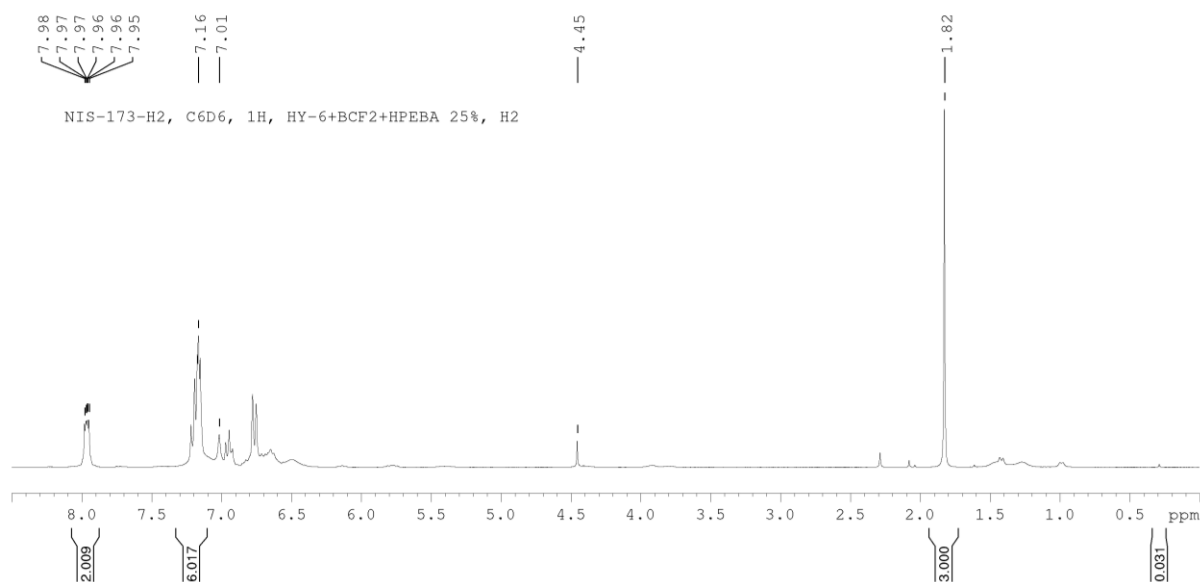
4.4 General procedure B for NMR-scale hydrogenations

In a glove box borane **1c** (8.7 mg, 25 μmol, 25 mol%), base (25 μmol, 25 mol%) and substrate (100 μmol, 1.00 equiv.) were dissolved in 0.6 mL C₆D₆ and transferred to a J. YOUNG NMR tube with teflon tap. The sample was then frozen in liquid nitrogen, the headspace was evacuated and the sample was charged with hydrogen at -196 °C. After sealing and thawing, the hydrogen pressure inside the sample reached approximately 4 bar. The sample was then heated to 90 °C on a shaking plate to ensure hydrogen exchange. After 18 h the NMR tube was cooled to room temperature and the crude reaction mixture was analyzed by ¹H-NMR spectroscopy. For HPLC analysis, the crude reaction mixture was purified as stated below.

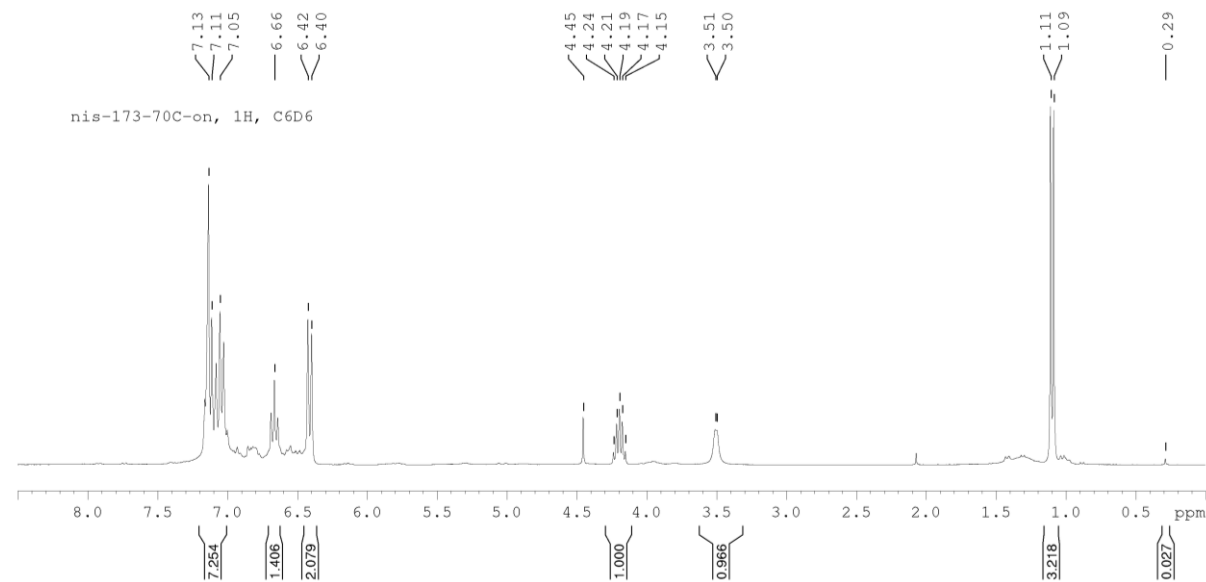
4.5 Hydrogenation of substrate 6



$^1\text{H-NMR}$ (300 MHz, 298 K, C_6D_6) before heating:



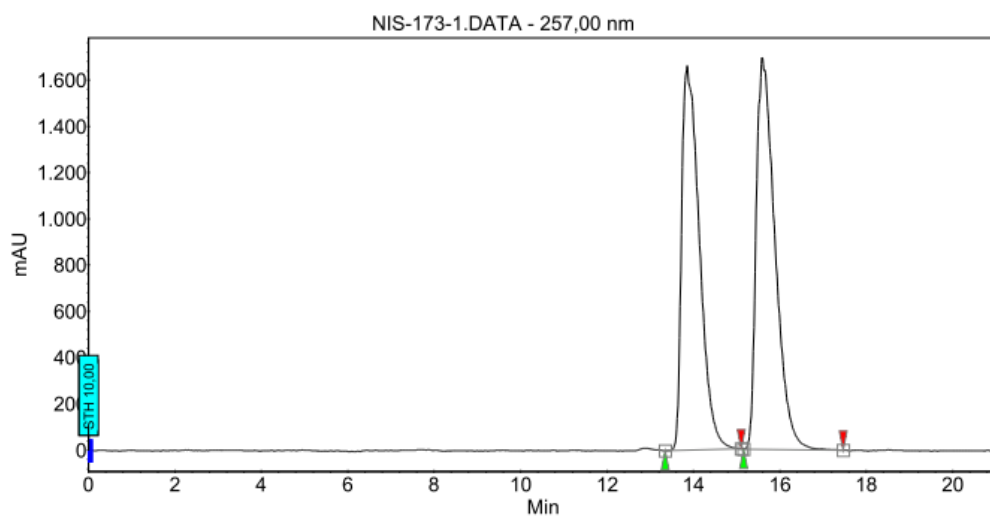
$^1\text{H-NMR}$ (300 MHz, 298 K, C_6D_6) after 18 h at 70 °C:



NMR-Yield: >95%

Purification for HPLC was done by evaporation of the volatiles, solvation of the remains in hot solvent mixture (CH/EA: 100/1) and filtration over a pad of silica (CH/EA: 100/1).

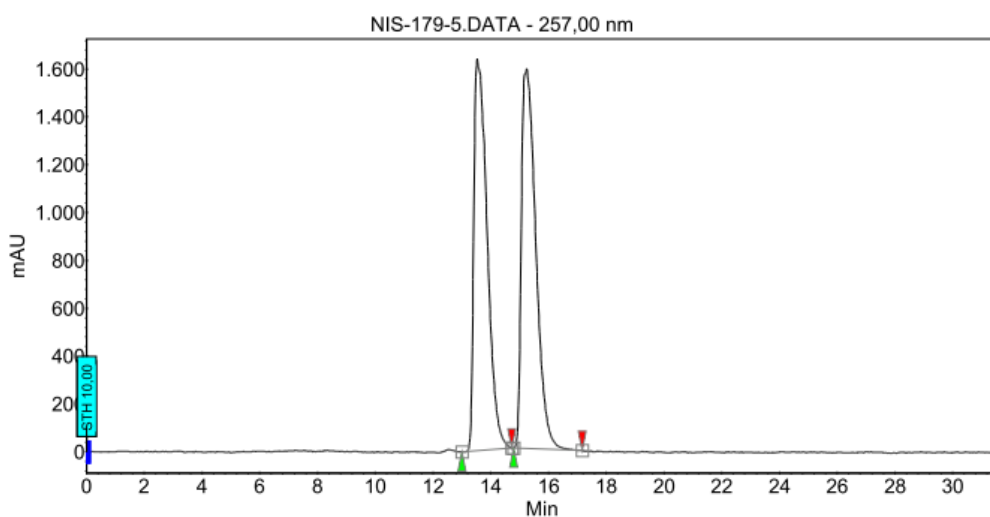
HPLC (IB, 15 °C, heptane/*i*-PrOH: 99/1, flow rate: 0.5 mL/min, 257 nm): $t_R = 13.5$ min,
 $t_R = 15.2$ min.



Peak results :

Index	Name	Time [Min]	Quantity [% Area]	Height [mAU]	Area [mAU.Min]	Area % [%]
1	UNKNOWN	13.85	48.05	1663.2	790.0	48.045
2	UNKNOWN	15.59	51.95	1694.1	854.3	51.955
Total			100.00	3357.3	1644.3	100.000

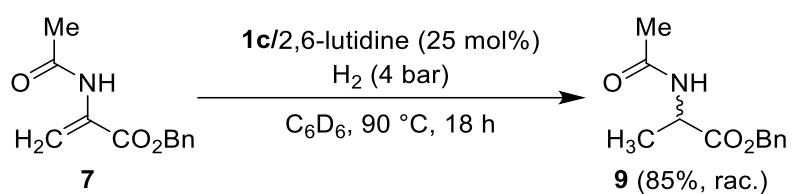
racemic sample:



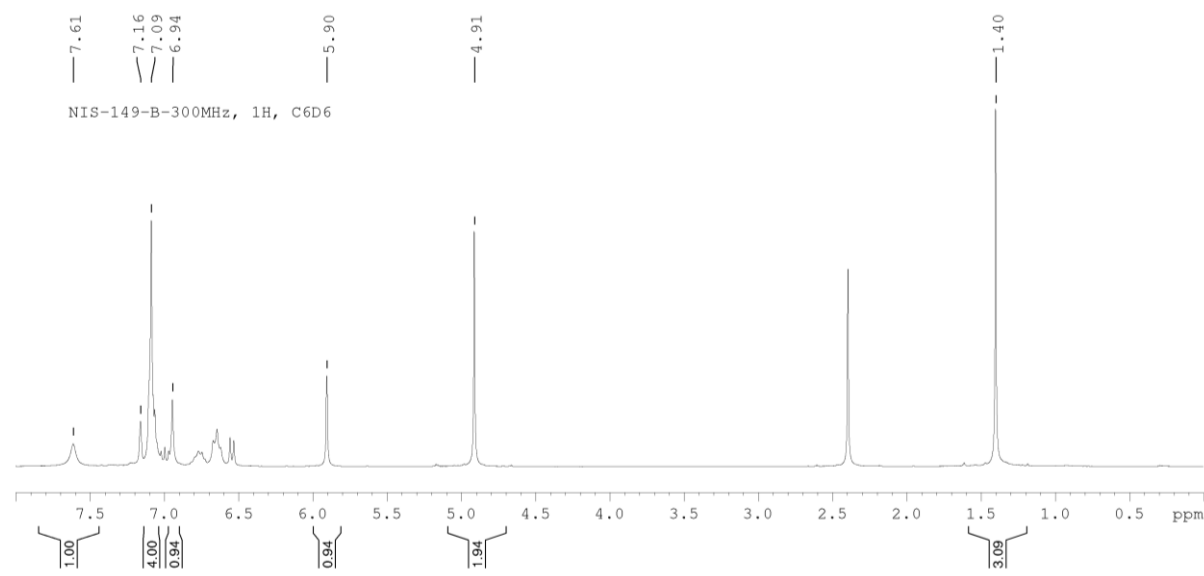
Peak results :

Index	Name	Time [Min]	Quantity [% Area]	Height [mAU]	Area [mAU.Min]	Area % [%]
1	UNKNOWN	13.53	48.76	1637.5	874.8	48.756
2	UNKNOWN	15.24	51.24	1587.8	919.5	51.244
Total			100.00	3225.4	1794.3	100.000

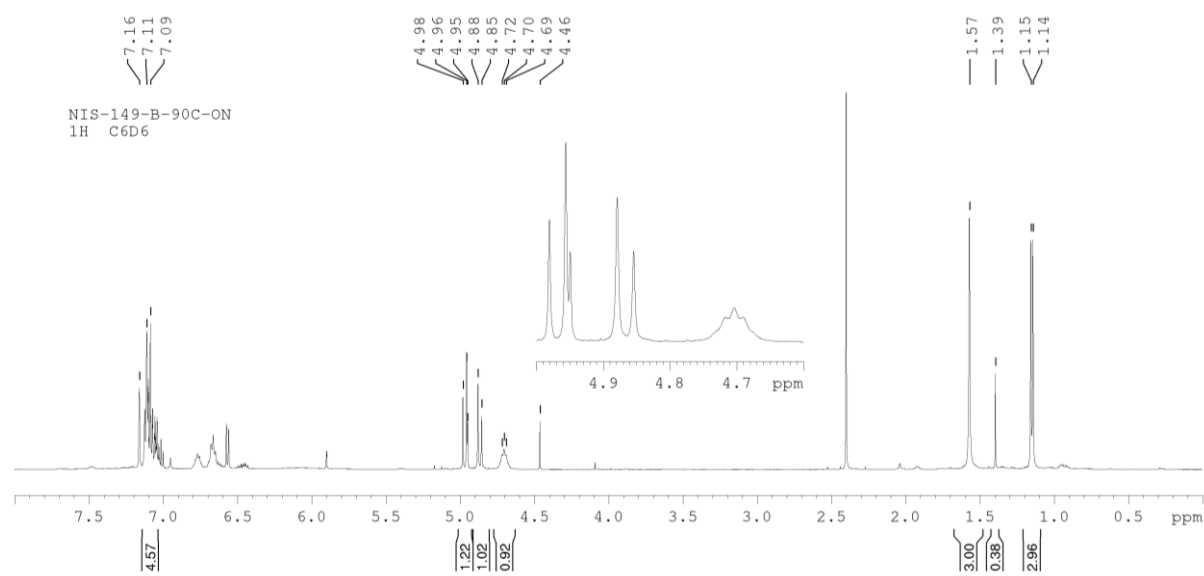
4.6 Hydrogenation of substrate 7



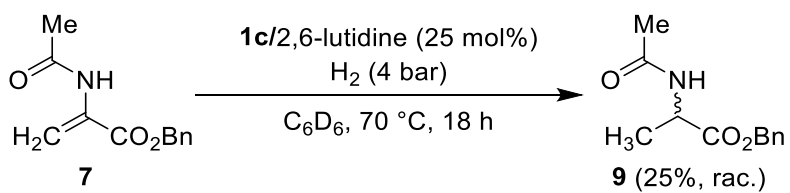
$^1\text{H-NMR}$ (300 MHz, 298 K, C_6D_6) before applying 4 bar H_2 -pressure:



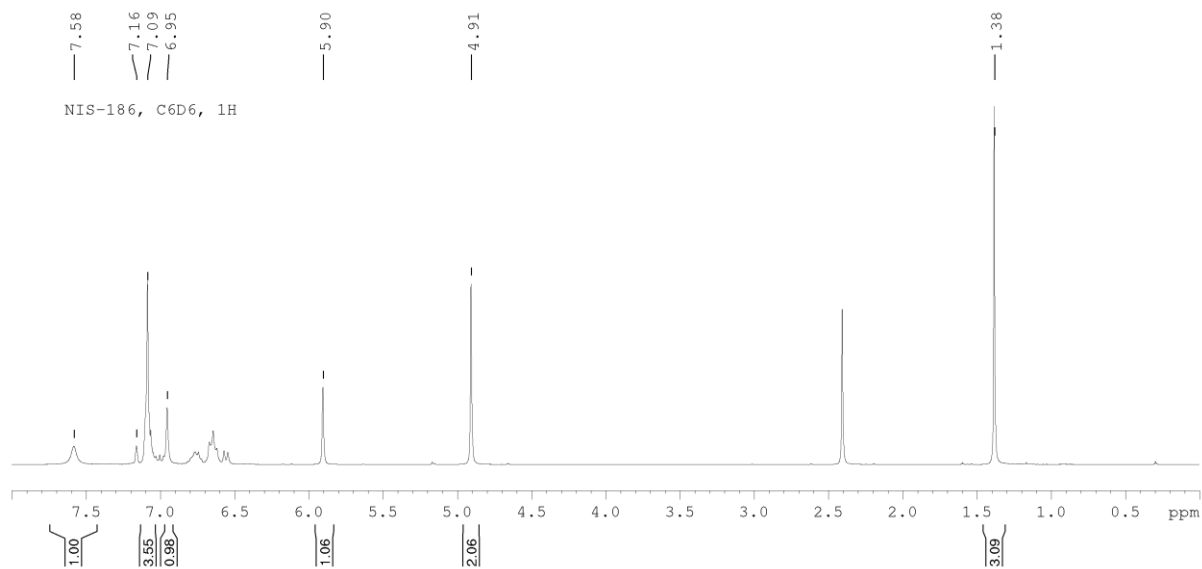
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:



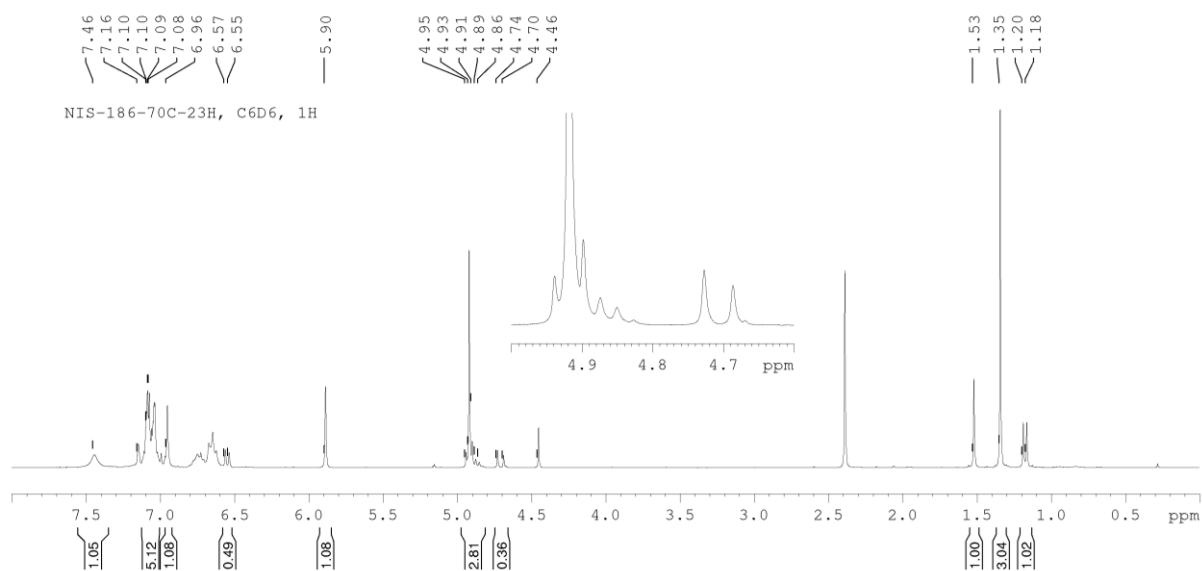
NMR-Yield: 85%



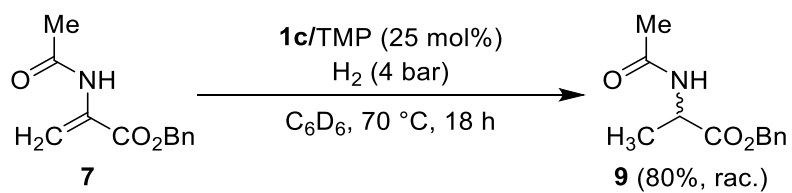
¹H-NMR (300 MHz, 298 K, C₆D₆) before applying 4 bar H₂-pressure:



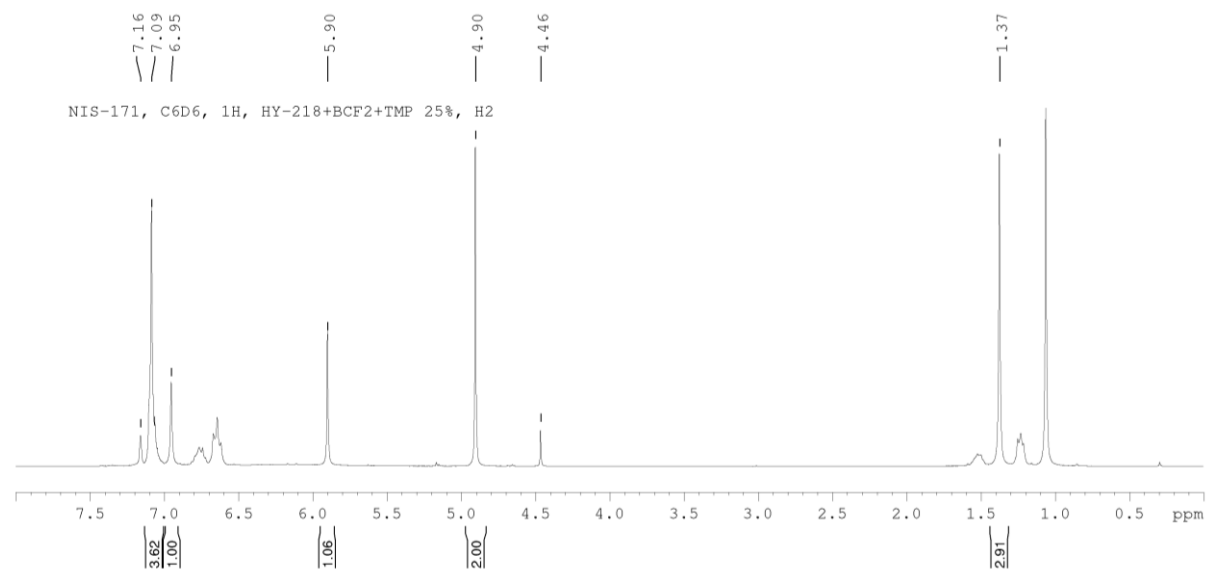
¹H-NMR (300 MHz, 298 K, C₆D₆) after 18 h at 70 °C:



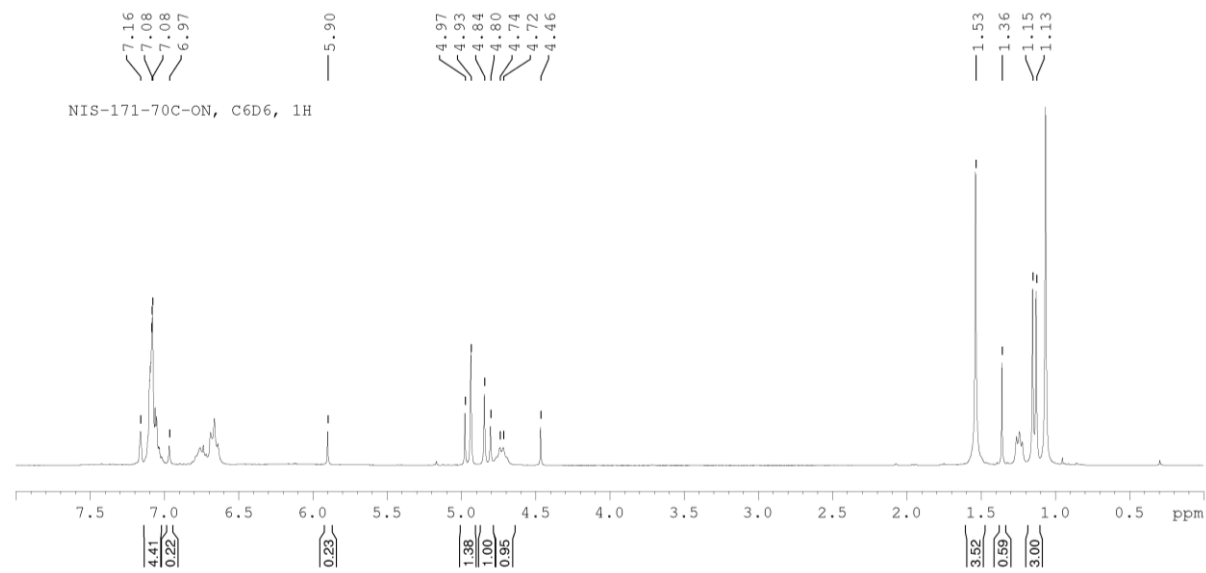
NMR-Yield: 25%



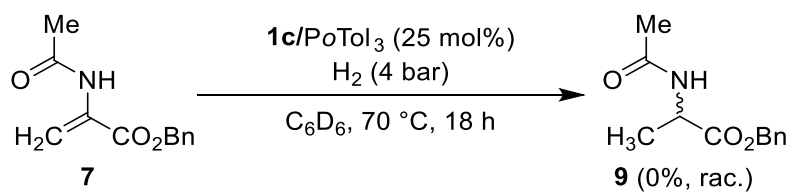
¹H-NMR (300 MHz, 298 K, C₆D₆) before heating:



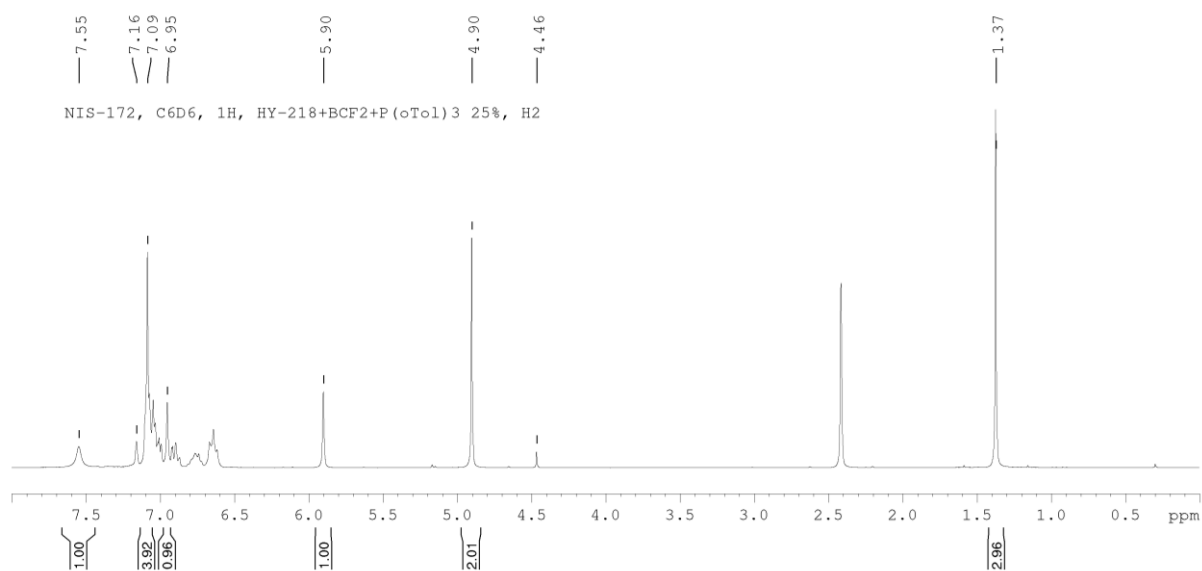
¹H-NMR (300 MHz, 298 K, C₆D₆) after 18 h at 70 °C:



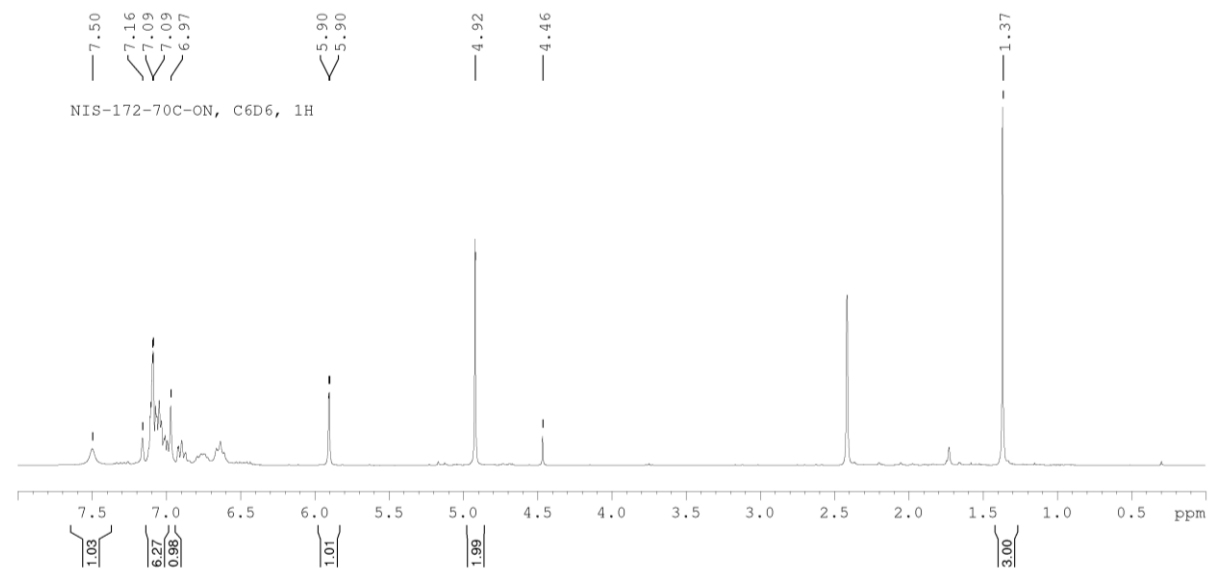
NMR-Yield: 80%



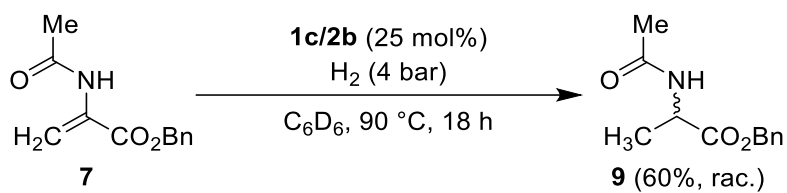
¹H-NMR (300 MHz, 298 K, C₆D₆) before heating:



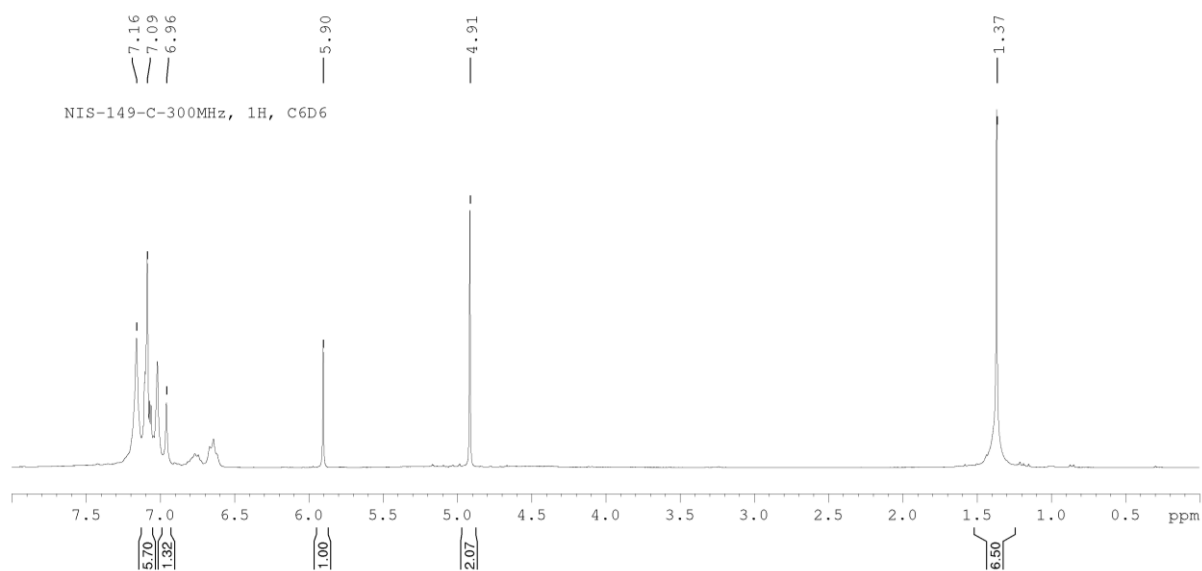
¹H-NMR (300 MHz, 298 K, C₆D₆) after 18 h at 70 °C:



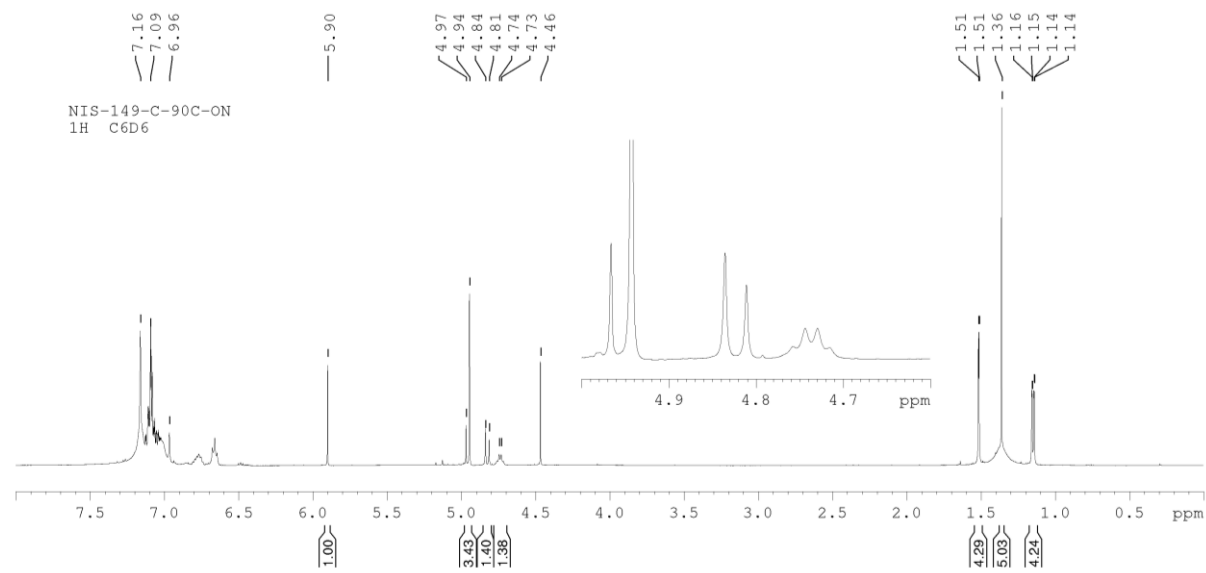
NMR-Yield: 0%



1H -NMR (300 MHz, 298 K, C_6D_6) before applying 4 bar H_2 -pressure:

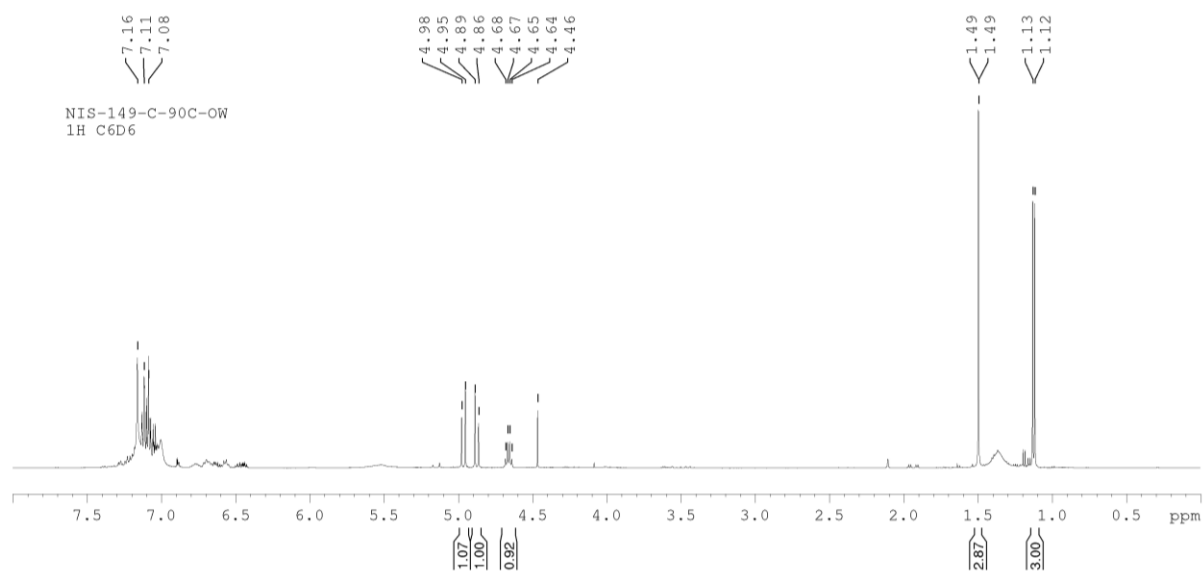


1H -NMR (500 MHz, 303 K, C_6D_6) after 18 h at 90 °C:



NMR-Yield: 55%

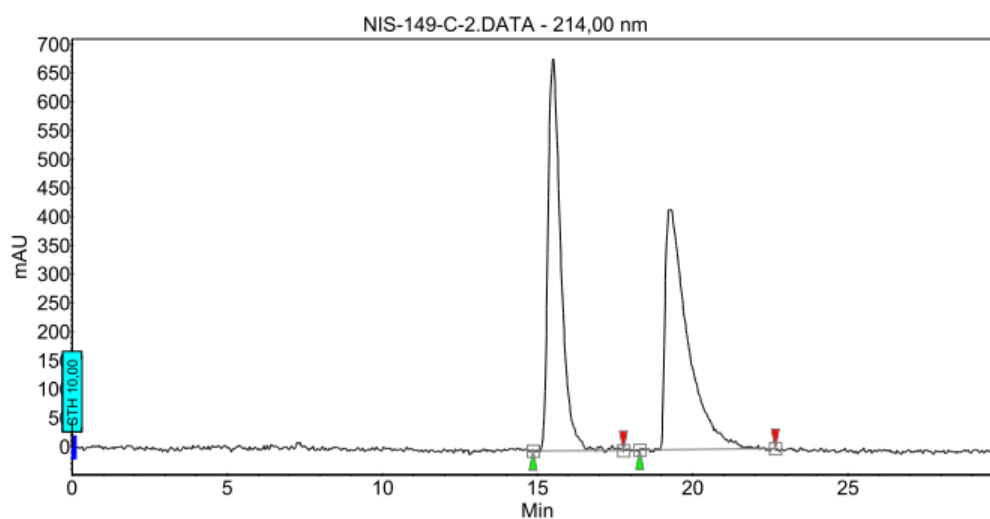
$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 96 h at 90 °C:



NMR-Yield (after 96 h): > 95%

Purification for HPLC was done by column chromatography (silica, CH/EA: 5/1 then CH/EA: 1/1).

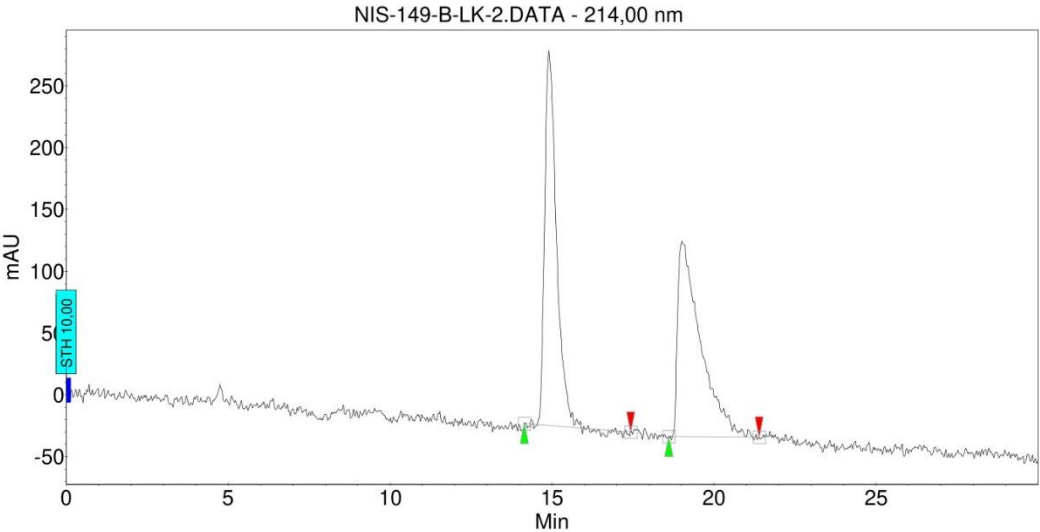
HPLC (IA, 15 °C, heptane/*i*-PrOH: 90/10, flow rate: 0.7 mL/min, 214 nm): $t_R = 15.5$ min, $t_R = 19.2$ min.



Peak results :

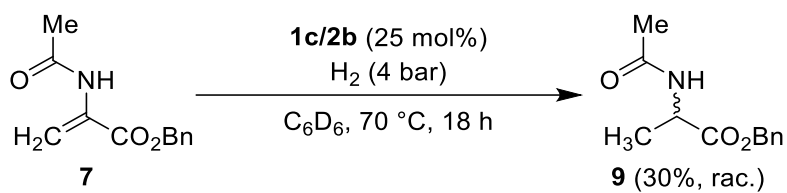
Index	Name	Time [Min]	Quantity [% Area]	Height [mAU]	Area [mAU.Min]	Area % [%]
1	UNKNOWN	15,51	48,50	681,9	328,3	48,498
2	UNKNOWN	19,24	51,50	417,4	348,7	51,502
Total			100,00	1099,3	677,0	100,000

racemic sample:

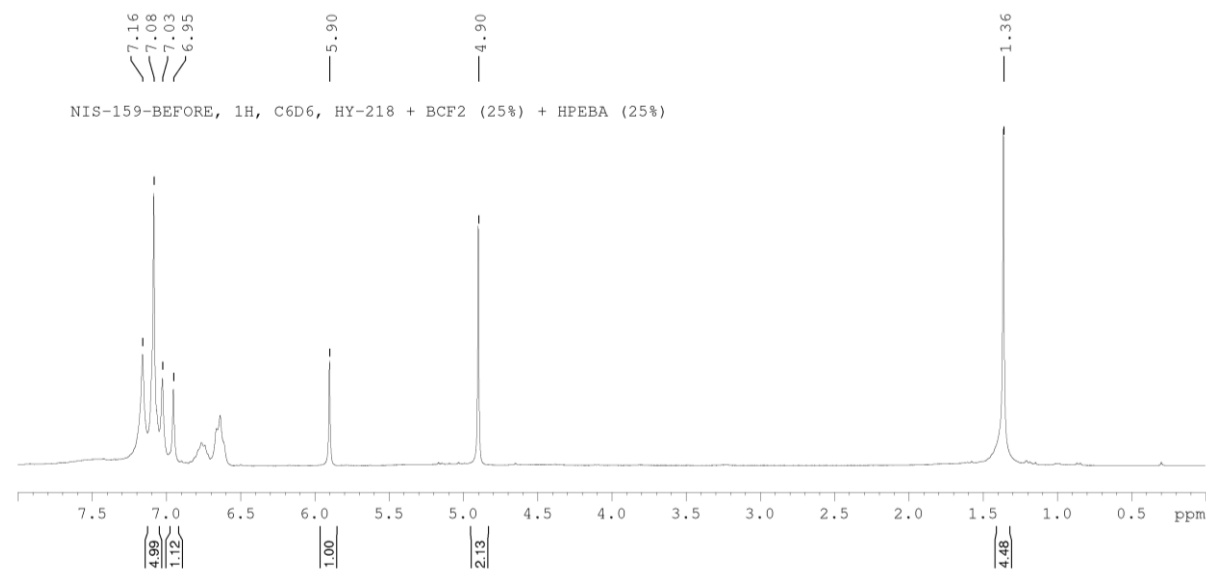


Peak results :

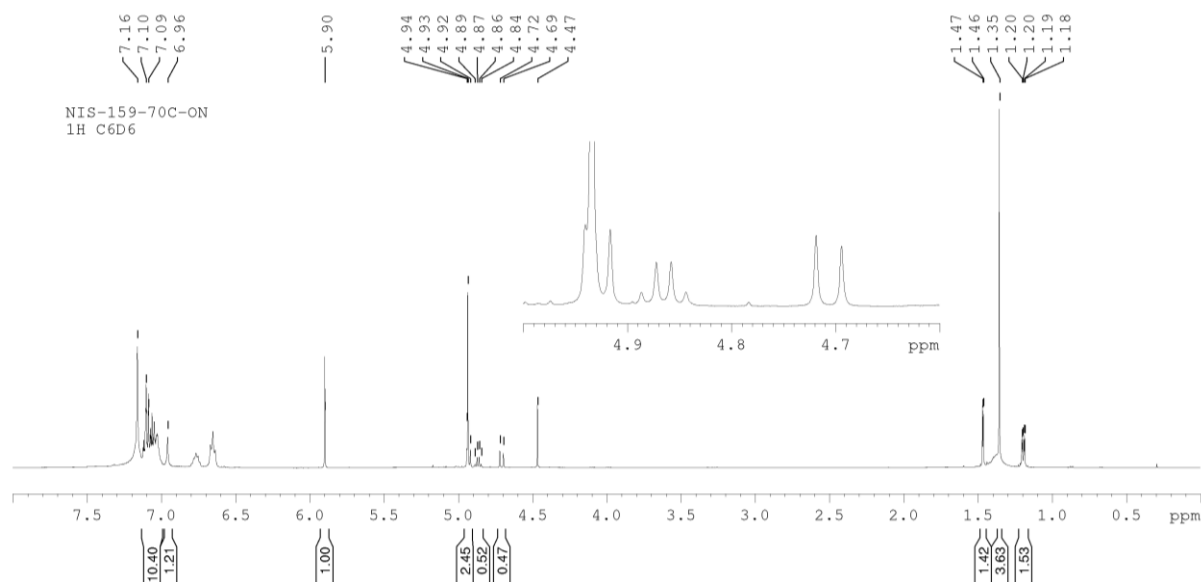
Index	Name	Time [Min]	Quantity [% Area]	Height [mAU]	Area [mAU.Min]	Area % [%]
1	UNKNOWN	14.89	49.45	303.5	125.9	49.445
2	UNKNOWN	19.00	50.55	158.1	128.8	50.555
Total			100.00	461.6	254.7	100.000



1H -NMR (300 MHz, 298 K, C_6D_6) before applying 4 bar H_2 -pressure:

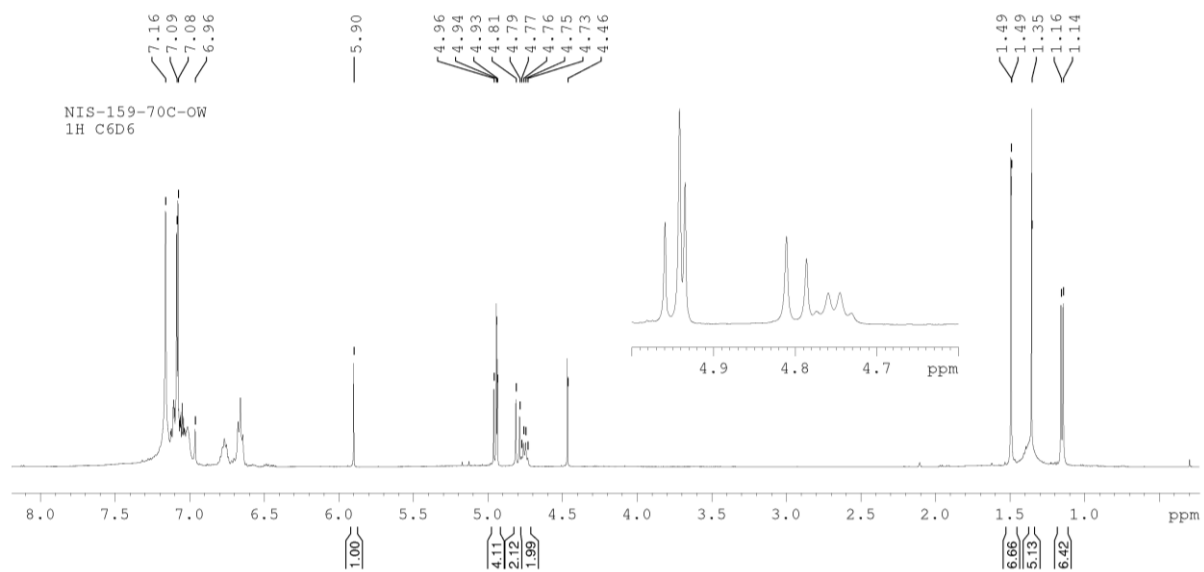


1H -NMR (500 MHz, 303 K, C_6D_6) after 18 h at 70 °C:

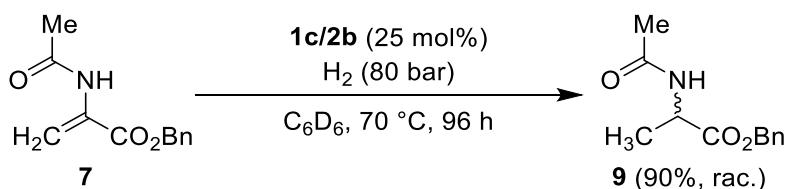


NMR-Yield: 30%

$^1\text{H-NMR}$ (500 MHz, 303 K, C_6D_6) after 96 h at 70 °C:

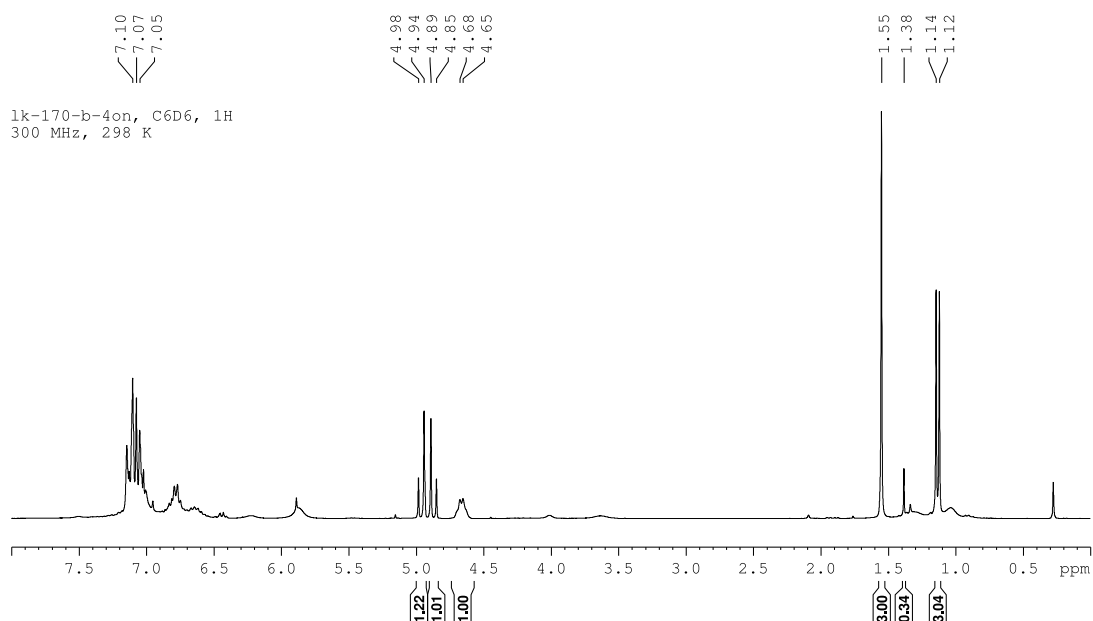


NMR-Yield (after 96 h): 65%



In a glovebox B(2,6-F₂-C₆H₃)₃ (**1c**) (8.8 mg, 25 μmol, 25 mol%), amidine **2b** (8.2 mg, 25 μmol, 25 mol%) and substrate **7** (21.9 mg, 100 μmol, 1.00 equiv.) were dissolved in 0.6 ml C₆D₆. The sample was transferred to a Millireactor, charged with 80 bar H₂ and heated to 70 °C in an oil bath. After 96 h, the crude reaction mixture was transferred to an NMR tube and analyzed by ¹H-NMR spectroscopy.

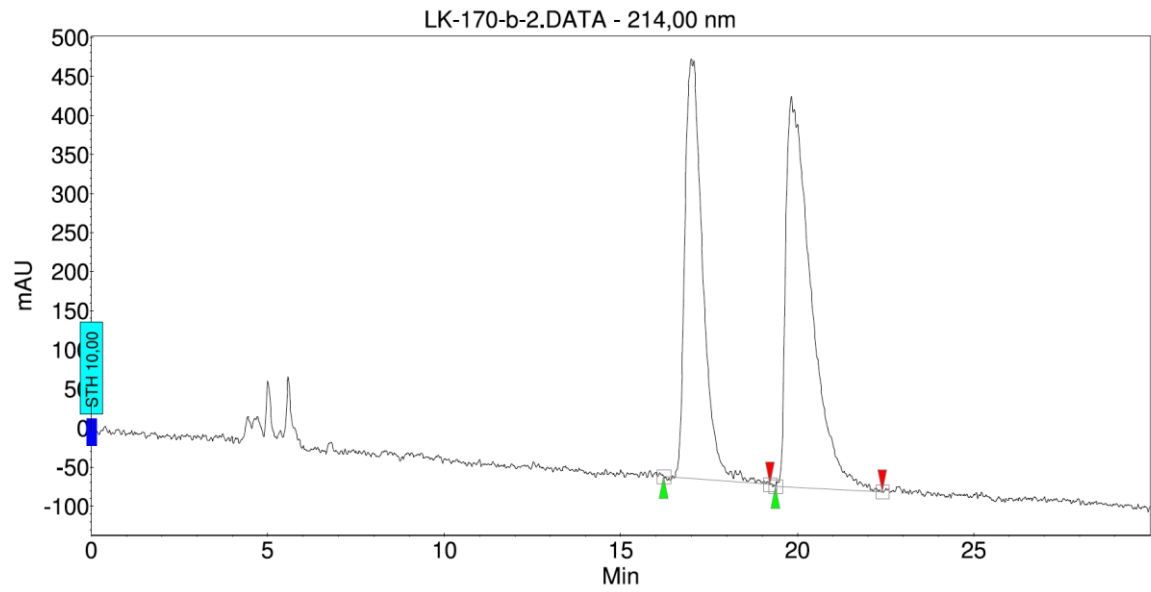
¹H-NMR (300 MHz, 298 K, C₆D₆) after 96 h at 70 °C (80 bar H₂):



NMR-Yield (after 96 h): 90%

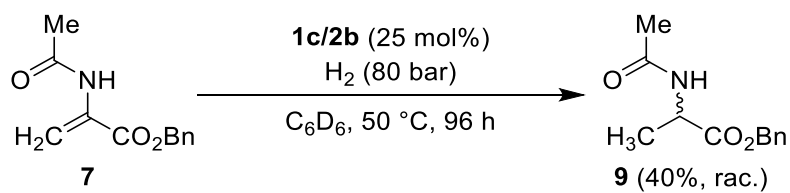
Purification for HPLC was achieved by column chromatography over silica (CH/EA: 5/1, then CH/EA: 1/1).

HPLC (IA, 15 °C, heptane/*i*-PrOH: 90/10, flow rate: 0.7 mL/min, 214 nm): t_R = 17.0 min, t_R = 19.8 min.

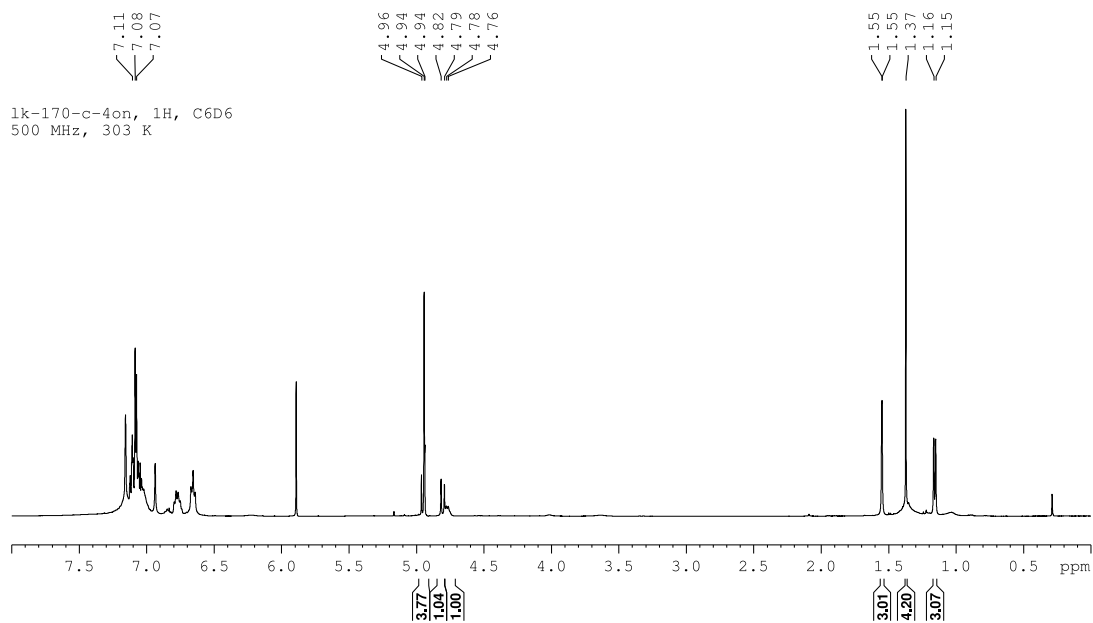


Peak results :

Index	Name	Time [Min]	Quantity [% Area]	Height [mAU]	Area [mAU.Min]	Area % [%]
1	UNKNOWN	16.99	43.21	537.1	315.6	43.206
2	UNKNOWN	19.83	56.79	500.0	414.9	56.794
Total			100.00	1037.1	730.5	100.000



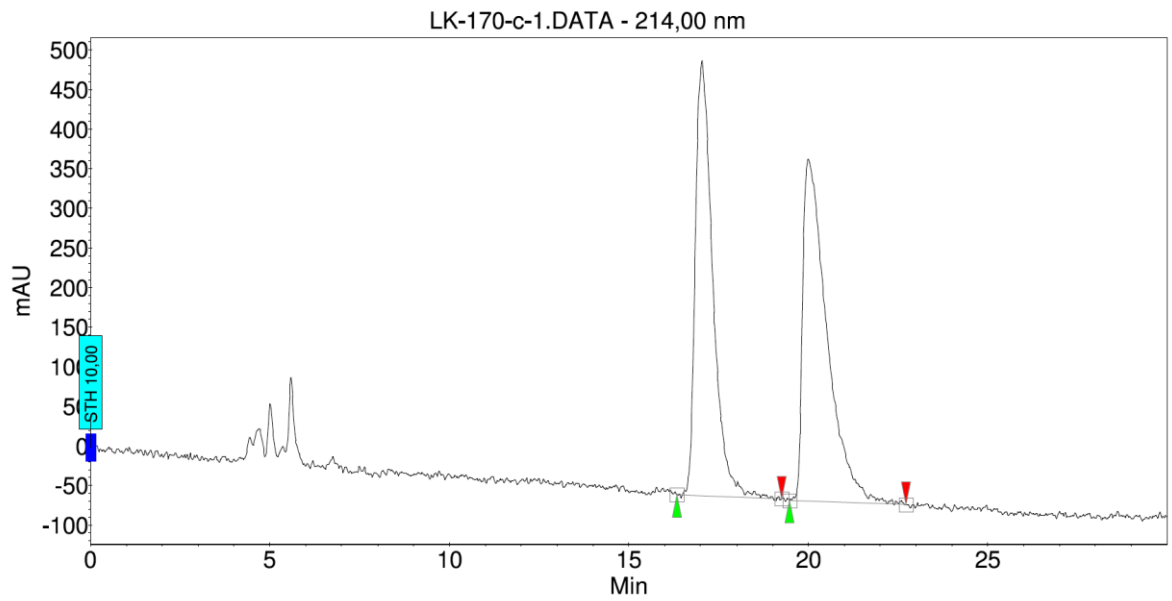
¹H-NMR (500 MHz, 303 K, C₆D₆) after 96 h at 50 °C (80 bar H₂):



NMR-Yield (after 96 h): 40%

Purification for HPLC was achieved by column chromatography over silica (CH/EA: 5/1, then CH/EA: 1/1).

HPLC (IA, 15 °C, heptane/*i*-PrOH: 90/10, flow rate: 0.7 mL/min, 214 nm): $t_R = 17.0$ min, $t_R = 20.0$ min.

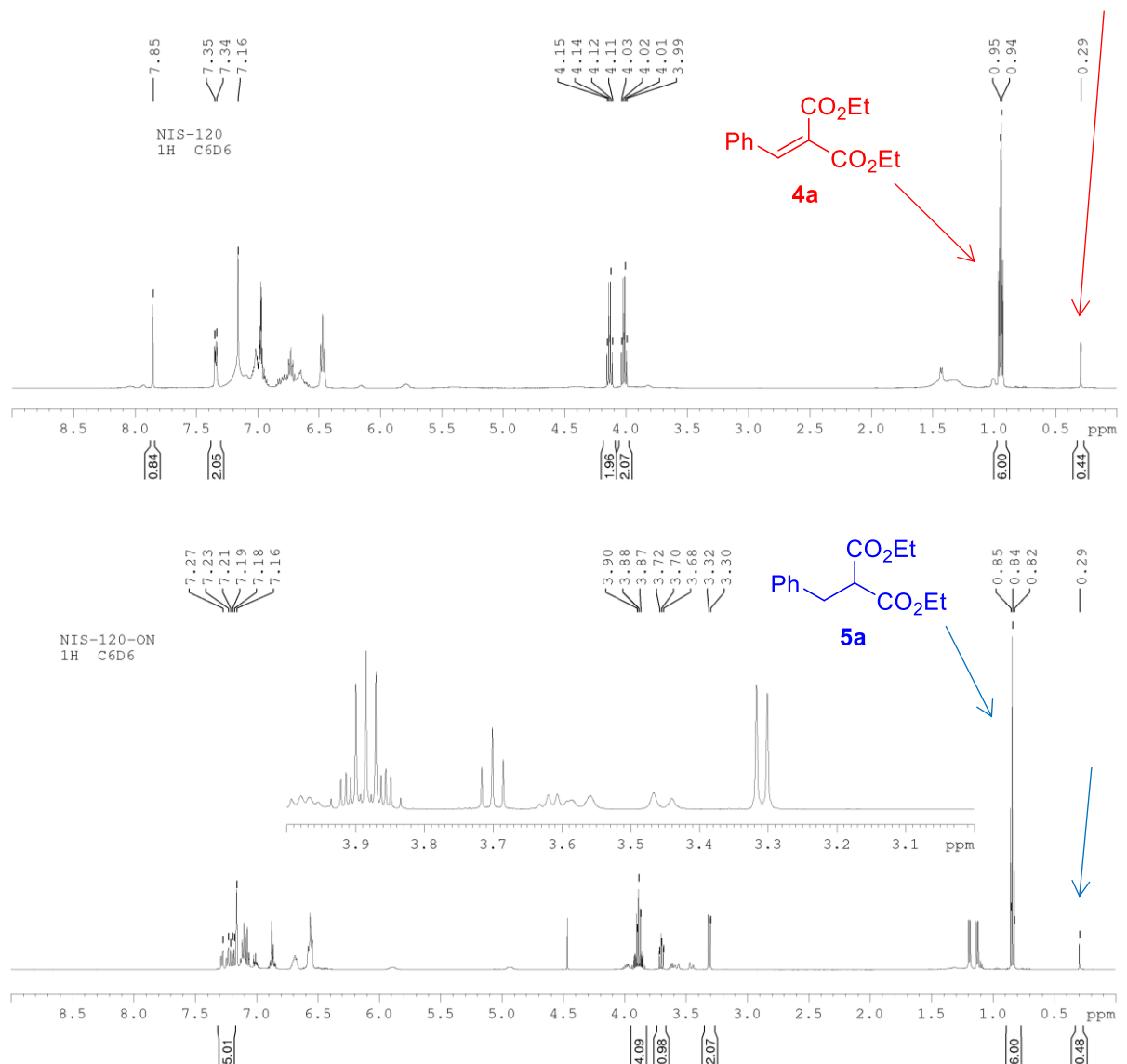


Peak results :

Index	Name	Time [Min]	Quantity [% Area]	Height [mAU]	Area [mAU.Min]	Area % [%]
1	UNKNOWN	17.04	47.72	549.4	309.3	47.720
2	UNKNOWN	19.99	52.28	432.1	338.8	52.280
Total			100.00	981.5	648.1	100.000

4.7 Calculation examples for NMR Yield

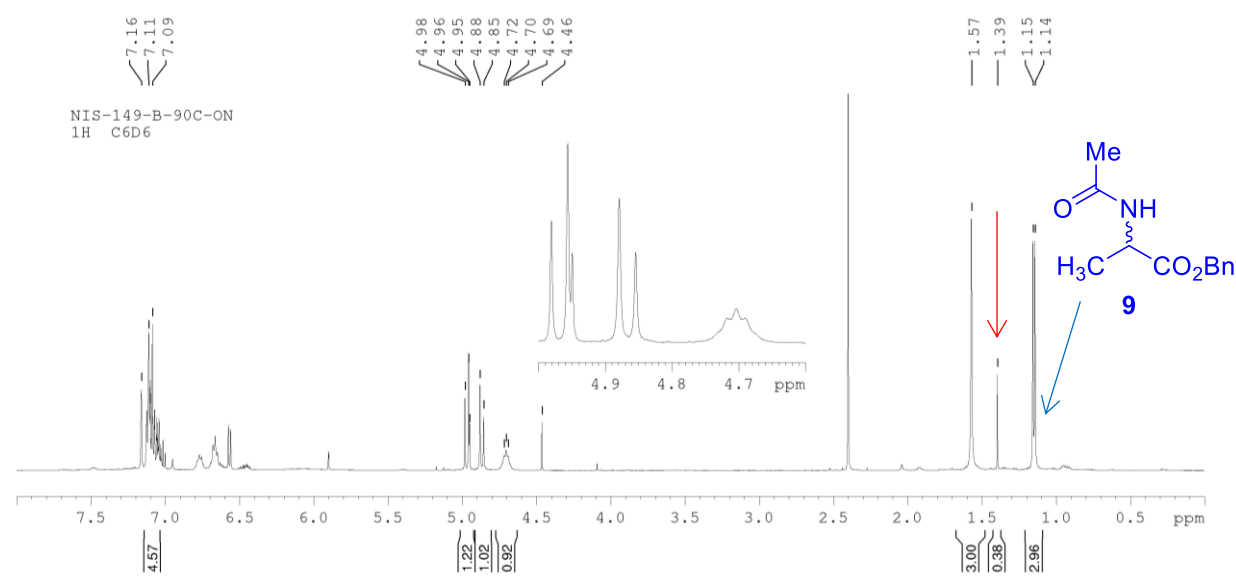
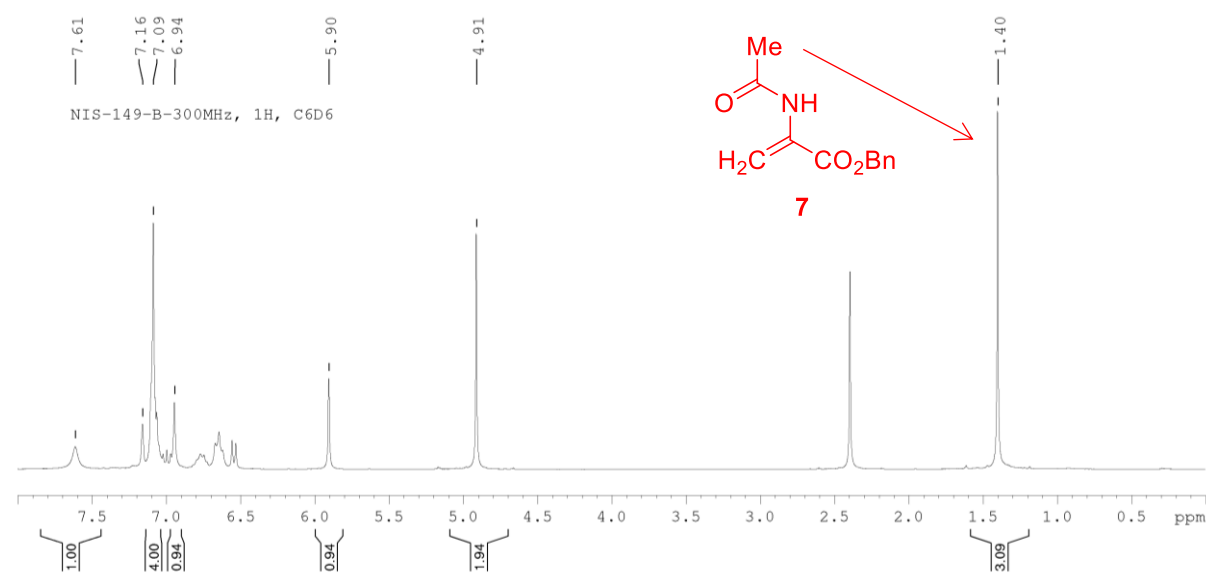
For samples according to general method A:



For yield calculation utilizing silicone grease as internal standard, normalization was done on proton integral from starting material resp. product. The integrals of silicone grease were compared (see below). Yields are just supposed to be estimations, therefore rounded down to the next multiple of 5%.

$$\begin{aligned} \text{Yield} &= \text{Silicone grease proton signal at start} / \text{Silicone grease proton signal at end} \\ &= 0.44 / 0.48 = 91,7\% \approx 90\% \end{aligned}$$

For samples according to general method B:



For yield calculation with neglectable side products, equivalent authentic signals of the remaining starting material and the formed product were integrated and compared (see below). Yields are just supposed to be estimations, therefore rounded down to the next multiple of 5%.

$$\text{Yield} = \frac{\text{Proton integral product}}{(\text{Proton integral product} + \text{Proton integral starting mat.})}$$

$$= \frac{3}{(3+0.38)} = 88.7\% \approx 85\%$$

5 References for Synthesis

- [SI1] a) S. Tussing, *Frustrierte Lewisaare: von autoinduzierter Hydrierung von Iminen zur FLP-Reaktivitätsskala*. Dissertation, Shaker Verlag, Aachen, **2017**; b) L. Greb, C.-G. Daniliuc, K. Bergander, J. Paradies, *Angew. Chem. Int. Ed.* **2013**, *52*, 5876–5879.
- [SI2] a) P. Benndorf, C. Preuß, P. W. Roesky, *J. Organomet. Chem.* **2011**, *696*, 1150-1155; b) T. S. Brunner, P. Benndorf, M. T. Gamer, N. Knöfel, K. Gugau, P. W. Roesky, *Organometallics* **2016**, *35*, 3474-3487.
- [SI3] C. R. Brindaban, S. Kampak, *Tetrahedron* **2003**, *59*, 7901-7906.
- [SI4] J. A. Nicasio Collazo, S. Steinberg, B. Ines, M. Alcarazo, *Chem. Eur. J.* **2013**, *19*, 11016-11020.
- [SI5] B. Li, N. Wang, Y. Liang, S. Xu, B. Wang, *Org. Lett.* **2013**, *15*, 136–139.

6 Computational Details

The calculations were performed with density functional theory (DFT) as implemented in the ORCA 4.2.1 package. Structures were optimized using PBEh-3c/def2-mSVP functional including dispersion correction D3BJ and thermochemical properties at 90 °C were obtained from frequency calculations. Equilibrium geometries were confirmed by the absence of imaginary frequencies whereas transition states were characterized by one imaginary frequency along the reaction trajectory. Final energy evaluations were conducted with the double hybrid functional PWP95/def2-QZVPP using RI-acceleration, D3BJ and solvation model based on density (SMD) for benzene.

Table S1: Computed energies in atomic units (Eh).

compound	energies in atomic units		thermodynamic correction for 363 K		entropy corr.	
	single point energy (PWPB86) def2-TZVP, SMD (Benzene)		thermo corr. kB*T	enthalpy corr. dH	T*S	final dG
H ₂	-1,1695		0,0011	0,0131	0,0188	-1,1741
1c (B(2,6-F ₂ -C ₆ H ₃) ₃)	-1315,1276		0,0011	0,2640	0,0912	-1314,9537
s-trans/trans- 2b	-1000,1465		0,0011	0,4590	0,0967	-999,7831
s-trans/cis- 2b	-1000,1501		0,0011	0,4588	0,0963	-999,7865
s-cis/trans- 2b	-1000,1502		0,0011	0,4589	0,0982	-999,7884
TS s-cis/trans- 2b -> s-trans/trans- 2b	-1000,1252		0,0011	0,4572	0,0949	-999,7617
TS s-cis/trans- 2b -> s-trans/cis- 2b	-1000,1151		0,0011	0,4570	0,0963	-999,7533
s-trans/trans- 2b • 1c	-2315,2846		0,0011	0,7265	0,1582	-2314,7151
s-trans/cis- 2b • 1c	-2315,2848		0,0011	0,7263	0,1589	-2314,7162
s-cis/trans- 2b • 1c	-2315,2897		0,0011	0,7267	0,1584	-2314,7202
TS s-trans/trans- 2b ...H...H... 1c	-2316,4457		0,0011	0,7406	0,1575	-2315,8615
TS s-trans/cis- 2b ...H...H... 1c	-2316,4468		0,0011	0,7404	0,1566	-2315,8618
TS s-cis/trans- 2b ...H...H... 1c	-2316,4482		0,0011	0,7414	0,1557	-2315,8612
[trans/s-trans- 2b -H][H- 1c]	-2316,4992		0,0011	0,7500	0,1566	-2315,9047
[s-trans/s-cis- 2b -H][H- 1c]	-2316,4977		0,0011	0,7495	0,1571	-2315,9042
[s-cis/s-trans- 2b -H][H- 1c]	-2316,4958		0,0011	0,7497	0,1555	-2315,9004