

## Supporting information

### Remote 1,5-stereoselectivity control by an *N*-ligand switch in the Pd(0)/InI-promoted reactions of 4-ethynyl- $\beta$ -lactams with aldehydes.

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## Contents

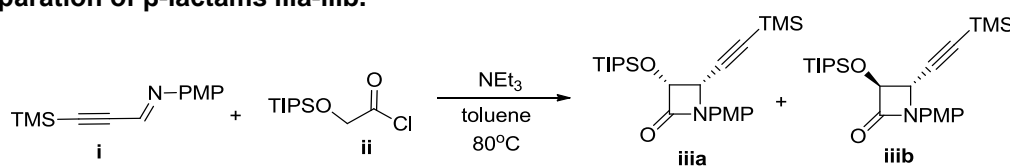
1. General Remarks.....	S2
2. Experimental details and characterization data for $\beta$ -lactams <b>iiia-iiib</b> , <b>iv</b> , (+)- <b>iv</b> , <b>v</b> , (-)- <b>v</b> , <b>vi</b> , <b>vii</b> , <b>1</b> , (+)- <b>1</b> , <b>10</b> , <b>12</b> , (+)- <b>12</b> , <b>13-15</b> , allene- $\alpha,\alpha'$ -diols <b>2a</b> , (-)- <b>2a</b> , <b>2b</b> , (+)- <b>2b</b> , <b>3a-7a</b> , (-)- <b>7a</b> , <b>3b-7b</b> , (-)- <b>7b</b> , <b>8a-9a</b> , <b>8b-9b</b> , <b>11</b> , <b>16a</b> , <b>16b</b> , <b>17a</b> , 2,6-diol <b>18</b> , $\alpha$ -allenyl ketone <b>19</b> , 1,5-dihydrofuranes <b>20a-20b</b> and Mosher's esters <b>viii</b> , <b>ix</b> , <b>viii/viii'</b> and <b>ix/ix'</b> .....	S2
3. <sup>1</sup> H and <sup>13</sup> C NMR spectra for all new and selected known compounds.....	S18
4. <sup>19</sup> F NMR spectra of Mosher's esters <b>viii</b> , <b>ix</b> , <b>viii/viii'</b> and <b>ix/ix'</b> .....	S63
5. HPLC chromatograms of <b>iv</b> , (+)- <b>iv</b> , <b>v</b> and (-)- <b>v</b> .....	S67
6. X-ray crystallographic data for (-)- <b>v</b> , <b>8b</b> and <b>20b</b> .....	S69
7. References and notes.....	S75

## 1. General remarks.

1nI was purchased from Sigma Aldrich and powdered in a mortar prior to use.<sup>1</sup> Other reagents were purchased from ABCR, Acros, Alfa Aesar or Sigma Aldrich and used as received. Dry solvents were obtained by distillation over Na/benzophenone (THF) or CaH<sub>2</sub> (CH<sub>2</sub>Cl<sub>2</sub>). Air- and moisture-sensitive reactions were conducted in oven-dried glassware under an atmosphere of argon. Column chromatography was carried out using Kiesel gel (230-400 mesh). Analytical TLC was performed on Silica gel 60 F254 aluminium plates (Merck, Darmstadt). Indication was achieved with UV light ( $\lambda = 254$  nm) and common dip stains (potassium permanganate or cerium ammonium molybdate). NMR spectra were recorded on Varian Mercury 400 MHz, Varian VNMRS 500 MHz or Varian VNMRS 600 MHz spectrometers in CDCl<sub>3</sub> or C<sub>6</sub>D<sub>6</sub> solutions. Chemical shifts are quoted on the  $\delta$  scale, ppm, and are calibrated using residual solvents signals (<sup>1</sup>H NMR: CDCl<sub>3</sub>: 7.26 ppm, C<sub>6</sub>D<sub>6</sub>: 7.16 ppm; <sup>13</sup>C {<sup>1</sup>H} NMR: CDCl<sub>3</sub>: 77.16 ppm, C<sub>6</sub>D<sub>6</sub>: 128.06 ppm). Multiplicities for <sup>1</sup>H NMR signals are described using the following abbreviations: *s* = singlet, *d* = doublet, *t* = triplet, *q* = quartet, *quint* = quintet, *sep* = septet, *m* = multiplet, *br* = broad signal. Coupling constants, *J*, are given in Hertz (Hz). Infrared spectra (IR) were measured on a FT-IR-1600-Perkin Elmer spectrophotometer and are reported in cm<sup>-1</sup>. The samples were prepared as thin films. High resolution mass spectra (HRMS) were obtained on ESI-TOF Mariner spectrometer (Perspective Biosystem) and are given in *m/z*. Melting points (*m.p.*) were determined with Melting Point Meter MPM-H2 apparatus and are uncorrected. Optical rotations [ $\alpha$ ] were measured on Jasco P-2000 Polarimeter in a quartz glass cuvette at  $\lambda = 589$  nm (Na D-line). Concentrations [*c*] are given in g/100 mL. Analytical high-performance liquid chromatography (HPLC) was performed using Knauer HPLC system (WellChrom K-1001 pump, WellChrom K-2501 UV detector, WellChrom K-2301 RI detector) outfitted with Daicel Chiralpak ASH (250 mm x 4.6 mm, 5  $\mu$ m) column. Operating procedures and retention times are reported with the corresponding chromatograms. 4-Methoxy-*N*-(3-trimethylsilylpropynylidene)aniline (**i**)<sup>2</sup> and 2-((triisopropylsilyl)oxy)acetyl chloride (**ii**)<sup>3</sup> were prepared following the previously reported procedures and their analytical data were consistent with those published in the literature.

## 2. Experimental details and characterization data for $\beta$ -lactams **iiia-iiib**, **iv**, (+)-**iv**, **v**, (-)-**v**, **vi**, **vii**, **1**, (+)-**1**, **10**, **12**, (+)-**12**, **13-15**, allene- $\alpha,\alpha'$ -diols **2a**, (-)-**2a**, **2b**, (+)-**2b**, **3a-7a**, (-)-**7a**, **3b-7b**, (-)-**7b**, **8a-9a**, **8b-9b**, **11**, **16a**, **16b**, **17a**, **2,6-diol 18**, $\alpha$ -allenyl ketone **19**, **1,5-dihydrofurans 20a-20b** and Mosher's esters **viii**, **ix**, **viii/viii'** and **ix/ix'**.

### 2.1. Preparation of $\beta$ -lactams **iiia-iiib**.



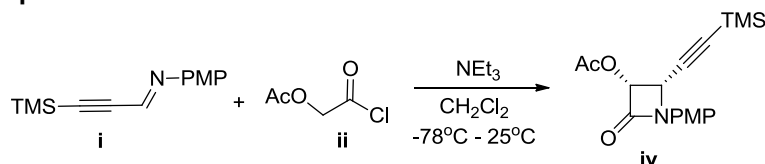
To a solution of 4-methoxy-*N*-(3-trimethylsilylpropynylidene)aniline (**i**) (10.412 g, 45 mmol) in anhydrous toluene (650 mL), NEt<sub>3</sub> (9.408 mL, 67.5 mmol) and 2-((triisopropylsilyl)oxy)acetyl chloride (**ii**) (13.545 g, 54 mmol) were sequentially added, both in one portion at 25 °C under an atmosphere of argon. The resulting mixture was heated to 80 °C for 1 h and after being cooled to 25 °C, poured into water and layers were separated. Water layer was extracted with portion of toluene (50 mL) and combined extracts were washed with 5% aqueous HCl solution (300 mL), saturated solution of NaHCO<sub>3</sub> (300 mL) and brine (300 mL), dried over MgSO<sub>4</sub> and concentrated. Purification of the crude product by column chromatography on silica gel using an MTBE/hexane mixture as an eluent afforded  $\beta$ -lactams **iiia** and **iiib** as colorless crystals.

(3*R*,4*S*\*)-1-(4-methoxyphenyl)-3-((triisopropylsilyl)oxy)-4-((trimethylsilyl)ethynyl)azetidin-2-one (**iiia**). Yield: 16.849 g (84%); colorless crystals; *mp* = 128.3-128.7 °C; *R<sub>f</sub>* (20% MTBE/hexane) 0.80; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$ : 7.52 – 7.42 (m, 2H), 6.93 – 6.82 (m, 2H), 5.07 (d, *J* = 4.8 Hz, 1H), 4.72 (d, *J* = 4.8 Hz, 1H), 3.79 (s, 3H), 1.30 – 1.06 (m, 21H), 0.15 (s, 9H); <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$ : 164.6, 156.6, 131.0, 118.7, 114.4, 98.3, 94.6, 77.3, 55.6, 51.9, 18.0, 17.9, 12.2, -0.2; IR (film)  $\nu$ : 2944, 2867, 2178,

1757, 1513, 1465, 1385, 1249, 1187, 1119, 1035, 962, 886, 844, 761, 736, 688, 514, 418  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{24}\text{H}_{40}\text{NNO}_3\text{Si}_2$   $[\text{M} + \text{H}^+]$  446.2547. Found 446.2540.

(3*R*\*,4*R*\*)-1-(4-methoxyphenyl)-3-((triisopropylsilyl)oxy)-4-((trimethylsilyl)ethynyl)azetid-2-one (**iiib**). Yield: 2.206 g (11%); colorless crystals; mp = 79.8-81.3 °C;  $R_f$  (20% MTBE/hexane) 0.90;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.56 – 7.41 (m, 2H), 6.92 – 6.87 (m, 2H), 5.00 (d,  $J = 1.9$  Hz, 1H), 4.32 (d,  $J = 1.9$  Hz, 1H), 3.80 (s, 3H), 1.24 – 1.09 (m, 21H), 0.16 (s, 9H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$ : 164.2, 156.6, 130.9, 118.7, 114.4, 100.0, 94.1, 83.5, 55.6, 53.4, 17.83, 17.80, 12.0, -0.3; IR (film)  $\nu$ : 2945, 2868, 2175, 1766, 1514, 1465, 1385, 1249, 1153, 1115, 1038, 930, 882, 848, 761, 715, 688, 520, 501, 458  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{24}\text{H}_{40}\text{NNO}_3\text{Si}_2$   $[\text{M} + \text{H}^+]$  446.2547. Found 446.2540.

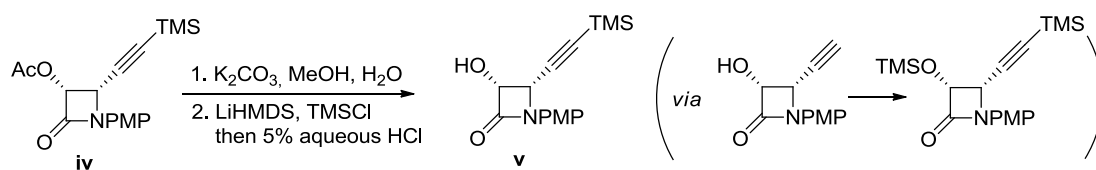
## 2.2. Preparation of $\beta$ -lactam **iv**.



To a solution of 4-methoxy-*N*-(3-trimethylsilylpropynylidene)aniline (**i**) (2.314 g, 10 mmol) in anhydrous  $\text{CH}_2\text{Cl}_2$  (25 mL),  $\text{NEt}_3$  (2.091 mL, 15 mmol) was added in one portion followed by acetoxycarbonyl chloride (1.29 mL, 12 mmol), dropwise over 15 min at -78 °C under an atmosphere of argon. The resulting mixture was stirred for an additional hour at the same temperature and then allowed to warm to 25 °C slowly overnight. At the end of this time, the reaction was quenched with 5% aqueous HCl solution (25 mL), poured into water and layers were separated. Water layer was extracted with  $\text{CH}_2\text{Cl}_2$  (2 x 25 mL) and combined extracts were washed successively with 5% aqueous HCl solution (75 mL), saturated solution of  $\text{NaHCO}_3$  (50 mL) and water (75 mL), dried over  $\text{MgSO}_4$  and concentrated. Purification of the crude product by column chromatography on silica gel using an ethyl acetate/hexane mixture as an eluent afforded  $\beta$ -lactam **iv** as colorless crystals.

((3*R*\*,4*S*\*)-1-(4-methoxyphenyl)-2-oxo-4-((trimethylsilyl)ethynyl)azetid-3-yl acetate (**iv**). Yield: 3.049 g (92%); colorless crystals; mp = 136.1-137.2 °C;  $R_f$  (30% AcOEt/hexane) 0.65;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 7.51 – 7.37 (m, 2H), 6.95 – 6.81 (m, 2H), 5.74 (d,  $J = 4.7$  Hz, 1H), 4.85 (d,  $J = 4.7$  Hz, 1H), 3.79 (s, 3H), 2.19 (s, 3H), 0.15 (s, 9H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$ : 169.5, 160.3, 157.0, 130.2, 118.8, 114.5, 96.3, 95.3, 75.4, 55.6, 50.0, 20.6, -0.3; IR (film)  $\nu$ : 2959, 2902, 2838, 2177, 1759, 1514, 1389, 1297, 1250, 1220, 1114, 1135, 845, 761, 642, 517  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{17}\text{H}_{21}\text{NNaO}_4\text{Si}$   $[\text{M} + \text{Na}^+]$  354.1138. Found 354.1126.

## 2.3. Preparation of $\beta$ -lactam **v** (racemic sample used as chiral HPLC analysis standart).

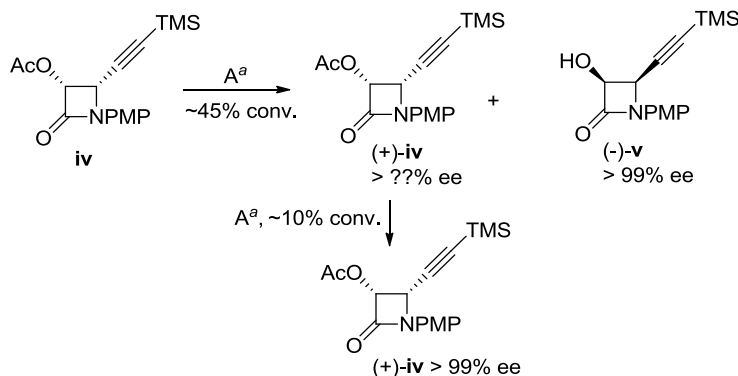


To a vigorously stirred solution of  $\beta$ -lactam **iv** (166 mg, 0.5 mmol) in MeOH (7 mL), solution of  $\text{K}_2\text{CO}_3$  (138 mg, 1 mmol) in water (3.5 mL) was added in one portion at 25 °C and the mixture was stirred for 5 min at the same temperature. The reaction was then quenched with 5% aqueous solution of HCl (25 mL), poured into water and extracted with EtOAc (2 x 15 mL). The combined extracts were successively washed with water (25 mL), saturated solution of  $\text{NaHCO}_3$  (25 mL) and brine (25 mL), dried over anhydrous  $\text{MgSO}_4$  and concentrated under reduced pressure. Resulting crude 3-OH-4-propargyl- $\beta$ -lactam was then dissolved in anhydrous THF (10 mL) and to this mixture 1M LiHMDS solution in THF (2 mL, 2 mmol) was added dropwise at -30 °C under atmosphere of argon. After 30 min of stirring at the same temperature, trimethylsilyl chloride (1.27 mL, 10 mmol) was added dropwise and after additional 15 min at the same temperature the cooling bath was removed. Once warmed to 25 °C, 5% aqueous HCl solution (10 mL) was added in one portion and stirring was continued for 15 min at the same temperature. Subsequently, the reaction mixture was poured into water and extracted with EtOAc (2 x 15 mL). The combined extracts were successively washed with 5% aqueous HCl solution (25 mL), saturated solution of  $\text{NaHCO}_3$  (25 mL) and brine (25 mL), dried over anhydrous  $\text{MgSO}_4$  and concentrated under reduced pressure. Purification of the crude product by column

chromatography on silica gel using an ethyl acetate/hexane mixture as an eluent afforded  $\beta$ -lactam **v** as colorless crystals.

(3*R*\*,4*S*\*)-3-hydroxy-1-(4-methoxyphenyl)-4-((trimethylsilyl)ethynyl)azetid-2-one (**v**). Yield: 83 mg (57%); colorless crystals; mp = 178.1-178.9 °C (with decomposition);  $R_f$  (30% AcOEt/hexane) 0.50;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  7.46 – 7.38 (m, 2H), 6.89 – 6.81 (m, 2H), 4.99 (dd,  $J$  = 10.8, 5.0 Hz, 1H), 4.80 (d,  $J$  = 5.0 Hz, 1H), 3.79 (s, 3H), 3.31 (br d,  $J$  = 10.8 Hz, 1H), 0.20 (s, 9H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$ : 164.9, 156.8, 130.3, 118.8, 114.4, 97.3, 96.3, 76.2, 55.5, 51.6, -0.2; IR (film)  $\nu$ : 3269, 2959, 1737, 1583, 1512, 1439, 1400, 1299, 1250, 1180, 1120, 1024, 840, 761, 732, 701, 636, 608, 527, 510  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{15}\text{H}_{19}\text{NNaO}_3\text{Si}$  [ $M + \text{Na}^+$ ] 312.1032. Found 312.1025.

## 2.4. Preparation of $\beta$ -lactams (+)-**iv** and (-)-**v**.<sup>4</sup>



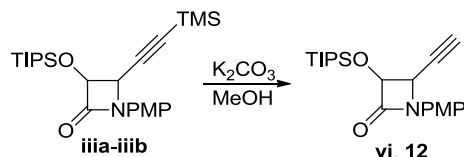
<sup>a</sup> Amano Lipase PS,  $\text{CH}_3\text{CN}$ , 0.2 M sodium phosphate buffer (pH 7.5), 50°C

To a vigorously stirred mixture of racemic  $\beta$ -lactam **iv** (2.154 g, 6.5 mmol) in 0.2 M sodium phosphate buffer (pH 7.5, 75 mL)<sup>5</sup> and acetonitrile (8.6 mL), Amano Lipase PS (1.077 g, immobilized on diatomite) was added in one portion at 25°C and reaction was heated to 50 °C. After 3 h at the same temperature (ca. 45% conversion according to  $^1\text{H}$  NMR of crude reaction mixture) the mixture was cooled to 25 °C, filtered through a pad of Celite and extracted with  $\text{CH}_2\text{Cl}_2$  (3 x 50 mL). The combined extracts were dried over  $\text{MgSO}_4$ , concentrated under reduced pressure and the resulting enantioenriched  $\beta$ -lactams (+)-**iv** (1.14 g, 88% ee) and (-)-**v** (0.767 g, >99% ee) were separated by column chromatography on silica gel using an ethyl acetate/hexane mixture as an eluent.  $\beta$ -Lactam (+)-**iv** (1.14 g, 88% ee) was then dissolved in acetonitrile (4.6 mL) and 0.2 M sodium phosphate buffer (pH 7.5, 40 mL)<sup>5</sup> was added followed by Amano Lipase PS (0.57 g, immobilized on diatomite), both in one portion at 25 °C and the resulting mixture was intensively stirred at 50 °C within 3 h (ca. 10% conversion according to  $^1\text{H}$  NMR of crude reaction mixture). After that time the mixture was cooled to 25 °C, filtered through a pad of Celite and extracted with  $\text{CH}_2\text{Cl}_2$  (3 x 25 mL). The combined extracts were dried over  $\text{MgSO}_4$ , and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an ethyl acetate/hexane mixture as an eluent afforded enantioenriched  $\beta$ -lactam (+)-**iv** (1.049g, >99% ee) as colorless crystals.

(3*R*,4*S*)-1-(4-methoxyphenyl)-2-oxo-4-((trimethylsilyl)ethynyl)azetid-3-yl acetate ((+)-**iv**). Yield: 1.049 g (49%); colorless crystals; mp = 89.8-90.6 °C;  $R_f$  (30% AcOEt/hexane) 0.65;  $[\alpha]_{\text{D}}^{25} = 73.6$  ( $c = 0.91$ ,  $\text{CHCl}_3$ ); >99% ee (chiral HPLC); NMR and IR spectra were consistent with those recorded for the racemate; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{17}\text{H}_{21}\text{NNaO}_4\text{Si}$  [ $M + \text{Na}^+$ ] 354.1138. Found 354.1139.

(3*S*,4*R*)-3-hydroxy-1-(4-methoxyphenyl)-4-((trimethylsilyl)ethynyl)azetid-2-one ((-)-**v**). Yield: 0.767 g (41%); colorless crystals; mp = 169.1-169.8 °C (with decomposition);  $R_f$  (30% AcOEt/hexane) 0.50;  $[\alpha]_{\text{D}}^{25} = -281.8$  ( $c = 0.53$ ,  $\text{CHCl}_3$ ); >99% ee (chiral HPLC); NMR and IR spectra were consistent with those recorded for the racemate; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{15}\text{H}_{19}\text{NNaO}_3\text{Si}$  [ $M + \text{Na}^+$ ] 312.1032. Found 312.1029.

## 2.5. Preparation of $\beta$ -lactams **vi** and **12**.

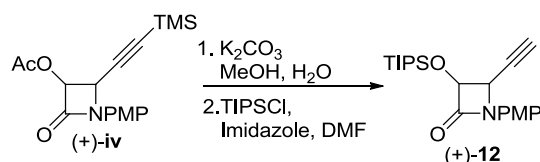


To a vigorously stirred solution of  $\beta$ -lactams **iii**a or **iii**b (8.914 g, 20 mmol) in MeOH (350 mL),  $K_2CO_3$  (5.528 g, 40 mmol) was added in one portion at 25 °C and the mixture was stirred for 10 min at the same temperature. The reaction was then quenched with 5% aqueous HCl solution (350 mL), poured into water and extracted with EtOAc (3 x 200 mL). The combined extracts were successively washed with saturated solution of  $NaHCO_3$  (300 mL) and brine (300 mL), dried over anhydrous  $MgSO_4$  and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an MTBE/hexane mixture as an eluent afforded  $\beta$ -lactam **vi** and **12** as colorless crystals.

(3*R*\*,4*S*\*)-4-ethynyl-1-(4-methoxyphenyl)-3-((triisopropylsilyl)oxy)azetidin-2-one (**12**). Yield: 6.351 g (85%); colorless crystals; mp = 117.1-117.8 °C;  $R_f$  (20% MTBE/hexane) 0.65;  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta$ : 7.51 – 7.42 (m, 2H), 6.93 – 6.84 (m, 2H), 5.12 (d,  $J = 4.8$  Hz, 1H), 4.73 (dd,  $J = 4.8, 2.1$  Hz, 1H), 3.79 (s, 3H), 2.51 (d,  $J = 2.1$  Hz, 1H), 1.30 – 1.06 (m, 21H);  $^{13}C$  NMR (101 MHz,  $CDCl_3$ )  $\delta$ : 164.3, 156.6, 130.7, 118.6, 114.5, 77.22, 77.16, 77.1, 55.6, 51.1, 17.9, 17.8, 12.1; IR (film)  $\nu$ : 3308, 3252, 2944, 2867, 2125, 1755, 1514, 1464, 1388, 1249, 1187, 1122, 885, 828, 733, 688, 655, 505  $cm^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $C_{21}H_{31}NNaO_3Si$  [ $M + Na^+$ ] 396.1971. Found 396.1963.

(3*R*\*,4*R*\*)-4-ethynyl-1-(4-methoxyphenyl)-3-((triisopropylsilyl)oxy)azetidin-2-one (**vi**). Yield: 1.496 g (89%, starting from 4.5 mmol of **iii**b); colorless crystals; mp = 104.1-105.2 °C;  $R_f$  (20% MTBE/hexane) 0.65;  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta$ : 7.49 – 7.42 (m, 2H), 6.93 – 6.86 (m, 2H), 5.04 (d,  $J = 1.8$  Hz, 1H), 4.33 (dd,  $J = 2.1, 1.8$  Hz, 1H), 3.79 (s, 3H), 2.60 (d,  $J = 2.1$  Hz, 1H), 1.27 – 1.07 (m, 21H);  $^{13}C$  NMR (101 MHz,  $CDCl_3$ )  $\delta$ : 163.9, 156.7, 130.6, 118.7, 114.5, 83.1, 78.5, 76.6, 55.6, 52.6, 17.81, 17.79, 12.0; IR (film)  $\nu$ : 3292, 3253, 2944, 2867, 1762, 1514, 1464, 1386, 1298, 1249, 1154, 1035, 995, 930, 882, 849, 829, 715, 686, 661, 521, 501, 444  $cm^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $C_{21}H_{31}NNaO_3Si$  [ $M + Na^+$ ] 396.1971. Found 396.1973.

## 2.6. Preparation of $\beta$ -lactams (+)-**12**.

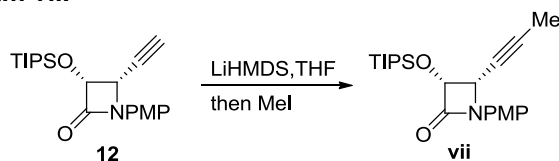


To a vigorously stirred solution of  $\beta$ -lactam (+)-**iv** (1.061 g, 3.2 mmol) in MeOH (40 mL),  $K_2CO_3$  (885 mg, 6.4 mmol) in water (20 mL) was added in one portion at 25 °C and the mixture was stirred for 5 min at the same temperature. The reaction was then quenched with 5% aqueous HCl solution (50 mL), poured into water and extracted with EtOAc (3 x 50 mL). The combined extracts were successively washed with water (150 mL), saturated solution of  $NaHCO_3$  (50 mL) and brine (50 mL), dried over anhydrous  $MgSO_4$  and concentrated under reduced pressure. The crude 3-OH-4-propargyl- $\beta$ -lactam was then dissolved in anhydrous DMF (5 mL), imidazole (545 mg, 8 mmol) and TIPSCI (0.753 mL, 3.52 mmol) were sequentially added both in one portion at 0 °C under an atmosphere of argon and the mixture was stirred for 15 min at the same temperature. Then the cooling bath was removed and the stirring was continued at 25 °C overnight. At the end of this time the reaction mixture was poured into water and extracted with ethyl acetate (3 x 50 mL). Combined extracts were washed with 5% aqueous solution of HCl (2 x 100 mL), saturated solution of  $NaHCO_3$  (50 mL) and brine (50 mL), dried over anhydrous  $MgSO_4$  and concentrated under reduced pressure. Purification of the crude product by crystallization from hexane afforded  $\beta$ -lactam (+)-**12** as colorless crystals.

(3*R*,4*S*)-4-ethynyl-1-(4-methoxyphenyl)-3-((triisopropylsilyl)oxy)azetidin-2-one ((+)-**12**). Yield: 813 mg (68%); colorless crystals; mp = 133.2-133.8 °C;  $R_f$  (20% MTBE/hexane) 0.65;  $[\alpha]_D^{25} = 139.1$  ( $c = 0.53$ ,

CHCl<sub>3</sub>); >99% ee; NMR and IR spectra were consistent with those recorded for racemate; HRMS (ESI-TOF) m/z calcd for C<sub>21</sub>H<sub>31</sub>NNaO<sub>3</sub>Si [M + Na<sup>+</sup>] 396.1971. Found 396.1962.

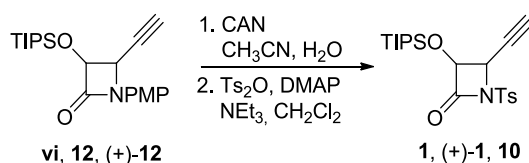
## 2.7. Preparation of β-lactam vii.



To a vigorously stirred solution of β-lactam **12** (1.121 g, 3 mmol) in anhydrous THF (50 mL), 1M LiHMDS solution in THF (6 mL, 6 mmol) was added dropwise at -30 °C under atmosphere of argon and the stirring was continued for 30 min at the same temperature. Subsequently MeI (3.735 mL, 60 mmol) was added dropwise and after 30 min at the same temperature the cooling bath was removed and once warmed to 25 °C the mixture was poured into water and extracted with EtOAc (3 x 50 mL). The combined extracts were successively washed with 5% aqueous HCl solution (50 mL), saturated solution of NaHCO<sub>3</sub> (50 mL) and brine (50 mL), dried over anhydrous MgSO<sub>4</sub> and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an MTBE/hexane mixture as an eluent afforded β-lactam **vii** as colorless crystals.

(3*R*\*,4*S*\*)-1-(4-methoxyphenyl)-4-(prop-1-yn-1-yl)-3-((triisopropylsilyl)oxy)azetidin-2-one (**vii**). Yield: 954 mg (82%); colorless crystals; mp = 120.4-121.0 °C; R<sub>f</sub> (20% MTBE/hexane) 0.65; Analytical data were consistent with previously reported values.<sup>6</sup>

## 2.8. Preparation of *N*-Ts-azetidin-2-ones **1**, (+)-**1** and **10**. General procedure.



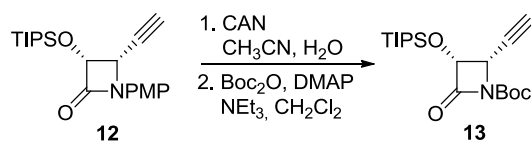
To a solution of *N*-PMP-azetidin-2-one **vi**, **12** or (+)-**12** (747 mg, 2 mmol) in acetonitrile (80 mL) and water (15 mL) cooled to -10 °C a solution of CAN (3.838 g, 7 mmol) in water (65 mL) was added dropwise within 15 min and the resulting mixture was stirred at the same temperature for 3.5 h. At the end of this time the reaction was quenched with saturated aqueous Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub> solution (20 mL), poured into water and extracted with ethyl acetate (3 x 40 mL). The combined extracts were washed with water (200 mL), saturated aqueous solution of NaHCO<sub>3</sub> (100 mL) and brine (100 mL), dried over MgSO<sub>4</sub> and concentrated under reduced pressure. Filtration of the residue through a pad of silica gel with CH<sub>2</sub>Cl<sub>2</sub> (to remove quinone formed as the byproduct) and then ethyl acetate/hexane mixture afforded crude NH-β-lactam which was then dissolved in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (10 mL). To this mixture NEt<sub>3</sub> (1.116 mL, 8 mmol), DMAP (24.4 mg, 0.2 mmol) and Ts<sub>2</sub>O (3.264 g, 8 mmol) were sequentially added, all in one portion at 0 °C under atmosphere of argon and the cooling bath was removed. After 24 h at 25 °C the reaction mixture was poured into water, layers were separated and a water layer was extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 50 mL). The combined extracts were washed successively with water (200 mL) and saturated solution of NaHCO<sub>3</sub> (100 mL), dried over anhydrous MgSO<sub>4</sub> and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an ethyl acetate/hexane or acetone/hexane mixture as an eluent afforded desired *N*-Ts-azetidin-2-one **1**, (+)-**1** and **10** as colorless crystals.

(3*R*\*,4*S*\*)-4-ethynyl-1-tosyl-3-((triisopropylsilyl)oxy)azetidin-2-one (**1**). Starting from **12**: 4.867 g (77 %, 15 mmol of **12** instead of 2 mmol was used); colorless crystals; mp = 122.1-123.7 °C; R<sub>f</sub> (15% ethyl acetate/hexane) 0.50; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ: 8.02 – 7.87 (m, 2H), 7.42 – 7.29 (m, 2H), 5.09 (d, *J* = 5.5 Hz, 1H), 4.88 (dd, *J* = 5.5, 2.2 Hz, 1H), 2.52 – 2.39 (m, 4H), 1.18 – 1.02 (m, 21H); <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ: 163.7, 145.6, 135.8, 130.0, 128.0, 78.1, 77.6, 75.4, 52.8, 21.9, 17.73, 17.67, 12.0; IR (film) ν: 3269, 2944, 2868, 2126, 1805, 1597, 1464, 1368, 1241, 1196, 1172, 1143, 1090, 996, 883, 730, 675, 629, 552, 524 cm<sup>-1</sup>; HRMS (ESI-TOF) m/z calcd for C<sub>21</sub>H<sub>31</sub>NNaO<sub>4</sub>SSi [M + Na<sup>+</sup>] 444.1641. Found 444.1636.

(3*R*,4*S*)-4-ethynyl-1-tosyl-3-((triisopropylsilyloxy)azetid-2-one ((+)-**1**). Starting from (+)-**12**: 605 mg (72 %); colorless wax;  $R_f$  (15% ethyl acetate/hexane) 0.50;  $[\alpha]_D^{25} = 95.6$  ( $c = 0.54$ ,  $\text{CHCl}_3$ ); >99% ee; NMR and IR spectra were consistent with those recorded for racemate; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{21}\text{H}_{31}\text{NNaO}_4\text{SSi}$   $[\text{M} + \text{Na}^+]$  444.1641. Found 444.1633.

(3*R*\*,4*R*\*)-4-ethynyl-1-tosyl-3-((triisopropylsilyloxy)azetid-2-one (**10**). Starting from **vi**: 430 mg (51 %); colorless crystals; mp = 91.4-92.2 °C;  $R_f$  (15% ethyl acetate/hexane) 0.50;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  8.08 – 7.67 (m, 2H), 7.49 – 7.24 (m, 2H), 4.87 (d,  $J = 2.5$  Hz, 1H), 4.41 (dd,  $J = 2.5, 2.1$  Hz, 1H), 2.61 (d,  $J = 2.1$  Hz, 1H), 2.44 (s, 3H), 1.18 – 0.78 (m, 21H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$ : 163.4, 145.7, 135.6, 130.1, 127.9, 83.1, 77.3, 77.1, 54.2, 21.8, 17.65, 17.62, 11.8; IR (film)  $\nu$ : 3276, 2946, 2868, 2127, 1808, 1597, 1464, 1371, 1172, 1124, 1090, 1074, 882, 846, 814, 715, 692, 671, 588, 543, 499, 461  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{21}\text{H}_{32}\text{NO}_4\text{SSi}$   $[\text{M} + \text{H}^+]$  422.1821. Found 422.1807.

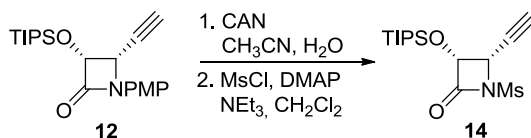
## 2.9. Preparation of $\beta$ -lactam **13**.



To a solution of *N*-PMP-azetid-2-one **12** (374 mg, 1 mmol) in acetonitrile (40 mL) and water (8 mL) cooled to -10 °C a solution of CAN (1.919 g, 3.5 mmol) in water (32 mL) was added dropwise within 15 min and the reaction mixture was stirred at the same temperature for 3.5 h. At the end of this time the reaction was quenched with saturated aqueous  $\text{Na}_2\text{S}_2\text{O}_3$  solution (10 mL), poured into water and extracted with ethyl acetate (3 x 20 mL). The combined extracts were washed with water (100 mL), saturated aqueous solution of  $\text{NaHCO}_3$  (50 mL) and brine (50 mL), dried over  $\text{MgSO}_4$  and concentrated under reduced pressure. Filtration of the residue through a pad of silica gel with  $\text{CH}_2\text{Cl}_2$  (to remove quinone formed as the byproduct) and then ethyl acetate/hexane mixture afforded crude NH- $\beta$ -lactam which was then dissolved in anhydrous  $\text{CH}_2\text{Cl}_2$  (10 mL). To this solution  $\text{NEt}_3$  (0.417 mL, 3 mmol), DMAP (61 mg, 0.5 mmol) and  $\text{Boc}_2\text{O}$  (262 mg, 1.2 mmol) were sequentially added all in one portion at 0 °C under argon atmosphere and after 15 min the cooling bath was removed and stirring was continued at 25 °C overnight. At the end of this time the reaction was quenched with saturated aqueous solution of  $\text{NH}_4\text{Cl}$  (10 mL), poured into water and extracted with  $\text{CH}_2\text{Cl}_2$  (2 x 20 mL). The combined extracts were washed successively with saturated solution of  $\text{NaHCO}_3$  (50 mL) and water (50 mL), dried over anhydrous  $\text{MgSO}_4$  and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an  $\text{CH}_2\text{Cl}_2$  as an eluent afforded  $\beta$ -lactam **13** as colorless wax.

(2*S*\*,3*R*\*)-tert-butyl 2-ethynyl-4-oxo-3-((triisopropylsilyloxy)azetid-1-carboxylate (**13**). Yield: 287 mg (78%); colorless wax;  $R_f$  (100%  $\text{CH}_2\text{Cl}_2$ ) 0.80;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 5.01 (d,  $J = 5.5$  Hz, 1H), 4.67 (dd,  $J = 5.5, 2.1$  Hz, 1H), 2.48 (d,  $J = 2.1$  Hz, 1H), 1.52 (s, 9H), 1.20 – 1.06 (m, 21H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  164.7, 147.6, 84.1, 77.0, 76.5, 76.4, 50.4, 28.1, 17.8, 17.7, 12.0; IR (film)  $\nu$ : 3313, 3270, 2944, 2894, 2868, 1817, 1730, 1465, 1370, 1324, 1252, 1206, 1154, 1108, 1022, 999, 891, 849, 775, 688, 665, 593, 506, 461  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{19}\text{H}_{33}\text{NNaO}_4\text{Si}$   $[\text{M} + \text{Na}^+]$  390.2077. Found 390.2039.

## 2.10. Preparation of $\beta$ -lactam **14**.

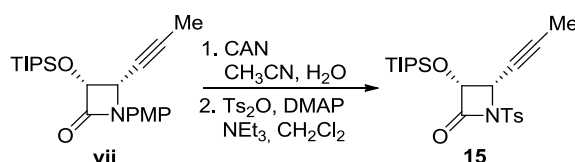


To a solution of *N*-PMP-azetid-2-one **12** (374 mg, 1 mmol) in acetonitrile (40 mL) and water (8 mL) cooled to -10 °C a solution of CAN (1.919 g, 3.5 mmol) in water (32 mL) was added dropwise within 15 min and the reaction mixture was stirred at the same temperature for 3.5 h. At the end of this time the reaction was quenched with saturated aqueous  $\text{Na}_2\text{S}_2\text{O}_3$  solution (10 mL), poured into water and extracted with ethyl acetate (3 x 20 mL). The combined extracts were washed with water (100 mL), saturated aqueous solution of  $\text{NaHCO}_3$  (50 mL) and brine (50 mL), dried over  $\text{MgSO}_4$  and concentrated under reduced pressure. Filtration of the residue through a pad of silica gel with  $\text{CH}_2\text{Cl}_2$

(to remove quinone formed as the byproduct) and then ethyl acetate/hexane mixture afforded crude NH- $\beta$ -lactam which was then dissolved in anhydrous CH<sub>2</sub>Cl<sub>2</sub> (15 mL). To this solution NEt<sub>3</sub> (1.394 mL, 10 mmol) and DMAP (122 mg, 1 mmol) were added both in one portion followed by methanesulfonyl chloride (0.774 mL, 10 mmol) dropwise at 0 °C under an atmosphere of argon. After 15 min the cooling bath was removed and stirring was continued at 25 °C overnight. At the end of this time the reaction was quenched with saturated aqueous solution of NH<sub>4</sub>Cl (15 mL), poured into water and extracted with CH<sub>2</sub>Cl<sub>2</sub> (2 x 20 mL). The combined extracts were washed successively with saturated solution of NaHCO<sub>3</sub> (50 mL) and water (50 mL), dried over anhydrous MgSO<sub>4</sub> and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an CH<sub>2</sub>Cl<sub>2</sub> as an eluent afforded  $\beta$ -lactam **14** as colorless crystals.

(3*R*\*,4*S*\*)-4-ethynyl-1-(methylsulfonyl)-3-((triisopropylsilyl)oxy)azetidin-2-one (**14**). Yield: 223 mg (64%); colorless crystals; mp = 135.8-136.7 °C; R<sub>f</sub> (100% CH<sub>2</sub>Cl<sub>2</sub>) 0.60; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$ : 5.19 (d, *J* = 5.5 Hz, 1H), 4.88 (dd, *J* = 5.5, 2.1 Hz, 1H), 3.26 (s, 3H), 2.67 (d, *J* = 2.1 Hz, 1H), 1.39 – 0.20 (m, 21H); <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$ : 164.1, 78.6, 77.9, 75.5, 52.7, 42.9, 17.8, 17.7, 12.0; IR (film)  $\nu$ : 3286, 2942, 2893, 2867, 2126, 1795, 1461, 1352, 1334, 1177, 1164, 1081, 963, 885, 776, 755, 692, 651, 537, 512, 494 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>15</sub>H<sub>27</sub>NNaO<sub>4</sub>SSi [M + Na<sup>+</sup>] 368.1328. Found 368.1306.

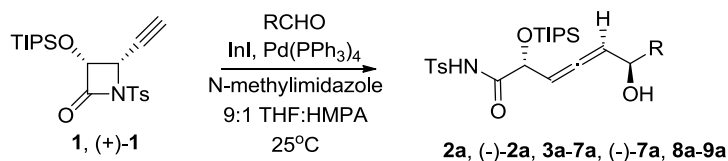
## 2.11. Preparation of $\beta$ -lactam **15**.



Compound **15** was obtained from  $\beta$ -lactam **vii** (775 mg, 2 mmol) according to general procedure 2.8.

(3*R*\*,4*S*\*)-4-(prop-1-yn-1-yl)-1-tosyl-3-((triisopropylsilyl)oxy)azetidin-2-one (**15**). Yield: 548 mg (63 %); colorless crystals; mp = 128.3-129.5 °C; R<sub>f</sub> (15% ethyl acetate/hexane) 0.50; <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>)  $\delta$ : 8.06 – 7.77 (m, 2H), 7.52 – 7.28 (m, 2H), 5.02 (d, *J* = 5.5 Hz, 1H), 4.84 (dq, *J* = 5.5, 2.1 Hz, 1H), 2.45 (s, 3H), 1.73 (d, *J* = 2.1 Hz, 3H), 1.20 – 0.95 (m, 21H); <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>)  $\delta$ : 164.2, 145.3, 136.2, 129.8, 128.0, 86.5, 77.4, 70.9, 53.6, 21.8, 17.7, 17.6, 12.0, 3.8; IR (film)  $\nu$ : 2945, 2893, 2868, 2250, 1806, 1598, 1464, 1367, 1245, 1200, 1188, 1171, 1127, 1091, 1033, 996, 882, 814, 735, 706, 666, 627, 553, 521, 499 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>22</sub>H<sub>33</sub>NNaO<sub>4</sub>SSi [M + Na<sup>+</sup>] 458.1797. Found 458.1809.

## 2.12. Pd/InI/*N*-methylimidazole promoted additions of *N*-Ts- $\beta$ -lactams **1** and (+)-**1** to aldehydes. Synthesis of 2,5-*syn*-2,6-*anti*-allenediols **2a**, (-)-**2a**, **3a-7a**, (-)-**7a**, and **8a-9a**. General procedure.



To a vigorously stirred solution of *N*-Ts- $\beta$ -lactam **1** or (+)-**1** (52.7 mg, 0.125 mmol) and aldehyde (0.25 mmol) in anhydrous 10% HMPA/THF<sup>7</sup> mixture (2 mL), *N*-methylimidazole (20  $\mu$ L, 0.25 mmol) and the mixture of InI<sup>1</sup> (90.7 mg, 0.375 mmol) and Pd(PPh<sub>3</sub>)<sub>4</sub> (7.2 mg, 6.25  $\mu$ mol) were sequentially added in one portion at 25 °C under an atmosphere of argon. The stirring was continued at the same temperature until full conversion of the starting  $\beta$ -lactam was observed (TLC monitoring, 1-3 hours). Reaction was then quenched with 1M aqueous HCl solution (2 mL), poured into water and extracted with EtOAc (3 x 10 mL). The combined extracts were washed successively with water (30 mL), saturated solution of NaHCO<sub>3</sub> (30 mL) and brine (30 mL), dried over anhydrous MgSO<sub>4</sub> and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an acetone/hexane mixture as eluent afforded products **2a**, (-)-**2a**, **3a-7a**, (-)-**7a** and **8a-9a** as colorless wax.

(2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-6-phenyl-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**2a**). Yield: 39.7 mg (60 %; 296.4 mg, 56% when 1 mmol of **1** instead of 0.125 mmol was used); **2a:2b** = 73:27;

colorless wax;  $R_f$  (30% acetone/hexane) 0.50;  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **2a**): 9.64 (br s, 1H), 8.13 – 8.06 (m, 2H), 7.44 – 7.35 (m, 2H), 7.22 – 7.16 (m, 2H), 7.11 – 7.03 (m, 1H), 6.79 – 6.69 (m, 2H), 5.47 (td,  $J = 5.7, 1.8$  Hz, 1H), 5.19 – 5.11 (m, 1H), 5.15 – 5.03 (m, 1H), 4.65 (dd, 1H), 3.20 (br s, 1H), 1.81 (s, 3H), 1.05 – 0.70 (m, 21H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  (major C6-epimer **2a**): 202.7, 169.8, 145.5, 142.7, 135.4, 129.7, 128.7, 128.6, 128.0, 126.1, 100.1, 94.5, 73.3, 71.8, 21.8, 17.91, 17.89, 12.0; IR (film)  $\nu$ : 3477, 3354, 2944, 2892, 2867, 1966, 1734, 1598, 1454, 1411, 1353, 1191, 1176, 1160, 1119, 1087, 1067, 1017, 880, 816, 695, 663, 549, 475  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{39}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 552.2216. Found 552.2213.

(2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-6-phenyl-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide ((-)-**2a**). Yield: 37.1 mg (56 %); (-)-**2a**:(+)-**2b** = 71:29; >98% ee (Mosher's esters analysis); colorless wax;  $R_f$  (30% acetone/hexane) 0.50;  $[\alpha]_{\text{D}}^{25} = -42.8$  ( $c = 0.51$ ,  $\text{CHCl}_3$ ); NMR and IR spectra were consistent with those recorded for racemate; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{39}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 552.2216. Found 552.2207.

(2*R*\*,4*S*\*,6*S*\*)-6-(4-cyanophenyl)-6-hydroxy-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**3a**) Yield 36.8 mg (53 %); **3a**:**3b** = 72:28; colorless wax;  $R_f$  (30% acetone/hexane) 0.45;  $^1\text{H}$  NMR (500 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **3a**): 9.59 (br s, 1H), 8.11 – 8.06 (m, 2H), 7.17 – 7.08 (m, 4H), 6.82 – 6.76 (m, 2H), 5.34 (td,  $J = 6.1, 1.9$  Hz, 1H), 5.12 (ddd,  $J = 6.9, 6.1, 2.7$  Hz, 1H), 5.08 (dd,  $J = 6.1, 2.7$  Hz, 1H), 4.64 (dd,  $J = 6.9, 1.9$  Hz, 1H), 3.70 (br s, 1H), 1.85 (s, 3H), 0.97 – 0.76 (m, 21H);  $^{13}\text{C}$  NMR (126 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **3a**): 203.2, 169.8, 148.1, 145.3, 136.1, 132.3, 129.8, 128.9, 126.8, 118.9, 111.8, 99.4, 94.6, 73.5, 71.2, 21.2, 17.9, 17.8, 12.0; IR (film)  $\nu$ : 3476, 3353, 2945, 2892, 2868, 2229, 1967, 1733, 1598, 1462, 1411, 1351, 1192, 1162, 1119, 1088, 1067, 1017, 880, 817, 737, 689, 663, 549, 476  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{38}\text{N}_2\text{NaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 577.2168. Found 577.2164.

(2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-6-(4-methoxyphenyl)-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**4a**) Yield 31.5 mg (45 %); **4a**:**4b** = 71:29; colorless wax;  $R_f$  (30% acetone/hexane) 0.45;  $^1\text{H}$  NMR (600 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **4a**): 9.79 (br s, 1H), 8.13 – 8.09 (m, 2H), 7.34 – 7.31 (m, 2H), 6.81 – 6.79 (m, 2H), 6.77 – 6.75 (m, 2H), 5.51 (ddd,  $J = 6.1, 5.3, 1.8$  Hz, 1H), 5.18 (dd,  $J = 5.3, 2.9$  Hz, 1H), 5.14 (ddd,  $J = 7.2, 6.1, 2.9$  Hz, 1H), 4.70 (dd,  $J = 7.2, 1.8$  Hz, 1H), 3.31 (s, 3H), 1.82 (s, 3H), 1.01 – 0.84 (m, 21H);  $^{13}\text{C}$  NMR (151 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **4a**): 203.0, 169.8, 159.8, 144.9, 136.5, 135.6, 129.7, 129.0, 127.6, 114.3, 100.4, 94.6, 73.7, 71.6, 54.9, 21.2, 17.91, 17.90, 12.1; IR (film)  $\nu$ : 3500, 3353, 2945, 2894, 2867, 1967, 1729, 1608, 1512, 1462, 1410, 1352, 1249, 1171, 1089, 1035, 879, 831, 664, 549, 474  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{41}\text{NNaO}_6\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 582.2322. Found 582.2318.

(2*R*\*,4*S*\*,6*S*\*)-6-(furan-2-yl)-6-hydroxy-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**5a**). Yield 35.7 mg (55 %); **5a**:**5b** = 65:35; colorless wax;  $R_f$  (30% acetone/hexane) 0.50;  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **5a**): 9.58 (br s, 1H), 8.11 – 8.07 (m, 2H), 7.07 (dd,  $J = 1.8, 0.8$  Hz, 1H), 6.78 – 6.73 (m, 2H), 6.22 (dd,  $J = 3.3, 0.8$  Hz, 1H), 6.04 (dd,  $J = 3.3, 1.8$  Hz, 1H), 5.60 (ddd,  $J = 6.1, 5.1, 1.8$  Hz, 1H), 5.19 (dd,  $J = 5.1, 3.0$  Hz, 1H), 5.10 (ddd,  $J = 7.3, 6.1, 3.0$  Hz, 1H), 4.62 (dd,  $J = 7.3, 1.8$  Hz, 1H), 3.33 (br s, 1H), 1.82 (s, 3H), 0.96 – 0.80 (m, 21H);  $^{13}\text{C}$  NMR (151 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **5a**): 203.5, 169.8, 155.7, 145.0, 142.4, 136.3, 129.7, 129.0, 110.6, 106.8, 97.3, 95.2, 73.5, 65.7, 21.2, 17.88, 17.86, 12.0; IR (film)  $\nu$ : 3471, 3355, 2945, 2892, 2867, 1970, 1729, 1622, 1597, 1463, 1410, 1352, 1165, 1089, 1016, 882, 815, 739, 663, 549, 475  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{43}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{H}^+$ ] 520.2189. Found 520.2204.

(2*R*\*,4*S*\*,6*R*\*)-6-hydroxy-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide (**6a**). Yield 34.2 mg (57 %), **6a**:**6b** = 64:36; colorless wax;  $R_f$  (30% acetone/hexane) 0.45;  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **6a**): 9.64 (br s, 1H), 8.14 – 8.07 (m, 2H), 6.79 – 6.72 (m, 2H), 5.26 (ddd,  $J = 6.2, 5.3, 1.8$  Hz, 1H), 5.08 (ddd,  $J = 7.2, 6.2, 2.8$  Hz, 1H), 4.64 (dd,  $J = 7.2, 1.8$  Hz, 1H), 4.07 – 3.92 (m, 1H), 2.64 (br s, 1H), 1.82 (s, 3H), 1.54 – 1.41 (m, 2H), 1.01 – 0.82 (m, 25H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **6a**): 203.5, 169.7, 144.9, 136.5, 129.6, 129.0, 99.4, 93.8, 73.9, 70.8, 30.9, 21.2, 17.9, 12.1, 9.7; IR (film)  $\nu$ : 3503, 3356, 2943, 2892, 2868, 1966, 1735, 1598, 1462, 1410, 1352, 1191, 1176, 1161, 1088, 1015, 880, 816, 776, 662, 549, 475  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{24}\text{H}_{39}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 504.2216. Found 504.2210.

(2*R*\*,4*S*\*,6*R*\*)-6-hydroxy-7-methyl-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide (**7a**). Yield 37.8 mg (61 %); **7a**:**7b** = 64:36; colorless wax;  $R_f$  (30% acetone/hexane) 0.55;  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **7a**): 9.64 (br s, 1H), 8.14 – 8.10 (m, 2H), 6.75 – 6.71 (m, 2H), 5.29 (ddd,  $J = 6.2,$

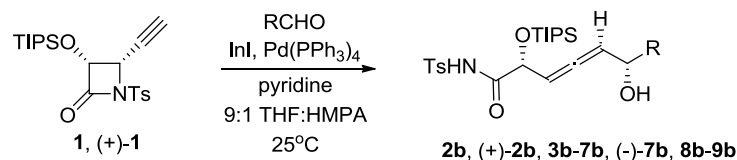
5.4, 1.8 Hz, 1H), 5.07 (ddd,  $J = 7.3, 6.2, 2.8$  Hz, 1H), 4.66 (dd,  $J = 7.3, 1.8$  Hz, 1H), 3.90 (td,  $J = 5.4, 2.8$  Hz, 1H), 1.82 (s, 3H), 1.63 (sepd,  $J = 6.9, 5.4$  Hz, 1H), 1.00 – 0.89 (m, 21H), 0.91 (d,  $J = 6.9$  Hz, 3H), 0.89 (d,  $J = 6.9$  Hz, 3H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **7a**): 204.0, 169.8, 144.9, 136.5, 129.6, 129.0, 97.8, 93.7, 74.4, 73.9, 34.7, 21.2, 18.3, 17.92, 17.91, 17.6, 12.2; IR (film)  $\nu$ : 3509, 3356, 2945, 2892, 2868, 1967, 1735, 1598, 1463, 1410, 1353, 1191, 1176, 1160, 1119, 1088, 1067, 1016, 881, 815, 688, 663, 549, 477  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{25}\text{H}_{41}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 518.2372. Found 518.2373.

(2*R*,4*S*,6*R*)-6-hydroxy-7-methyl-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide ((-)-**7a**). Yield 34.7 mg (56 %); (-)-**7a**:(-)-**7b** = 63:37; >98% ee (Mosher's ester analysis), colorless wax;  $R_f$  (30% acetone/hexane) 0.55;  $[\alpha]_{\text{D}}^{25} = -44.5$  ( $c = 0.92$ ,  $\text{CHCl}_3$ ); NMR and IR spectra were consistent with those recorded for racemate; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{25}\text{H}_{41}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 518.2372. Found 518.2357.

(2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-7,7-dimethyl-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide (**8a**). Yield 47.2 mg (74 %), **8a**:**8b** = 75:25;<sup>8</sup> colorless wax;  $R_f$  (30% acetone/hexane) 0.55;  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **8a**): 9.60 (br s, 1H), 8.13 – 8.06 (m, 2H), 6.78 – 6.70 (m, 2H), 5.43 (td,  $J = 6.0, 1.8$  Hz, 1H), 5.06 (ddd,  $J = 7.2, 6.1, 2.6$  Hz, 1H), 4.66 (dd,  $J = 7.3, 1.8$  Hz, 1H), 3.81 (dd,  $J = 6.0, 2.7$  Hz, 1H), 2.82 (br s, 1H), 1.82 (s, 3H), 0.99 – 0.89 (m, 21H), 0.91 (s, 9H);  $^{13}\text{C}$  NMR (151 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **8a**): 204.3, 169.8, 144.9, 136.4, 129.6, 129.0, 96.6, 93.5, 77.5, 73.9, 35.7, 25.6, 21.2, 17.9, 17.9, 12.1; IR (film)  $\nu$ : 3531, 3356, 2948, 2868, 1967, 1736, 1598, 1462, 1410, 1354, 1191, 1177, 1159, 1119, 1088, 1067, 1013, 880, 816, 662, 549, 477  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{26}\text{H}_{43}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 532.2529. Found 532.2532.

(2*R*\*,4*S*\*,6*R*\*)-6,9-dihydroxy-*N*-tosyl-2-((triisopropylsilyl)oxy)nona-3,4-dienamide (**9a**). In this case it appeared that a part of resulting adducts **9a** and **9b** reacts further with excess of 4-hydroxybutyraldehyde to give the mixture of cyclic acetals. Thus after standard water workup and concentration the crude product was dissolved in 60% aqueous AcOH solution (3 mL) and stirred at 25°C within 3h. At the end of this time, the reaction mixture was diluted with toluene (100 mL, to remove azeotropically AcOH and  $\text{H}_2\text{O}$ ) and concentrated under reduced pressure. Moreover, standard column chromatography on silica gel with acetone/hexane eluent provided product contaminated with  $\text{P}(\text{O})\text{Ph}_3$  resulting from oxidation of  $\text{PPh}_3$  catalyst ligand. This impurity was removed by further column chromatography eluting with ethyl acetate/hexane with addition of 0.5 % v/v  $\text{HCO}_2\text{H}$ .<sup>9</sup> Yield 29.4 mg (49 %); **9a**:**9b** = 62:38; colorless wax;  $R_f$  (40% acetone/hexane) 0.45;  $^1\text{H}$  NMR (600 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **9a**): 10.27 (br s, 1H), 8.20 – 8.07 (m, 2H), 6.82 – 6.69 (m, 2H), 5.27 (ddd,  $J = 6.2, 4.6, 1.5$  Hz, 1H), 5.15 (ddd,  $J = 7.8, 6.2, 1.5$  Hz, 1H), 4.72 (dd,  $J = 7.8, 1.5$  Hz, 1H), 4.21 – 4.13 (m, 1H), 3.49 – 3.43 (m, 2H), 1.83 (s, 3H), 1.56 – 1.49 (m, 4H), 0.99 – 0.93 (m, 21H);  $^{13}\text{C}$  NMR (151 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **9a**): 203.6, 169.8, 144.7, 136.7, 129.6, 129.0, 99.3, 94.2, 74.0, 69.4, 62.7, 35.7, 29.2, 21.2, 18.0, 12.2; IR (film)  $\nu$ : 3353, 2944, 2892, 2867, 1966, 1732, 1597, 1462, 1410, 1351, 1191, 1175, 1088, 1016, 881, 816, 662, 549, 475  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{25}\text{H}_{41}\text{NNaO}_6\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 534.2322. Found 534.2311.

### 2.13. Pd/InI/pyridine promoted additions of *N*-Ts- $\beta$ -lactams **1** and (+)-**1** to aldehydes. Synthesis of 2,5-*syn*-2,6-*syn*-allenediols **2b**, (+)-**2b**, **3b-7b**, (-)-**7b**, and **8b-9b**. General procedure.



To a vigorously stirred solution of *N*-Ts- $\beta$ -lactam **1** or (+)-**1** (52.7 mg, 0.125 mmol) and aldehyde (0.25 mmol) in anhydrous 10% HMPA/THF<sup>7</sup> mixture (2 mL), pyridine (20  $\mu\text{L}$ , 0.25 mmol) and the mixture of InI<sup>1</sup> (90.7 mg, 0.375 mmol) and  $\text{Pd}(\text{PPh}_3)_4$  (7.2 mg, 6.25  $\mu\text{mol}$ ) were sequentially added in one portion at 25 °C under an atmosphere of argon. The stirring was continued at the same temperature until full conversion of the starting  $\beta$ -lactam was observed (TLC monitoring, 1-3 hours). Reaction was then quenched with 1M aqueous HCl solution (2 mL), poured into water and extracted with EtOAc (3 x 10 mL). The combined extracts were washed successively with water (30 mL), saturated solution of  $\text{NaHCO}_3$  (30 mL) and brine (30 mL), dried over anhydrous  $\text{MgSO}_4$  and concentrated under reduced pressure. Purification of the crude product by column chromatography on

silica gel using an acetone/hexane mixture as eluent afforded allenediols **2b**, (+)-**2b**, **3b-7b**, (-)-**7b** and **8b-9b** as colorless wax.

*(2R\*,4S\*,6R\*)-6-hydroxy-6-phenyl-N-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (2b)*

Yield 280.8 mg (53 %, 1 mmol of **1** instead of 0.125 mmol was used); **2b:2a** = 81:19; colorless wax;  $R_f$  (30% acetone/hexane) 0.50;  $^1\text{H NMR}$  (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **2b**): 9.73 (br s, 1H), 8.26 – 8.05 (m, 2H), 7.45 – 7.32 (m, 2H), 7.23 – 7.16 (m, 2H), 7.12 – 7.01 (m, 1H), 6.87 – 6.69 (m, 2H), 5.41 – 5.32 (m, 1H), 5.14 – 5.07 (m, 2H), 4.62 (dd,  $J = 7.5, 1.6$  Hz, 1H), 3.08 (br s, 1H), 1.82 (s, 3H), 1.09 – 0.59 (m, 21H);  $^{13}\text{C NMR}$  (101 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **2b**): 202.8, 169.6, 144.9, 143.0, 136.6, 129.6, 129.0, 128.7, 126.6, 100.0, 95.2, 73.8, 71.5, 21.2, 17.91, 17.89, 12.1; IR (film)  $\nu$ : 3486, 3353, 2944, 2892, 2867, 1966, 1732, 1598, 1454, 1410, 1352, 1191, 1176, 1159, 1119, 1087, 880, 815, 690, 661, 548, 477  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{39}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 552.2216. Found 552.2217.

*(2R,4S,6R)-6-hydroxy-6-phenyl-N-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide ((+)-2b)*. Yield 33.8 mg (51 %), (+)-**2b**:(-)-**2a** = 79:21; >98% ee (Mosher's ester analysis); colorless wax;  $R_f$  (30% acetone/hexane) 0.50;  $[\alpha]_{\text{D}}^{25} = 20.6$  ( $c = 0.50$ ,  $\text{CHCl}_3$ ); NMR and IR spectra were consistent with those recorded for racemate; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{28}\text{H}_{39}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 552.2216. Found 552.2219.

*(2R\*,4S\*,6R\*)-6-(4-cyanophenyl)-6-hydroxy-N-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (3b)*

Yield 33.3 mg (48 %); **3b:3a** = 78:22; colorless wax;  $R_f$  (30% acetone/hexane) 0.45;  $^1\text{H NMR}$  (500 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **3b**): 9.53 (br s, 1H), 8.13 – 8.07 (m, 2H), 7.15 – 7.06 (m, 4H), 6.79 – 6.73 (m, 2H), 5.26 (ddd,  $J = 6.1, 5.2, 1.7$  Hz, 1H), 5.05 (ddd,  $J = 7.4, 6.1, 2.6$  Hz, 1H), 4.98 (dd,  $J = 5.2, 2.6$  Hz, 1H), 4.56 (dd,  $J = 7.4, 1.7$  Hz, 1H), 3.29 (br s, 1H), 1.82 (s, 3H), 0.95 – 0.79 (m, 21H);  $^{13}\text{C NMR}$  (126 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **3b**): 202.7, 169.7, 147.6, 145.2, 136.2, 132.2, 129.7, 129.0, 126.9, 118.9, 112.0, 99.4, 95.5, 73.6, 70.6, 21.2, 17.84, 17.82, 12.0; IR (film)  $\nu$ : 3476, 3353, 2945, 2892, 2868, 2229, 1967, 1733, 1598, 1462, 1411, 1351, 1192, 1162, 1119, 1088, 1067, 1017, 880, 817, 737, 689, 663, 549  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{38}\text{N}_2\text{NaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 577.2168. Found 577.2164.

*(2R\*,4S\*,6R\*)-6-hydroxy-6-(4-methoxyphenyl)-N-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (4b)*

Yield 35.7 mg (51 %); **4b:4a** = 78:22; colorless wax;  $R_f$  (30% acetone/hexane) 0.45;  $^1\text{H NMR}$  (600 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **4b**): 9.88 (br s, 1H), 8.16 – 8.11 (m, 2H), 7.33 – 7.27 (m, 2H), 6.84 – 6.79 (m, 2H), 6.77 – 6.72 (m, 2H), 5.44 – 5.39 (m, 1H), 5.17 – 5.11 (m, 2H), 4.67 – 4.62 (m, 1H), 3.33 (s, 3H), 1.82 (s, 3H), 0.99 – 0.88 (m, 21H);  $^{13}\text{C NMR}$  (151 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **4b**): 202.9, 169.6, 159.9, 144.8, 136.6, 135.0, 129.6, 129.0, 128.0, 114.2, 100.0, 95.1, 73.8, 71.3, 54.9, 21.2, 17.93, 17.91, 12.1; IR (film)  $\nu$ : 3494, 3354, 2944, 2867, 1966, 1733, 1600, 1512, 1462, 1410, 1352, 1250, 1175, 1118, 1088, 1034, 881, 816, 662, 549, 476  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{41}\text{NNaO}_6\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 582.2322. Found 582.2321.

*(2R\*,4S\*,6R\*)-6-(furan-2-yl)-6-hydroxy-N-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (5b)*

Yield 29.9 mg (46 %); **5b:5a** = 86:14; colorless wax;  $R_f$  (30% acetone/hexane) 0.50;  $^1\text{H NMR}$  (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **5b**): 9.62 (br s, 1H), 8.14 – 8.09 (m, 2H), 7.09 (dd,  $J = 1.9, 0.9$  Hz, 1H), 6.78 – 6.68 (m, 2H), 6.19 (dd,  $J = 3.3, 0.9$  Hz, 1H), 6.06 (dd,  $J = 3.3, 1.9$  Hz, 1H), 5.49 (ddd,  $J = 6.2, 5.1, 1.7$  Hz, 1H), 5.18 (dd,  $J = 5.1, 2.7$  Hz, 1H), 5.11 (ddd,  $J = 7.5, 6.2, 2.7$  Hz, 1H), 4.59 (dd,  $J = 7.5, 1.7$  Hz, 1H), 3.13 (br s, 1H), 1.81 (s, 3H), 1.04 – 0.79 (m, 21H);  $^{13}\text{C NMR}$  (151 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **5b**): 203.6, 169.5, 155.2, 144.9, 142.4, 136.5, 129.6, 129.0, 110.6, 107.1, 97.0, 95.5, 73.5, 65.4, 21.2, 17.89, 17.87, 12.1; IR (film)  $\nu$ : 3355, 2944, 2893, 2867, 1971, 1729, 1622, 1597, 1463, 1410, 1352, 1165, 1088, 1016, 882, 815, 740, 663, 549, 477  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{43}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{H}^+$ ] 520.2189. Found 520.2154.

*(2R\*,4S\*,6S\*)-6-hydroxy-N-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide (6b)*

Yield 32.5 mg (54 %); **6b:6a** = 64:36; colorless wax;  $R_f$  (30% acetone/hexane) 0.45;  $^1\text{H NMR}$  (500 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **6b**): 9.77 (br s, 1H), 8.15 – 8.09 (m, 2H), 6.77 – 6.71 (m, 2H), 5.25 (ddd,  $J = 6.3, 4.7, 1.6$  Hz, 1H), 5.08 (ddd,  $J = 7.7, 6.3, 2.7$  Hz, 1H), 4.61 (dd,  $J = 7.7, 1.6$  Hz, 1H), 4.08 – 3.97 (m, 1H), 2.71 (br s, 1H), 1.82 (s, 3H), 1.52 – 1.44 (m, 2H), 1.01 – 0.85 (m, 24H);  $^{13}\text{C NMR}$  (126 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$  (major C6-epimer **6b**): 203.1, 169.7, 144.8, 136.6, 129.6, 129.0, 99.2, 94.5, 73.9, 70.2, 30.6, 21.2, 17.92, 17.90, 12.1, 9.7; IR (film)  $\nu$ : 3508, 3355, 2943, 2868, 1966, 1735, 1598, 1462, 1410, 1352, 1191, 1176, 1161, 1088, 1067, 1015, 880, 816, 688, 662, 549, 477  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{24}\text{H}_{39}\text{NNaO}_5\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 504.2216. Found 504.2209.

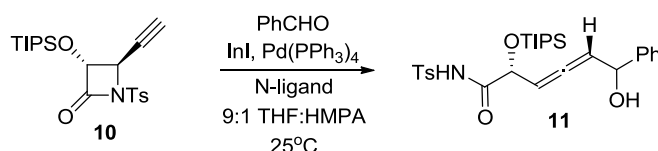
(2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-7-methyl-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide (**7b**). Yield 34.1 mg (55 %); **7b:7a** = 87:13; colorless wax; *R<sub>f</sub>* (30% acetone/hexane) 0.55; <sup>1</sup>H NMR (600 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **7b**): 9.80 (br s, 1H), 8.15 – 8.11 (m, 2H), 6.74 – 6.72 (m, 2H), 5.25 (ddd, *J* = 6.2, 4.7, 1.5 Hz, 1H), 5.04 (ddd, *J* = 7.9, 6.2, 2.8 Hz, 1H), 4.60 (dd, *J* = 7.9, 1.5 Hz, 1H), 3.94 (td, *J* = 4.9, 2.8 Hz, 1H), 1.81 (s, 3H), 1.65 (sepd, *J* = 6.8, 4.9 Hz, 1H), 1.00 – 0.91 (m, 21H), 0.90 (d, *J* = 6.8 Hz, 3H), 0.89 (d, *J* = 6.8 Hz, 3H); <sup>13</sup>C NMR (151 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **7b**): 203.5, 169.8, 144.8, 136.5, 129.6, 129.0, 97.6, 94.5, 74.0, 73.7, 34.5, 21.2, 18.2, 17.93, 17.91, 17.8, 12.1; IR (film) *v*: 3511, 3355, 2945, 2892, 2868, 1966, 1734, 1598, 1463, 1409, 1352, 1176, 1159, 1119, 1088, 1016, 880, 815, 662, 549, 475 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>25</sub>H<sub>41</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 518.2372. Found 518.2365.

(2*R*,4*S*,6*S*)-6-hydroxy-7-methyl-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide ((-)-**7b**). Yield 30.4 mg (49 %); (-)-**7b**:(-)-**7a** = 89:11; >98% ee (Mosher's ester analysis); colorless wax; *R<sub>f</sub>* (30% acetone/hexane) 0.55; [α]<sub>D</sub><sup>25</sup> = - 11.0 (*c* = 0.62, CHCl<sub>3</sub>); NMR and IR spectra were consistent with those recorded for racemate; HRMS (ESI-TOF) *m/z* calcd for C<sub>25</sub>H<sub>41</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 518.2372. Found 518.2357

(2*R*\*,4*S*\*,6*R*\*)-6-hydroxy-7,7-dimethyl-*N*-tosyl-2-((triisopropylsilyl)oxy)octa-3,4-dienamide (**8b**). Yield 47.2 mg (74 %); **8b:8a** = 76:24;<sup>10</sup> >98:2 after crystallization from hexane; colorless crystals; mp = 105.9-107.7 °C (*R<sub>f</sub>* (30% acetone/hexane) 0.55; <sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **8b**): (br s, 1H), 8.15 – 8.07 (m, 2H), 6.79 – 6.70 (m, 2H), 5.37 (ddd, *J* = 6.2, 4.8, 1.5 Hz, 1H), 5.02 (ddd, *J* = 7.9, 6.2, 2.8 Hz, 1H), 4.60 (dd, *J* = 7.9, 1.5 Hz, 1H), 3.82 (dd, *J* = 4.8, 2.8 Hz, 1H), 2.66 (br s, 1H), 1.82 (s, 3H), 1.00 – 0.92 (m, 21H), 0.90 (s, 9H); <sup>13</sup>C NMR (126 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **8b**): 203.8, 169.9, 144.9, 136.5, 129.7, 128.9, 96.8, 94.4, 76.7, 74.0, 35.9, 25.7, 21.2, 17.93, 17.91, 12.1; IR (film) *v*: 3520, 3356, 2948, 2868, 1966, 1735, 1598, 1463, 1410, 1354, 1191, 1177, 1159, 1119, 1088, 1067, 1013, 880, 815, 688, 663, 549, 475 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>26</sub>H<sub>43</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 532.2529. Found 532.2524.

(2*R*\*,4*S*\*,6*S*\*)-6,9-dihydroxy-*N*-tosyl-2-((triisopropylsilyl)oxy)nona-3,4-dienamide (**9b**). In this case it appeared that a part of resulting adducts **9a** and **9b** reacts further with excess of 4-hydroxybutyraldehyde to give the mixture of cyclic acetals. Thus after standard water workup and concentration the crude product was dissolved in 60% aqueous AcOH solution (3 mL) and stirred at 25°C within 3h. At the end of this time, the reaction mixture was diluted with toluene (100 mL, to remove azeotropically AcOH and H<sub>2</sub>O) and concentrated under reduced pressure. Moreover, standard column chromatography on silica gel with acetone/hexane eluent provided product contaminated with P(O)Ph<sub>3</sub> resulting from oxidation of PPh<sub>3</sub> catalyst ligand. This impurity was removed by further column chromatography eluting with ethyl acetate/hexane with addition of 0.5 % v/v HCO<sub>2</sub>H.<sup>9</sup> Yield 32.6 mg (51 %); **9b:9a** = 67:33; colorless wax; *R<sub>f</sub>* (40% acetone/hexane) 0.45; <sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **9b**): 10.26 (br s, 1H), 8.19 – 8.09 (m, 2H), 6.82 – 6.67 (m, 2H), 5.26 (ddd, *J* = 6.1, 4.6, 1.5 Hz, 1H), 5.14 (dtd, *J* = 8.0, 6.1, 2.9 Hz, 1H), 4.66 (dd, *J* = 8.0, 1.4 Hz, 1H), 4.20 – 4.14 (m, 1H), 3.53 – 3.43 (m, 2H), 1.84 (s, 3H), 1.61 – 1.48 (m, 4H), 1.02 – 0.89 (m, 21H); <sup>13</sup>C NMR (101 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **9b**): 203.3, 169.8, 144.7, 136.7, 129.6, 129.0, 99.3, 94.7, 74.0, 69.3, 62.7, 35.2, 29.2, 21.2, 17.9, 12.2; IR (film) *v*: 3355, 2941, 2892, 2867, 1966, 1732, 1597, 1460, 1410, 1350, 1191, 1176, 1088, 1017, 880, 815, 662, 549, 476 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>25</sub>H<sub>41</sub>NNaO<sub>6</sub>SSi [M + Na<sup>+</sup>] 534.2322. Found 534.2303.

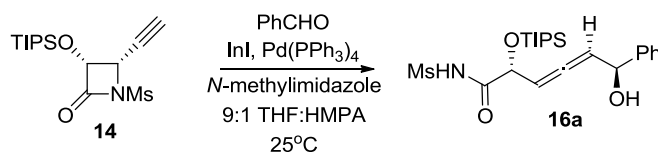
## 2.14. Synthesis of 2,5-*anti*-allendiols **11**



Compound **11** was obtained from β-lactam **10** (52.7 mg, 0.125 mmol) and benzaldehyde (25 μL, 0.25 mmol) according to general procedures 2.12. (Method A) and 2.13 (Method B).

(2*R*\*,4*R*\*,6*R*\*)-6-hydroxy-6-phenyl-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**11a**) and (2*R*\*,4*R*\*,6*S*\*)-6-hydroxy-6-phenyl-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**11b**). Method A: Yield: 26.5 mg (40 %) <sup>11</sup>; **11a:11b** = 51:49; Method B: Yield: 29.8 mg (45 %), <sup>12</sup> **11a:11b** = 50:50; colorless wax; *R*<sub>f</sub> (30% acetone/hexane) 0.50; <sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>) δ (**11a** and **11b**): 9.51 (br s, 1H), 9.46 (br s, 1H), 8.20 – 8.06 (m, 4H), 7.46 – 7.31 (m, 4H), 7.29 – 7.18 (m, 4H), 7.16 – 7.08 (m, 2H), 6.80 – 6.70 (m, 4H), 5.44 – 5.35 (m, 2H), 5.29 – 5.21 (m, 1H), 5.23 – 5.15 (m, 1H), 5.14 (dd, *J* = 5.8, 2.6 Hz, 1H), 4.98 (dd, *J* = 5.7, 2.4 Hz, 1H), 4.60 – 4.52 (m, 2H), 1.84 (s, 3H), 1.83 (s, 3H), 0.95 – 0.82 (m, 42H); <sup>13</sup>C NMR (101 MHz, C<sub>6</sub>D<sub>6</sub>) δ (**11a** and **11b**): 203.3, 202.8, 169.3, 169.0, 144.8, 143.3, 143.1, 136.64, 136.61, 129.61, 129.58, 129.1, 129.0, 128.74, 128.69, 128.0, 126.64, 126.57, 101.5, 101.2, 94.9, 94.3, 72.7, 72.6, 72.1, 71.8, 21.2, 17.93, 17.92, 17.90, 12.2, 12.1; IR (film) *v*: 3509, 3354, 2944, 2892, 2867, 1967, 1730, 1650, 1598, 1494, 1454, 1410, 1352, 1191, 1161, 1088, 1017, 881, 815, 764, 698, 664, 549, 476 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>28</sub>H<sub>39</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 552.2216. Found 552.2217.

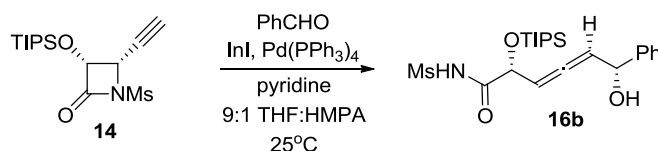
## 2.15. Synthesis of 2,5-*syn*-2,6-*anti*-allendiol **16a**



Compound **16a** was obtained from β-lactam **14** (43.2 mg, 0.125 mmol) and benzaldehyde (25 μL, 0.25 mmol) according to general procedure 2.12.

(2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-*N*-(methylsulfonyl)-6-phenyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**16a**). Yield 30.1 mg (53 %); **16a:16b** = 55:45; colorless wax; *R*<sub>f</sub> (30% acetone/hexane) 0.55; <sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **16a**): 9.44 (br s, 1H), 7.41 – 7.32 (m, 2H), 7.21 – 7.16 (m, 2H), 7.11 – 7.03 (m, 1H), 5.51 (ddd, *J* = 5.9, 5.2, 1.8 Hz, 1H), 5.26 (ddd, *J* = 7.1, 2.9 Hz, 1H), 5.21 (dd, *J* = 5.2, 2.9 Hz, 1H), 4.75 (dd, *J* = 7.1, 1.8 Hz, 1H), 3.22 (br s, 1H), 2.71 (s, 3H), 1.05 – 0.86 (m, 21H); <sup>13</sup>C NMR (101 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **16a**): 203.0, 171.0, 143.5, 128.8, 128.0, 126.3, 100.4, 94.7, 73.7, 71.8, 41.0, 17.92, 17.89, 12.1; IR (film) *v*: 3492, 3357, 2944, 2892, 2867, 1967, 1729, 1455, 1421, 1398, 1348, 1181, 1151, 1114, 972, 881, 746, 693, 519, 492, 449, 412 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>22</sub>H<sub>35</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 476.1903. Found 476.1887.

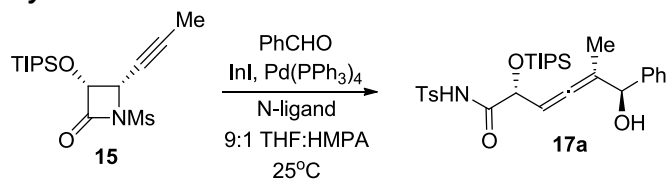
## 2.16. Synthesis of 2,5-*syn*-2,6-*syn*-allendiol **16b**



Compound **16b** was obtained from β-lactam **14** (43.2 mg, 0.125 mmol) and benzaldehyde (25 μL, 0.25 mmol) according to general procedure 2.13.

(2*R*\*,4*S*\*,6*R*\*)-6-hydroxy-*N*-(methylsulfonyl)-6-phenyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**16b**). Yield 27.2 mg (48 %); **16b:16a** = 79:21; colorless wax; *R*<sub>f</sub> (30% acetone/hexane) 0.55; <sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **16b**): 9.47 (br s, 1H), 7.44 – 7.32 (m, 2H), 7.22 – 7.14 (m, 2H), 7.12 – 7.03 (m, 1H), 5.43 (ddd, *J* = 6.4, 5.0, 1.6 Hz, 1H), 5.26 (ddd, *J* = 7.7, 6.2, 2.7 Hz, 1H), 5.14 (dd, *J* = 5.0, 2.7 Hz, 1H), 4.71 (dd, *J* = 7.7, 1.6 Hz, 1H), 3.17 (br s, 1H), 2.71 (s, 3H), 1.03 – 0.86 (m, 21H); <sup>13</sup>C NMR (101 MHz, C<sub>6</sub>D<sub>6</sub>) δ (major C6-epimer **16b**): 202.8, 170.9, 142.8, 128.7, 128.1, 126.6, 100.1, 95.2, 73.8, 71.6, 40.9, 17.94, 17.91, 12.2; IR (film) *v*: 3491, 3357, 2944, 2892, 2867, 1967, 1729, 1454, 1421, 1398, 1348, 1183, 1151, 1114, 1066, 973, 881, 746, 694, 520, 492, 426 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>22</sub>H<sub>35</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 476.1903. Found 476.1896.

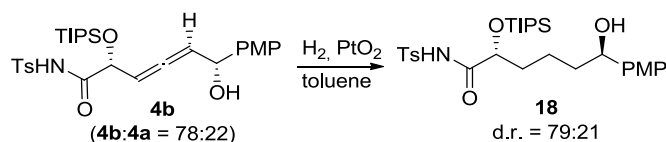
## 2.17. Synthesis of 2,5-*syn*-allendiol **17a**



Compound **17a** was obtained from  $\beta$ -lactam **15** (54.5 mg, 0.125 mmol) and benzaldehyde (25  $\mu$ L, 0.25 mmol) according to general procedures 2.12. (Method A) and 2.13. (Method B).

(2*R*\*,4*S*\*,6*R*\*)-6-hydroxy-5-methyl-6-phenyl-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**17a**) and (2*R*\*,4*S*\*,6*S*\*)-6-hydroxy-5-methyl-6-phenyl-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**17b**). Method A: Yield: 16.3 mg (24 %) <sup>13</sup>, **17a**:**17b** = 81:19; Modified Method A (HMPA was replaced with EtOH): Yield: 49.6 mg (73 %); **17a**:**17b** = 85:15; Method B: Yield: 17.7 mg (26 %) <sup>14</sup>; **17a**:**17b** = 59:41; Modified Method B (HMPA was replaced with EtOH): Yield: 48.3 mg (71 %); **17a**:**17b** = 77:23; <sup>15</sup> colorless wax; *R*<sub>f</sub> (30 acetone/hexane) 0.65; <sup>1</sup>H NMR (400 MHz, C<sub>6</sub>D<sub>6</sub>)  $\delta$  (major C6-epimer **17a**): 9.76 (br s, 1H), 8.12 – 8.07 (m, 2H), 7.47 – 7.39 (m, 2H), 7.22 – 7.17 (m, 2H), 7.11 – 7.06 (m, 1H), 6.78 – 6.73 (m, 2H), 5.20 – 5.12 (m, 1H), 5.06 (br d, *J* = 2.3 Hz, 1H), 4.72 (d, *J* = 7.1 Hz, 1H), 3.38 (br s, 1H), 1.81 (s, 3H), 1.47 (d, *J* = 2.8 Hz, 3H), 1.03 – 0.83 (m, 21H); (minor C6-epimer **17b**): 10.14 (br s, 1H), 8.16 – 8.12 (m, 2H), 7.37 – 7.34 (m, 2H), 7.22 – 7.17 (m, 2H), 7.13 – 7.09 (m, 1H), 6.79 – 6.73 (m, 2H), 5.12 – 5.09 (m, 1H), 4.93 (br d, *J* = 2.3 Hz, 1H), 4.65 (d, *J* = 8.1 Hz, 1H), 3.51 (br s, 1H), 1.82 (s, 3H), 1.41 (d, *J* = 2.8 Hz, 3H), 1.03 – 0.76 (m, 21H); <sup>13</sup>C NMR (101 MHz, C<sub>6</sub>D<sub>6</sub>)  $\delta$  (major C6-epimer **17a**): 201.6, 170.0, 144.9, 142.4, 136.5, 129.7, 129.0, 128.7, 127.9, 126.9, 107.6, 93.3, 75.2, 74.2, 21.2, 17.9, 13.9, 12.2; (minor C6-epimer **17b**): 201.1, 169.9, 144.7, 142.1, 136.8, 129.6, 129.0, 128.6, 127.9, 127.4, 107.5, 94.5, 75.6, 74.3, 21.2, 18.0, 14.8, 12.2; IR (film)  $\nu$ : 3501, 3352, 2944, 2892, 2867, 1968, 1734, 1598, 1454, 1410, 1352, 1191, 1175, 1119, 1087, 880, 814, 661, 548, 473 cm<sup>-1</sup>; HRMS (ESI-TOF) *m/z* calcd for C<sub>29</sub>H<sub>41</sub>NNaO<sub>5</sub>SSi [M + Na<sup>+</sup>] 566.2372. Found 566.2368.

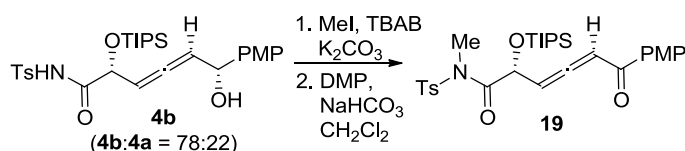
## 2.18. Synthesis of saturated 2,6-diol **18**.



To a solution of 2,6-allenediol **4b** (50.4 mg, 0.09 mmol, d.r. (**4b**:**4a**) = 78:22) in toluene (5 mL), PtO<sub>2</sub> (3.1 mg, 13.5  $\mu$ mol) was added in one portion at 25 °C and the resulting suspension was saturated with H<sub>2</sub>. After 2 h at the same temperature reaction mixture was diluted with toluene (5 mL) and filtered through a pad of Celite. Removal of solvent under reduced pressure and purification of the crude product by column chromatography on silica gel using an acetone/hexane mixture as an eluent afforded saturated 2,6-diol **18** as colorless wax.

(2*R*\*,6*R*\*)-6-hydroxy-6-(4-methoxyphenyl)-*N*-tosyl-2-((triisopropylsilyl)oxy)hexanamide (**18**). Yield: 38.1 mg (75%); 2,6-*anti*-:2,6-*syn*- = 79:21; colorless wax; *R*<sub>f</sub> (30% acetone/hexane) 0.70; Analytical data were consistent with previously reported values. <sup>16</sup>

## 2.19. Synthesis of $\alpha$ -allenyl ketone **19**. <sup>17</sup>

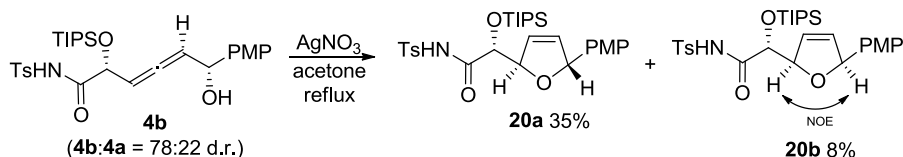


To a vigorously stirred solution of of 2,6-allenediol **4b** (100.8 mg, 0.18 mmol, d.r. (**4b**:**4a**) = 78:22) and TBAB (29 mg, 0.09 mmol) in MeI (2.5 mL), K<sub>2</sub>CO<sub>3</sub> (1 g) was added in one portion at 25 °C. After 12 h at the same temperature excess of K<sub>2</sub>CO<sub>3</sub> was filtered off, washed with CH<sub>2</sub>Cl<sub>2</sub> (25 mL) and combined filtrates were concentrated under reduced pressure. Filtration of the residue through a pad of silica gel with acetone/hexane mixture afforded crude product which was subsequently, without

further purification, dissolved in the in anhydrous  $\text{CH}_2\text{Cl}_2$  (2.2 mL). To this solution  $\text{NaHCO}_3$  (61 mg, 0.72 mmol) and Dess-Martin periodinane (DMP, 137 mg, 0.324 mmol) were sequentially added both in one portion at 0 °C. After 1 h of stirring at the same temperature the reaction mixture was diluted with  $\text{Et}_2\text{O}$  (2.2 mL) and saturated aqueous  $\text{Na}_2\text{SO}_3$  (1 mL) was added in one portion at 0 °C and cooling bath was removed. After 15 min at 25 °C the reaction mixture was poured into water and extracted with  $\text{EtOAc}$  (3 x 15 mL). The combined extracts were washed successively with water (50 mL), saturated solution of  $\text{NaHCO}_3$  (50 mL) and brine (50 mL), dried over anhydrous  $\text{MgSO}_4$  and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an ethyl acetate/hexane mixture as an eluent afforded  $\alpha$ -allenyl ketone **19**.

(2*R*\*,4*S*\*)-6-(4-methoxyphenyl)-*N*-methyl-6-oxo-*N*-tosyl-2-((triisopropylsilyl)oxy)hexa-3,4-dienamide (**19**). Yield: 35.0 mg (34%); d.r. = 85:15;<sup>18</sup> yellowish wax;  $R_f$  (30% ethyl acetate/hexane) 0.55;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  (major C5-epimer): 7.92 – 7.84 (m, 2H), 7.83 – 7.76 (m, 2H), 7.24 – 7.17 (m, 2H), 6.98 – 6.87 (m, 2H), 6.48 (dd,  $J$  = 6.2, 2.8 Hz, 1H), 5.78 (dd,  $J$  = 6.2, 5.7 Hz, 1H), 5.35 (dd,  $J$  = 5.7, 2.8 Hz, 1H), 3.88 (s, 3H), 3.40 (s, 3H), 2.36 (s, 3H), 1.17 – 0.88 (m, 21H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$  (major C5-epimer): 211.9, 187.8, 170.4, 163.8, 145.0, 135.7, 131.2, 130.3, 129.6, 128.6, 113.9, 96.3, 95.3, 72.8, 55.7, 33.3, 21.7, 17.9, 17.8, 12.1; IR (film)  $\nu$ : 2944, 2867, 1954, 1692, 1650, 1599, 1511, 1463, 1360, 1258, 1172, 1114, 1088, 1065, 993, 880, 848, 688, 594, 548, 525  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{30}\text{H}_{41}\text{NNaO}_6\text{SSi}$  [ $\text{M} + \text{Na}^+$ ] 594.2322. Found 594.2321.

## 2.20. Synthesis of 1,5-dihydrofurans **20a** and **20b**.

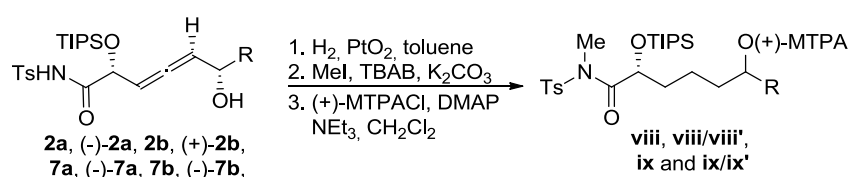


To a vigorously stirred solution of 2,6-allenediol **4b** (100.8 mg, 0.18 mmol, d.r. (**4b**:**4a**) = 78:22) in acetone (5 mL),  $\text{AgNO}_3$  (30.6 mg, 0.18 mmol) was added in one portion at 25 °C and the reaction mixture was then heated and refluxed within 3 hours. After being cooled to 25 °C, the mixture was diluted with acetone (15 mL), filtered through a pad of Celite and concentrated under reduced pressure. Purification of the crude product by column chromatography on silica gel using an MTBE/toluene mixture as an eluent afforded 1,5-dihydrofurans **20a** and **20b** as colorless wax and colorless crystals respectively.

(*R*\*)-2-((2*R*\*,5*R*\*)-5-(4-methoxyphenyl)-2,5-dihydrofuran-2-yl)-*N*-tosyl-2-((triisopropylsilyl)oxy)acetamide (**20a**). Yield: 35.3 mg (35%); colorless wax;  $R_f$  (20% MTPA/toluene) 0.80;  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$ : 8.94 (br s, 1H), 8.04 – 7.95 (m, 2H), 7.38 – 7.29 (m, 2H), 7.12 – 7.01 (m, 2H), 6.89 – 6.76 (m, 2H), 5.88 (ddd,  $J$  = 6.1, 2.3, 1.5 Hz, 1H), 5.72 (ddd,  $J$  = 6.1, 2.3, 1.5 Hz, 1H), 5.32 (dt,  $J$  = 6.1, 1.5 Hz, 1H), 5.23 – 5.14 (m, 1H), 4.33 (d,  $J$  = 2.3 Hz, 1H), 3.79 (s, 3H), 2.44 (s, 3H), 1.18 – 0.97 (m, 21H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{CDCl}_3$ )  $\delta$ : 168.7, 159.6, 145.2, 135.7, 133.5, 133.1, 129.6, 128.7, 127.8, 124.4, 114.1, 89.3, 88.3, 76.9, 55.4, 21.8, 18.0, 17.9, 12.2; IR (film)  $\nu$ : 3361, 3258, 2945, 2892, 2868, 1731, 1610, 1513, 1463, 1410, 1353, 1246, 1173, 1120, 1088, 1066, 1036, 881, 863, 831, 688, 664, 549, 534, 474  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{42}\text{NO}_6\text{SSi}$  [ $\text{M} + \text{H}^+$ ] 560.2502. Found 560.2472.

(*R*\*)-2-((2*R*\*,5*S*\*)-5-(4-methoxyphenyl)-2,5-dihydrofuran-2-yl)-*N*-tosyl-2-((triisopropylsilyl)oxy)acetamide (**20b**). Yield: 8.1 mg (8%); colorless crystals; mp = 152.1-152.9 °C;  $R_f$  (20% MTPA/toluene) 0.75;  $^1\text{H}$  NMR (400 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$ : 9.07 (br s, 1H), 8.14 – 8.04 (m, 2H), 7.34 – 7.25 (m, 2H), 6.96 – 6.86 (m, 2H), 6.76 – 6.65 (m, 2H), 5.83 (ddd,  $J$  = 6.1, 2.5, 1.4 Hz, 1H), 5.63 (ddd,  $J$  = 6.1, 2.6, 1.4 Hz, 1H), 5.58 – 5.51 (m, 1H), 4.93 – 4.85 (m, 1H), 4.28 (d,  $J$  = 4.4 Hz, 1H), 3.32 (s, 3H), 1.83 (s, 3H), 0.97 – 0.81 (m, 21H);  $^{13}\text{C}$  NMR (101 MHz,  $\text{C}_6\text{D}_6$ )  $\delta$ : 168.7, 160.4, 144.5, 136.9, 132.7, 132.4, 129.4, 129.3, 129.0, 127.5, 114.5, 88.2, 87.5, 77.1, 54.9, 21.2, 18.0, 12.5; IR (film)  $\nu$ : 3360, 3255, 2925, 2867, 1730, 1611, 1599, 1513, 1462, 1411, 1350, 1247, 1174, 1108, 1088, 1067, 1036, 860, 829, 787, 661, 548, 519, 472  $\text{cm}^{-1}$ ; HRMS (ESI-TOF)  $m/z$  calcd for  $\text{C}_{29}\text{H}_{42}\text{NO}_6\text{SSi}$  [ $\text{M} + \text{H}^+$ ] 560.2502. Found 560.2496.

## 2.21. Synthesis of Mosher's esters **viii** and **ix**. General procedure.<sup>19</sup>



To a solution of 2,6-allenediols **2a**, (-)-**2a**, **2b**, (+)-**2b**, **7a**, (-)-**7a**, **7b** or (-)-**7b** (0.02 mmol) in toluene (2.5 mL), PtO<sub>2</sub> (1.4 mg, 6 μl) was added in one portion at 25 °C and the resulting suspension was saturated with H<sub>2</sub>. After 2 h at the same temperature reaction mixture was diluted with toluene (15 mL), filtered through a pad of Celite, concentrated under reduced pressure and dissolved in MeI (2 mL). To this solution TBAB (3.2 mg, 0.01 mmol) and K<sub>2</sub>CO<sub>3</sub> (0.5 g) were sequentially added both in one portion at 25 °C and reaction mixture was vigorously stirred at the same temperature overnight. At the end of this time excess of K<sub>2</sub>CO<sub>3</sub> was filtered off, washed with CH<sub>2</sub>Cl<sub>2</sub> (25 mL) and combined filtrates were concentrated under reduced pressure. Filtration of the residue through a pad of silica gel with acetone/hexane mixture afforded crude *N*-methylated 2,6-diols which were subsequently, without further purification, dissolved in the anhydrous CH<sub>2</sub>Cl<sub>2</sub> (1 mL). To this mixture DMAP (0.6 mg; 0.005 mmol) and Et<sub>3</sub>N (5.6 μL, 0.04 mmol) were sequentially added both in one portion followed by 1M solution of (+)-MTPACl in CH<sub>2</sub>Cl<sub>2</sub> (22 μL, 0.022 mmol) dropwise at 25 °C. After 3h at the same temperature, reaction was quenched with saturated 5% aqueous solution of HCl (0.5 mL), poured into water (10 mL) and layers were separated. The water layer was extracted with CH<sub>2</sub>Cl<sub>2</sub> (3 x 10 mL) and the combined extracts were washed with saturated aqueous solution of NaHCO<sub>3</sub> (15 mL) and brine (15 mL), dried over MgSO<sub>4</sub> and concentrated. Filtration of the crude product through pad of silica gel with an ethyl acetate/hexane mixture afforded Mosher's esters **viii**, **viii/viii'**, **ix** or **ix/ix'** as inseparable mixtures of diastereomers.

(*S*)-(1*S*,5*R*)-6-(*N*,4-dimethylphenylsulfonamido)-6-oxo-1-phenyl-5-((triisopropylsilyl)oxy)hexyl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*syn*-**viii**) and (*S*)-(1*R*,5*R*)-6-(*N*,4-dimethylphenylsulfonamido)-6-oxo-1-phenyl-5-((triisopropylsilyl)oxy)hexyl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*anti*-**viii**) Inseparable mixture. Starting from (-)-**2a** (71:29 d.r.): Yield: 10.2 mg (67%); *syn*-**viii**:*anti*-**viii** = 69:31; colorless wax. Starting from (+)-**2b** (79:21 d.r.): Yield: 9.2 mg (60%); *anti*-**viii**:*syn*-**viii** = 81:19; colorless wax. R<sub>f</sub> (20% ethyl acetate/hexane) 0.70; <sup>19</sup>F NMR (376 MHz, CDCl<sub>3</sub>) δ: -71.25 (*anti*-**viii**), -71.62 (*syn*-**viii**); HRMS (ESI-TOF) *m/z* calcd for C<sub>39</sub>H<sub>52</sub>F<sub>3</sub>NNaO<sub>7</sub>SSi [M + Na<sup>+</sup>] 786.3084. Found 786.3071.

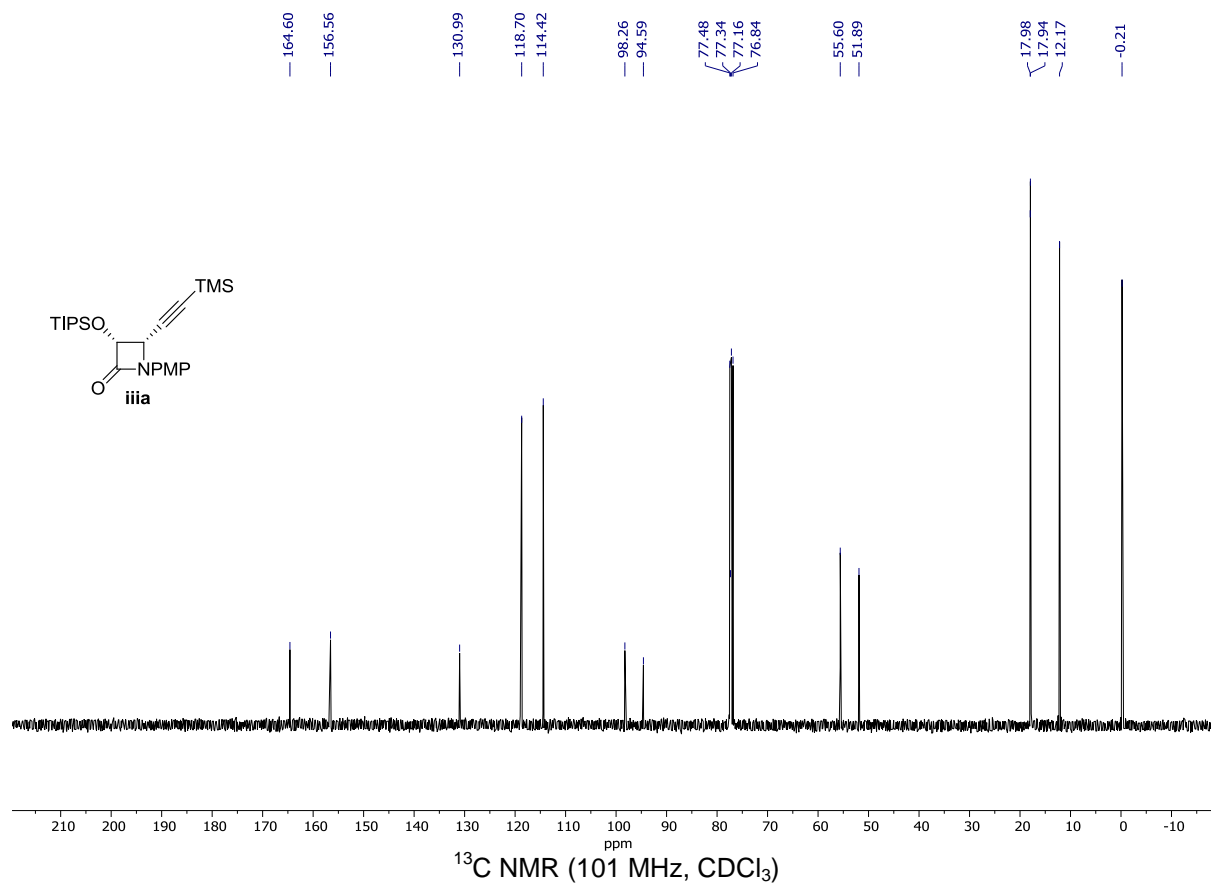
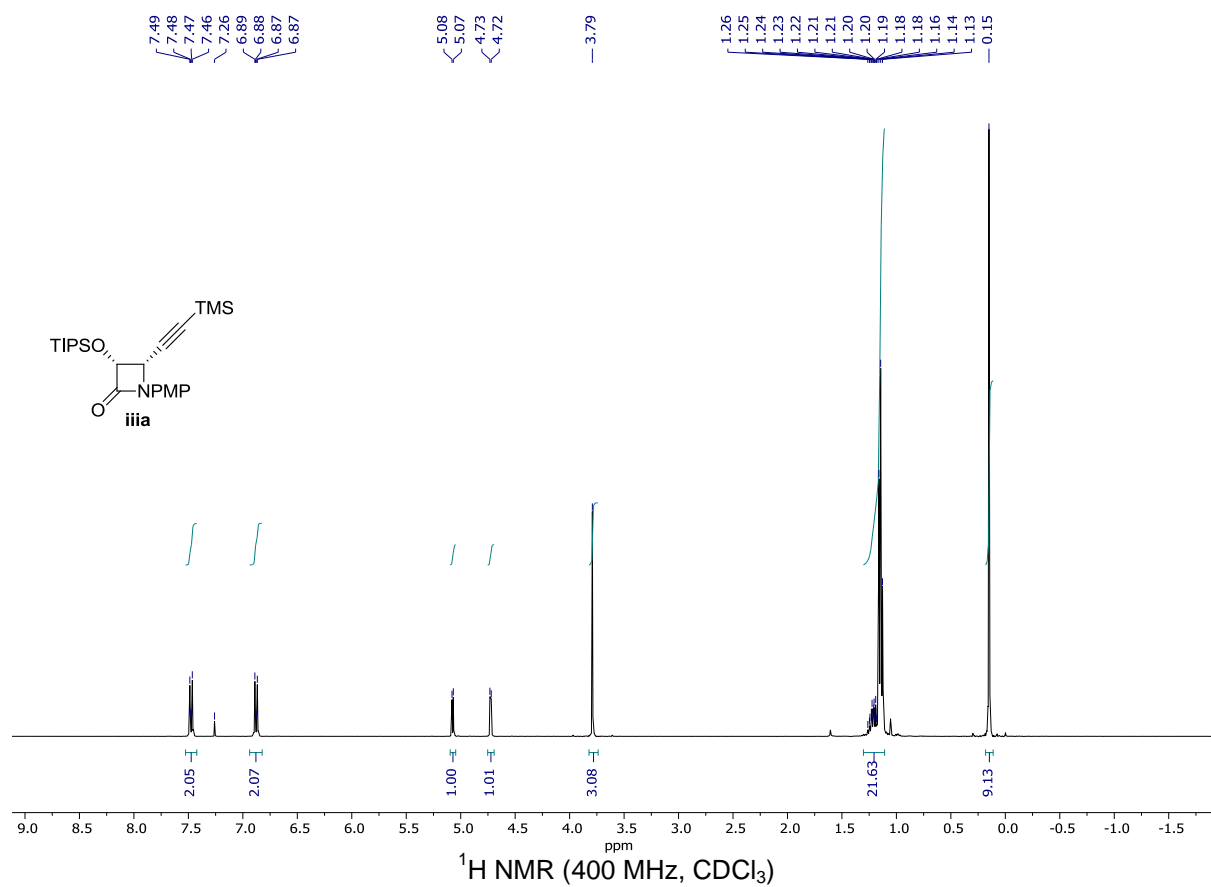
(*S*)-(1*S*,5*R*)-6-(*N*,4-dimethylphenylsulfonamido)-6-oxo-1-phenyl-5-((triisopropylsilyl)oxy)hexyl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*syn*-**viii**), (*S*)-(1*R*,5*S*)-6-(*N*,4-dimethylphenylsulfonamido)-6-oxo-1-phenyl-5-((triisopropylsilyl)oxy)hexyl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*syn*-**viii'**) and (*S*)-(1*R*,5*R*)-6-(*N*,4-dimethylphenylsulfonamido)-6-oxo-1-phenyl-5-((triisopropylsilyl)oxy)hexyl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*anti*-**viii**) and (*S*)-(1*S*,5*S*)-6-(*N*,4-dimethylphenylsulfonamido)-6-oxo-1-phenyl-5-((triisopropylsilyl)oxy)hexyl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*anti*-**viii'**). Inseparable mixture. Starting from **2a** (73:27 d.r.): Yield: 9.9 mg (65%); **viii**:**viii'** = 50:50; *syn*-**viii**:*anti*-**viii** = 65:35; *syn*-**viii'**:*anti*-**viii'** = 67:33; Starting from **2b** (81:19 d.r.): Yield: 9.5 mg (62%); **viii**:**viii'** = 50:50, *anti*-**viii**:*syn*-**viii** = 81:19; *anti*-**viii'**:*syn*-**viii'** = 80:20; colorless wax; R<sub>f</sub> (20% ethyl acetate/hexane) 0.70; <sup>19</sup>F NMR (376 MHz, CDCl<sub>3</sub>) δ: -71.25 (*anti*-**viii**), -71.30 (*syn*-**viii'**), -71.62 (*syn*-**viii**), -71.64 (*anti*-**viii'**); HRMS (ESI-TOF) *m/z* calcd for C<sub>39</sub>H<sub>52</sub>F<sub>3</sub>NNaO<sub>7</sub>SSi [M + Na<sup>+</sup>] 786.3084. Found 786.3077.

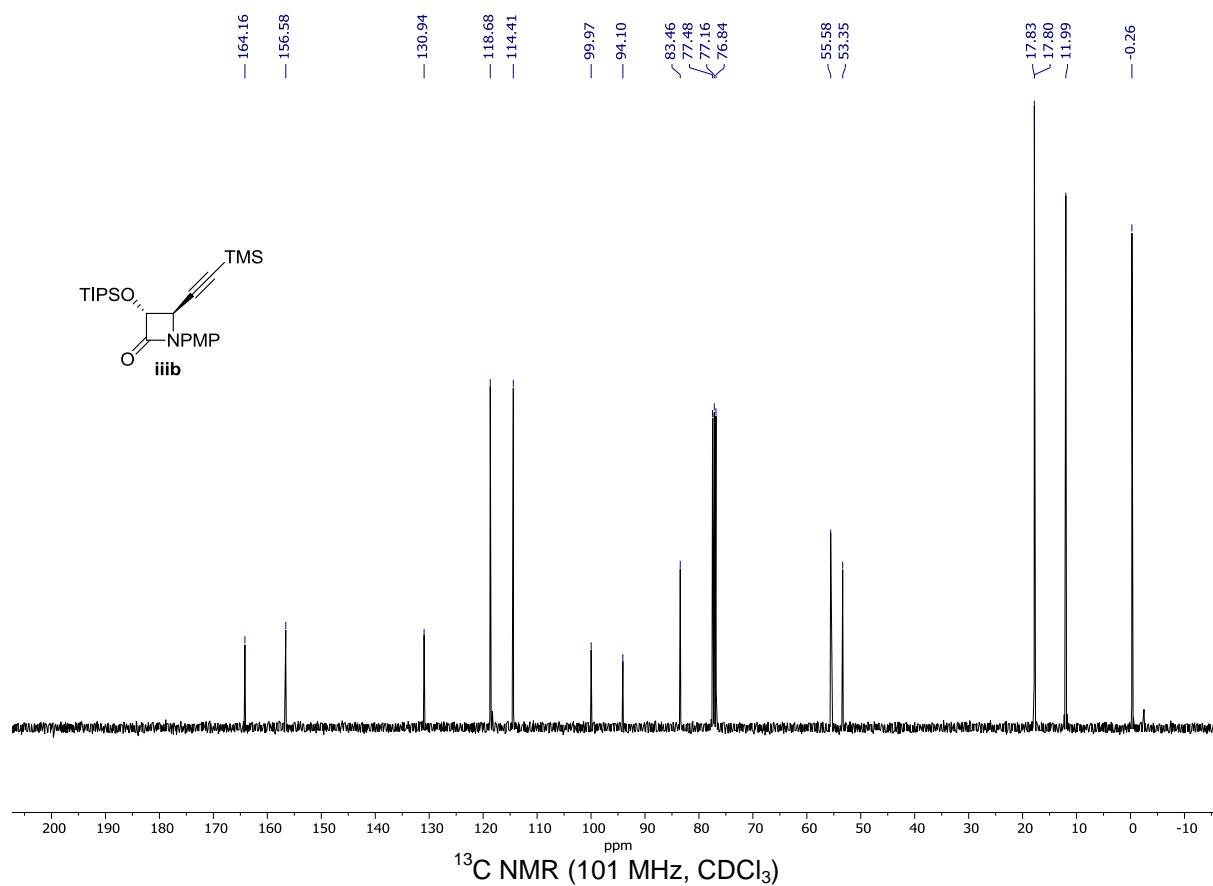
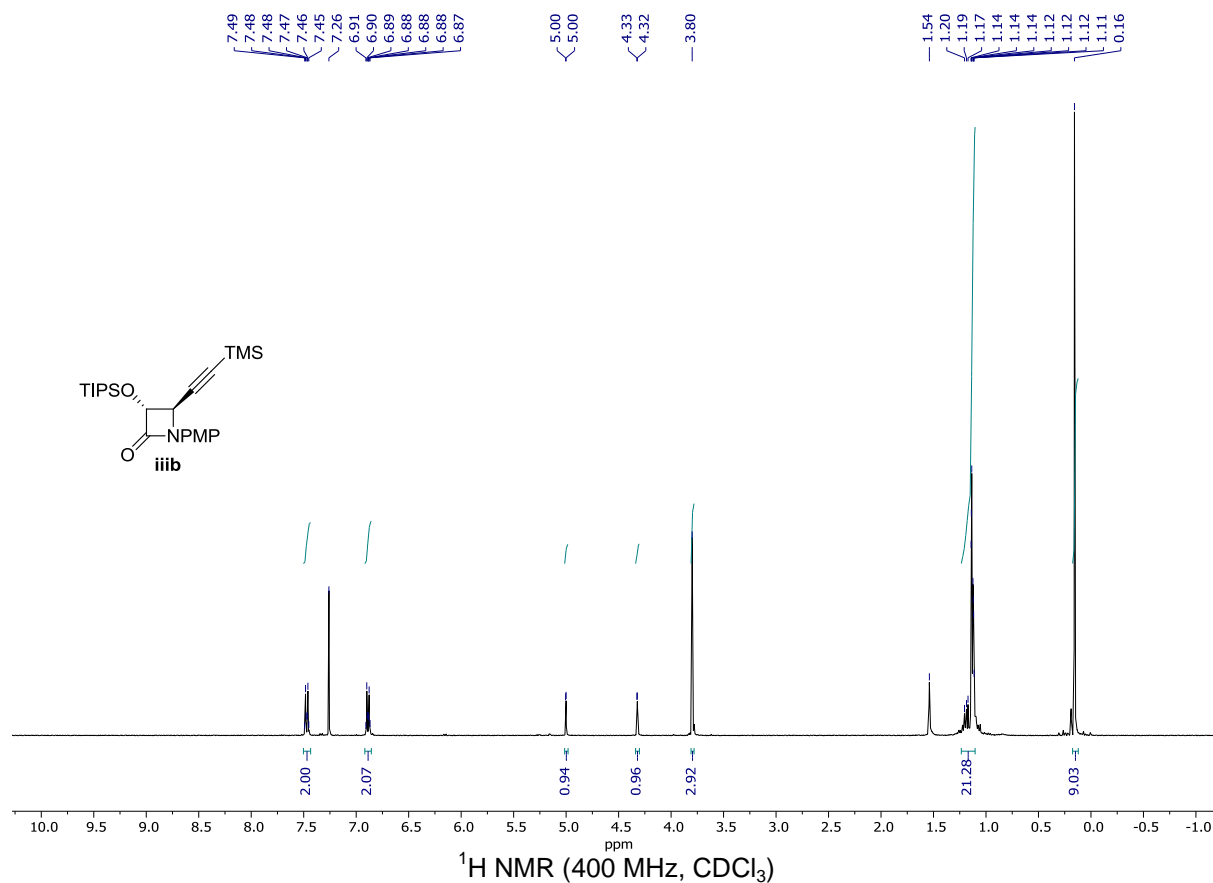
(*S*)-(3*S*,7*R*)-8-(*N*,4-dimethylphenylsulfonamido)-2-methyl-8-oxo-7-((triisopropylsilyl)oxy)octan-3-yl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*syn*-**ix**) and (*S*)-(3*R*,7*R*)-8-(*N*,4-dimethylphenylsulfonamido)-2-methyl-8-oxo-7-((triisopropylsilyl)oxy)octan-3-yl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*anti*-**ix**). Inseparable mixture. Starting from (-)-**7a** (63:37 d.r.): Yield: 9.2 mg (70%); *syn*:*anti* = 63:37; Starting from (-)-**7b** (89:11 d.r.): Yield: 7.2 mg (61%); *anti*:*syn* = 87:13; colorless wax; R<sub>f</sub> (20% ethyl acetate/hexane) 0.80; <sup>19</sup>F NMR (376 MHz, C<sub>6</sub>D<sub>6</sub>) δ: -71.25 (*syn*-**ix**), -71.26 (*anti*-**ix**); HRMS (ESI-TOF) *m/z* calcd for C<sub>36</sub>H<sub>55</sub>F<sub>3</sub>NO<sub>7</sub>SSi [M + H<sup>+</sup>] 730.3421. Found 730.3378.

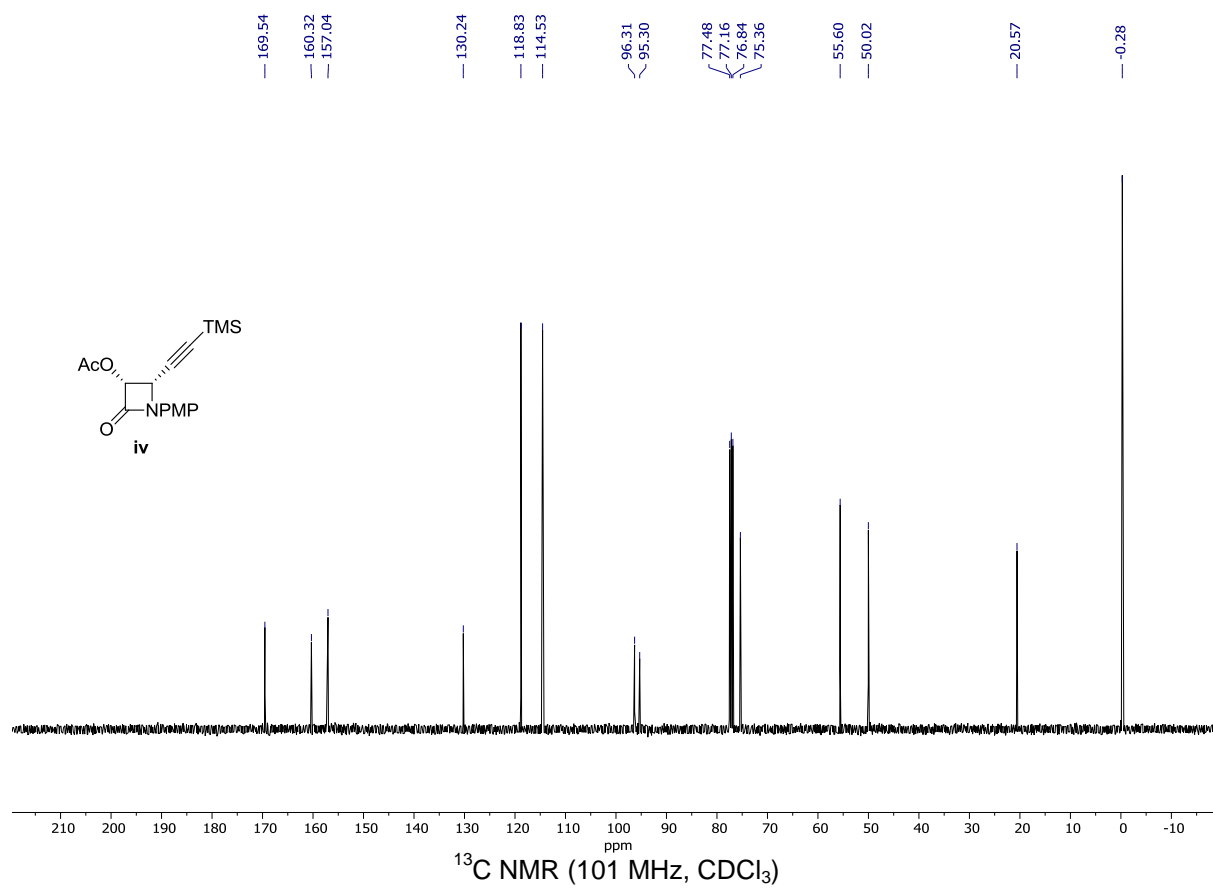
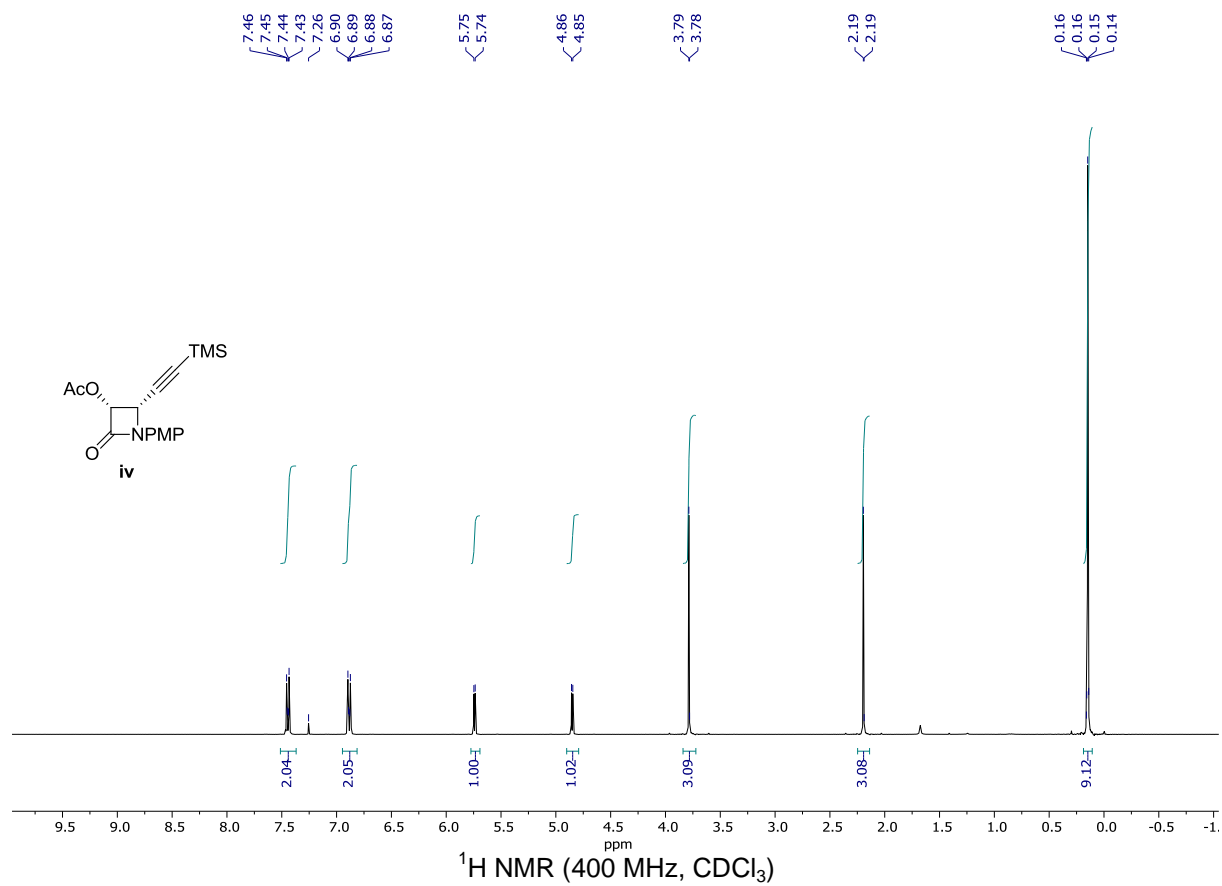
(*S*)-(3*S*,7*R*)-8-(*N*,4-dimethylphenylsulfonamido)-2-methyl-8-oxo-7-((triisopropylsilyl)oxy)octan-3-yl 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*syn*-**ix**), (*S*)-(3*R*,7*S*)-8-(*N*,4-dimethylphenylsulfonamido)-2-methyl-8-oxo-7-((triisopropylsilyl)oxy)octan-3-yl 3,3,3-trifluoro-2-

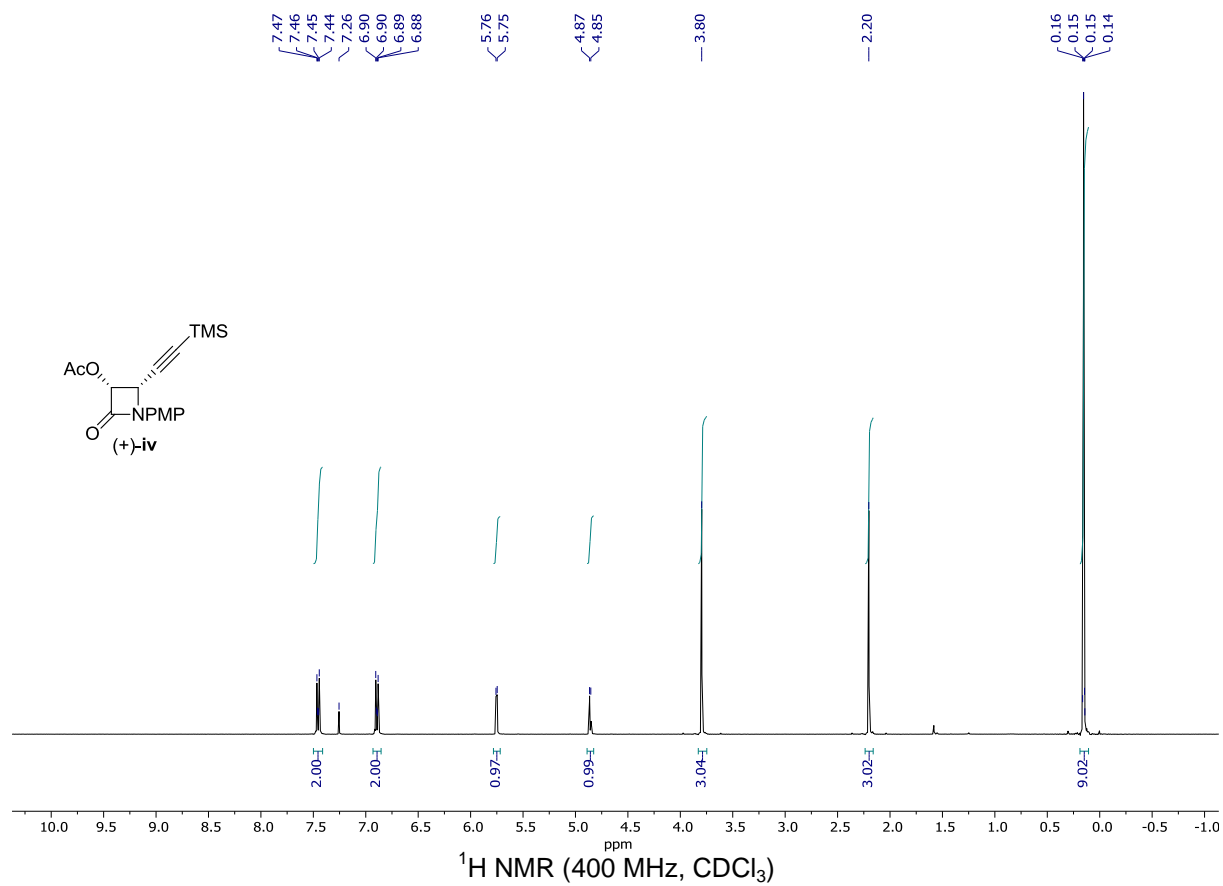
methoxy-2-phenylpropanoate (*syn-ix'*), (*S*)-(3*R*,7*R*)-8-(*N*,4-dimethylphenylsulfonamido)-2-methyl-8-oxo-7-((triisopropylsilyloxy)octan-3-yl) 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*anti-ix*) and (*S*)-(3*S*,7*S*)-8-(*N*,4-dimethylphenylsulfonamido)-2-methyl-8-oxo-7-((triisopropylsilyloxy)octan-3-yl) 3,3,3-trifluoro-2-methoxy-2-phenylpropanoate (*anti-ix'*). Inseparable mixture. Starting from **7a** (64:36 d.r.): Yield: 9.6 mg (66%); *ix:ix'* = 50:50; *syn-ix:anti-ix* = 63:37; *syn-ix':anti-ix'* = 60:40; Starting from **7b** (87:13): Yield: 9.9 mg (68%); *ix:ix'* = 50:50; *anti-ix:syn-ix* = 86:14; *anti-ix':syn-ix'* = 87:13; colorless wax; *R<sub>f</sub>* (20% ethyl acetate/hexane) 0.80; <sup>19</sup>F NMR (376 MHz, C<sub>6</sub>D<sub>6</sub>) δ: -71.19 (*anti-ix'*), -71.24 (*syn-ix*), -71.26 (*anti-ix*), -71.30 (*syn-ix'*); HRMS (ESI-TOF) *m/z* calcd for C<sub>36</sub>H<sub>55</sub>F<sub>3</sub>NO<sub>7</sub>SSi [M + H<sup>+</sup>] 730.3421. Found 730.3406.

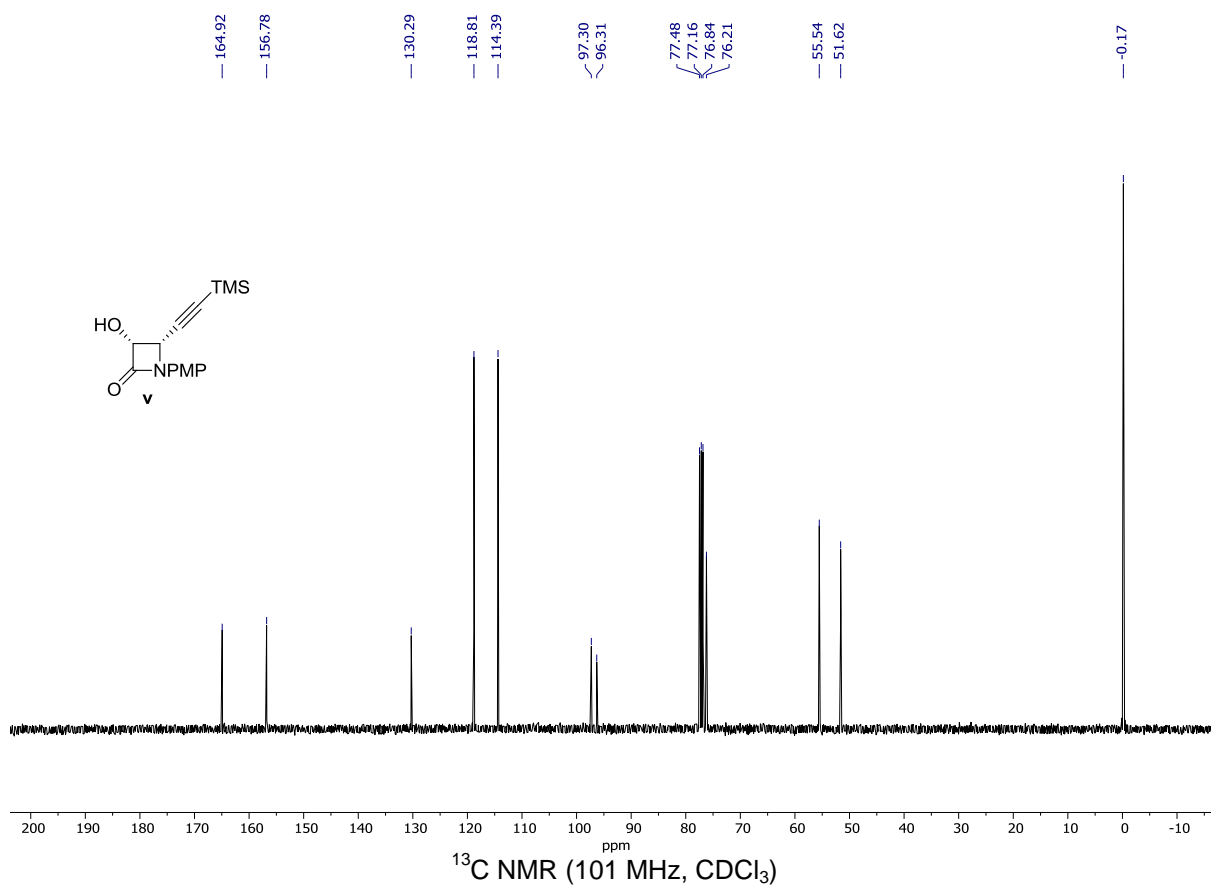
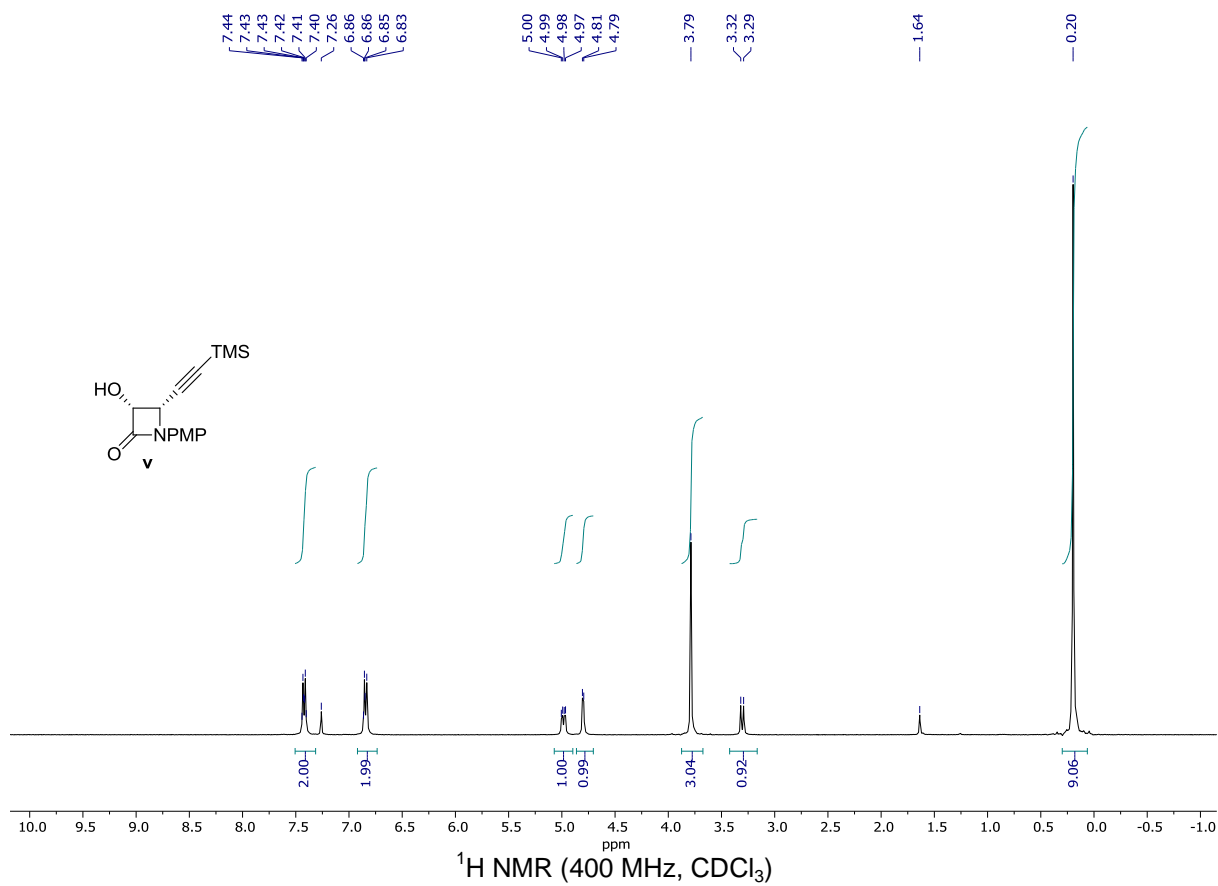
3.  $^1\text{H}$  and  $^{13}\text{C}$  NMR spectra for all new and selected known compounds.

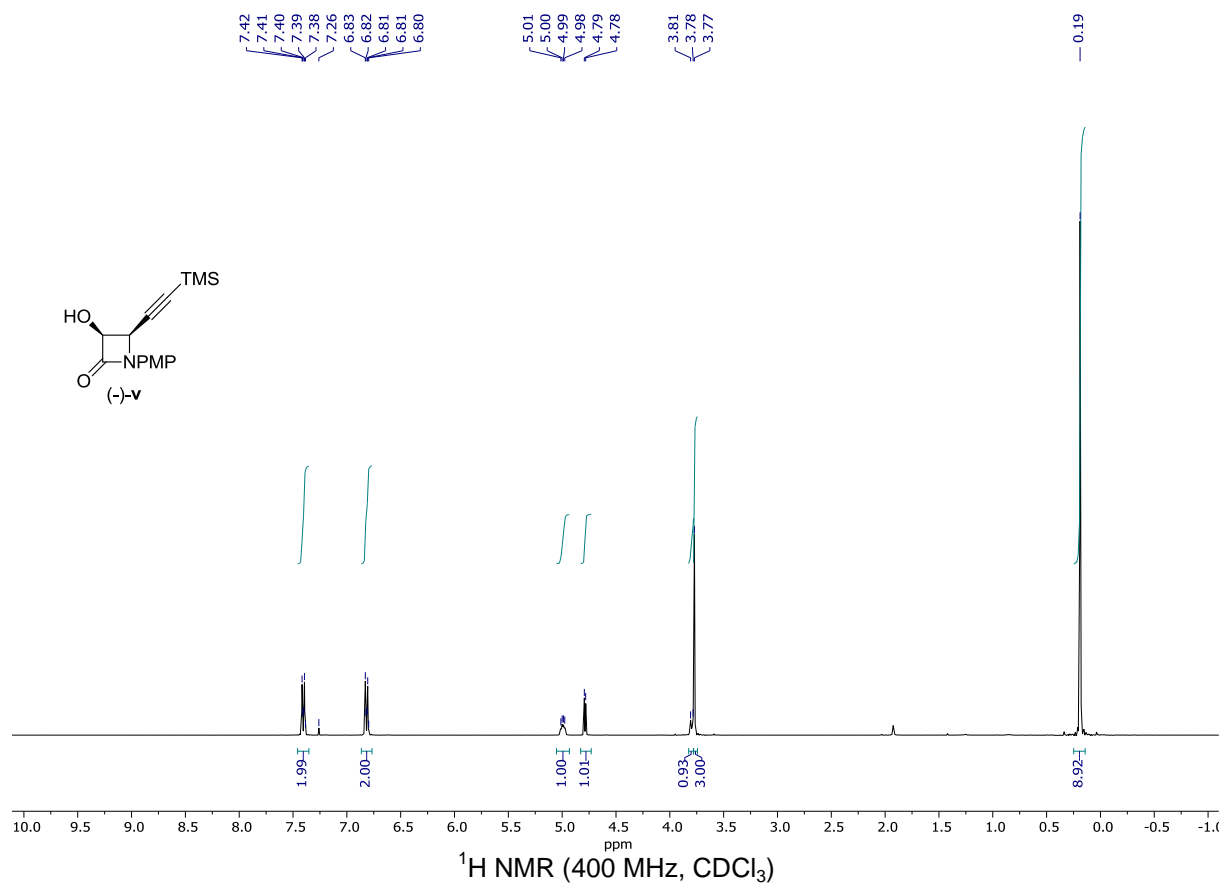


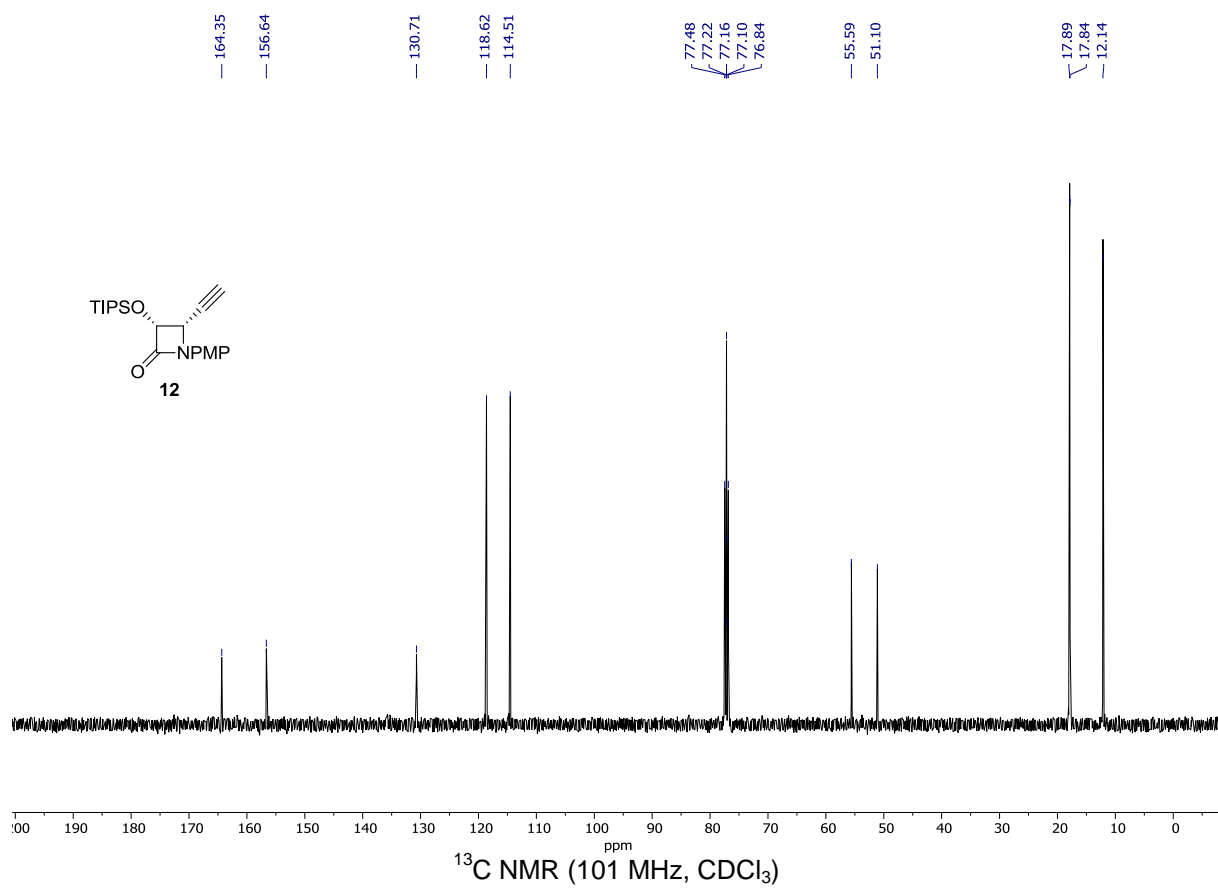
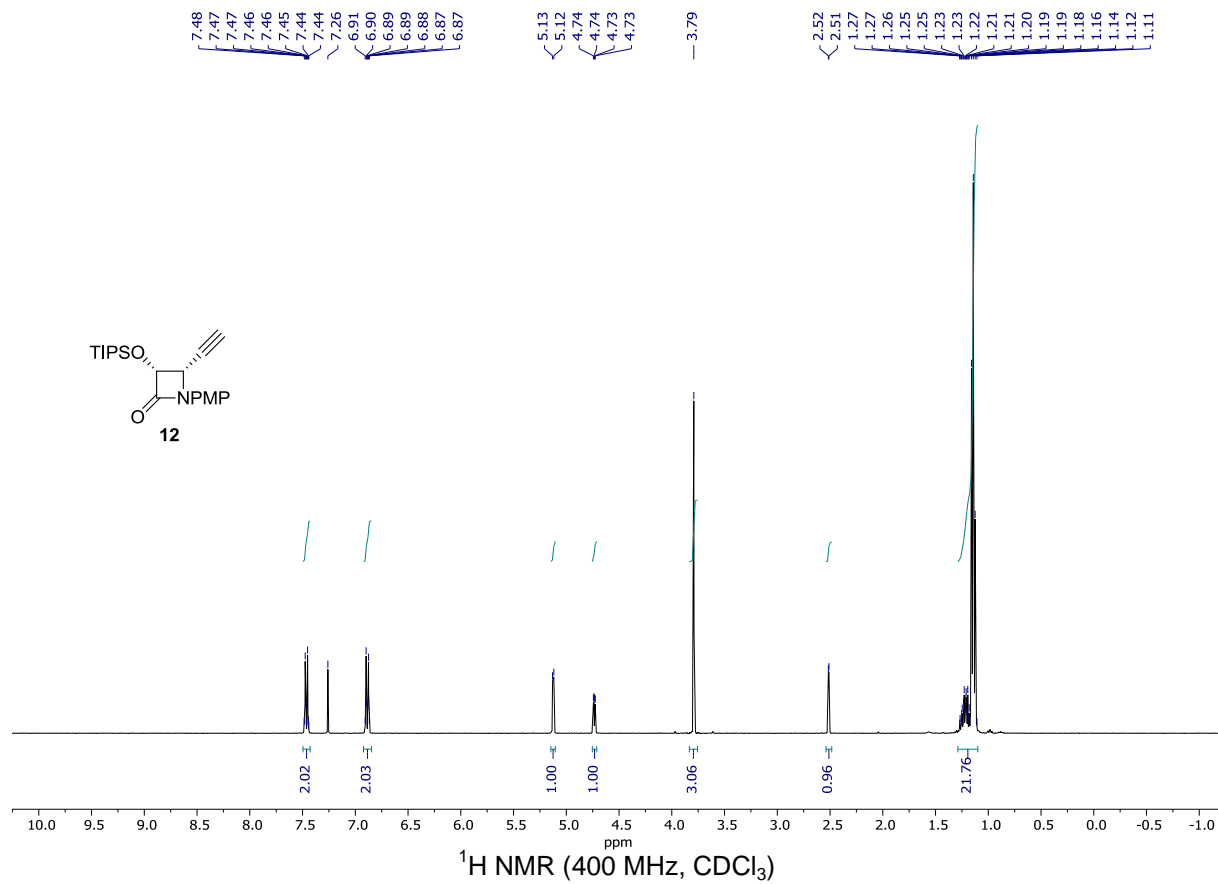




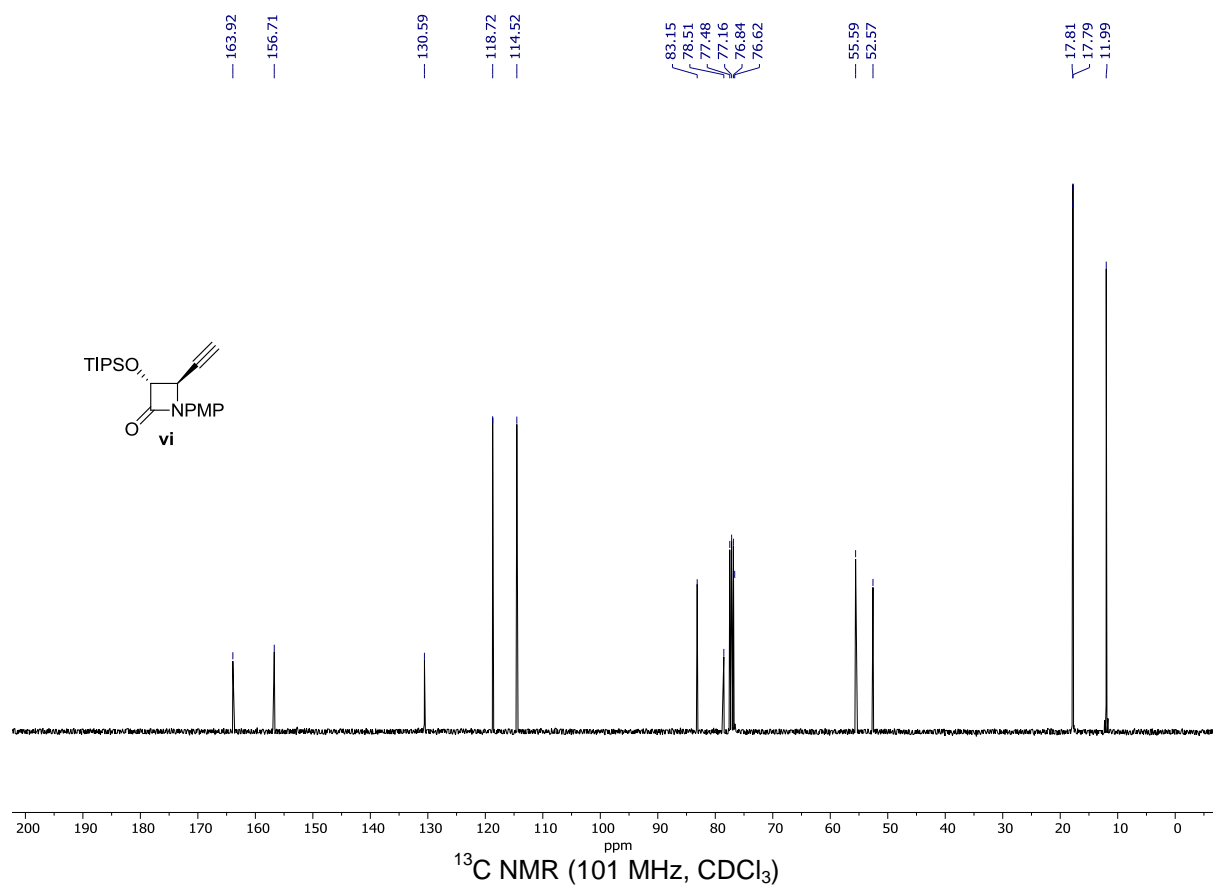
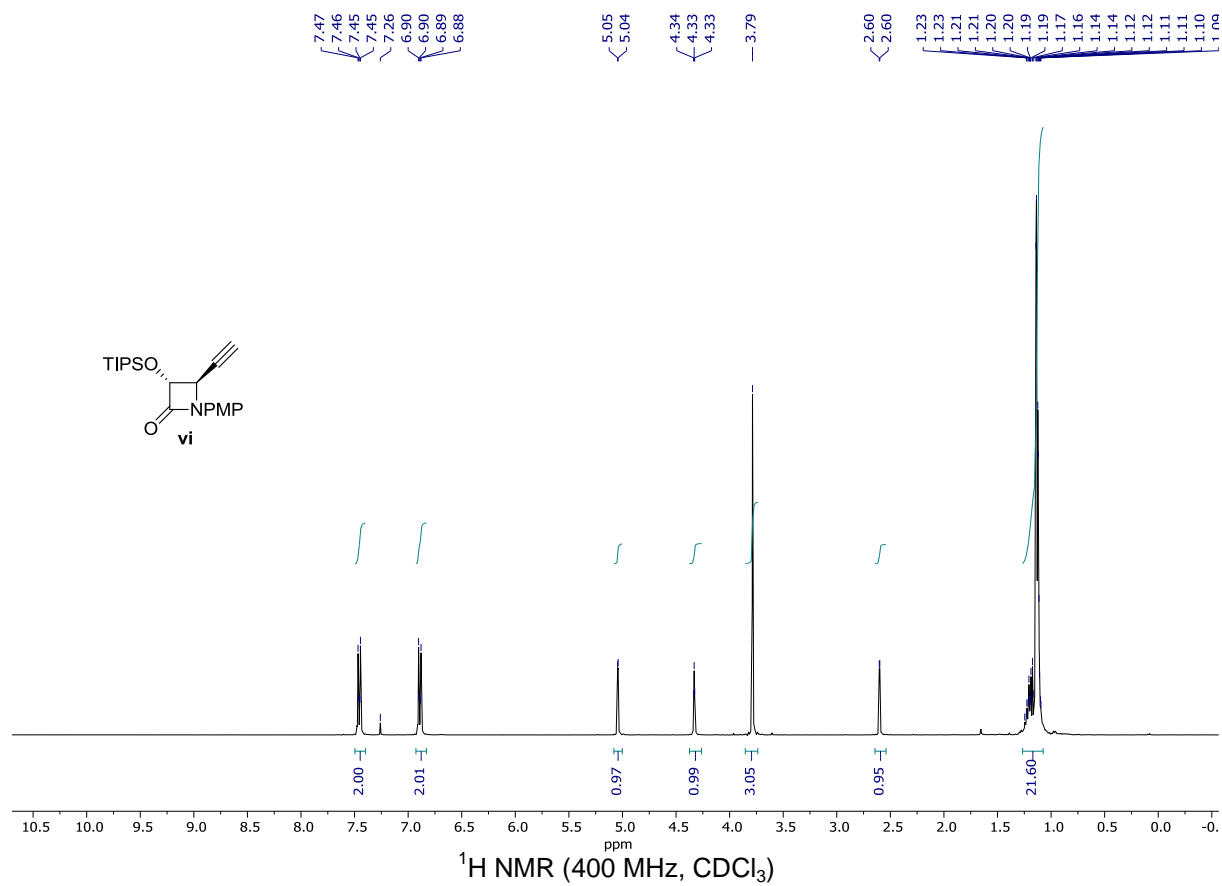


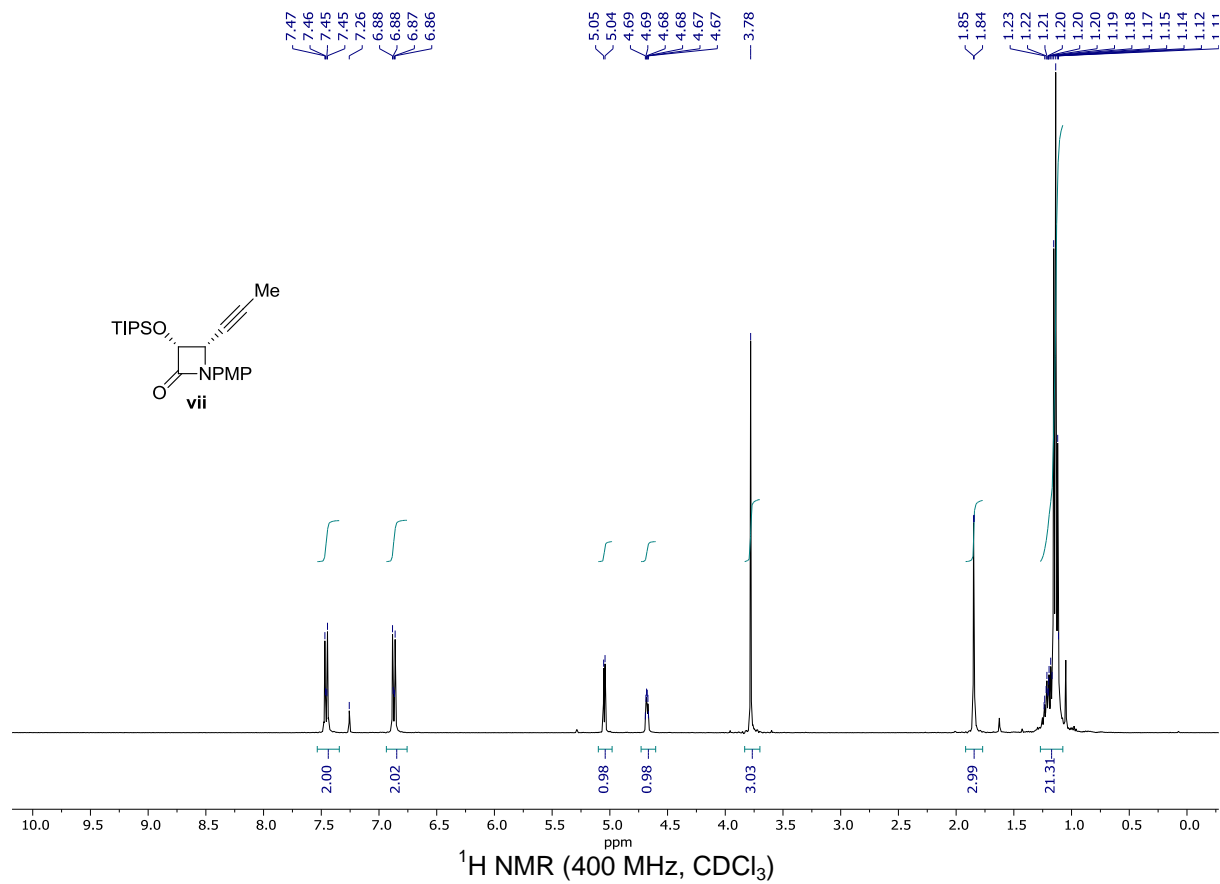


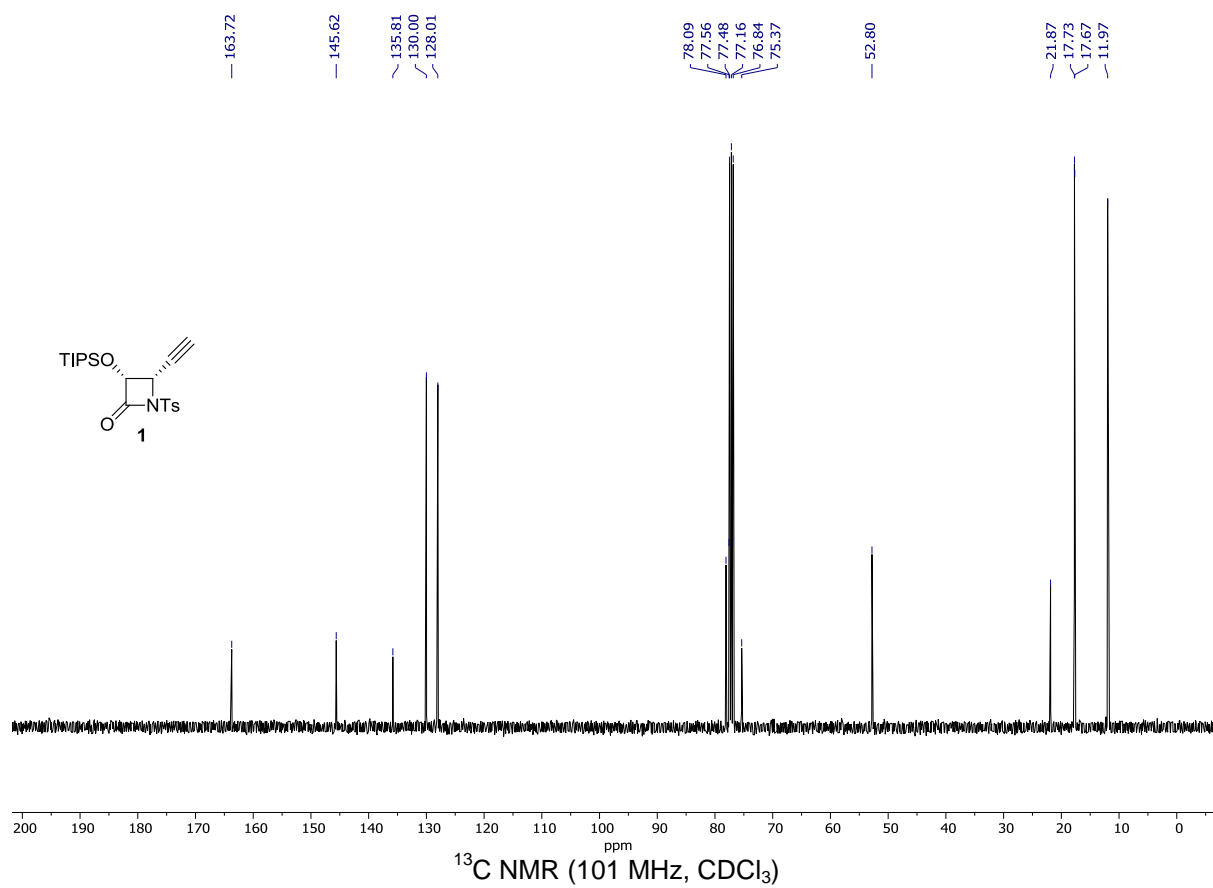
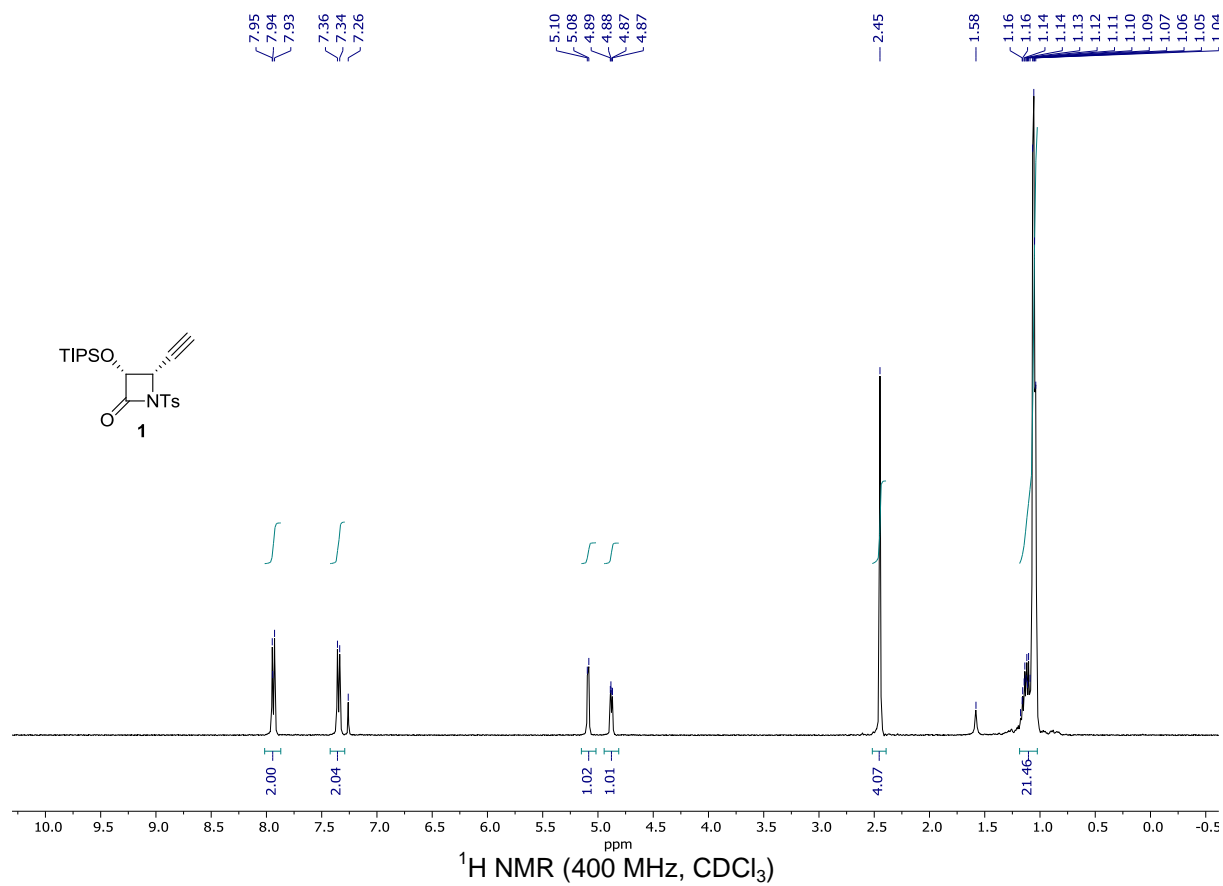


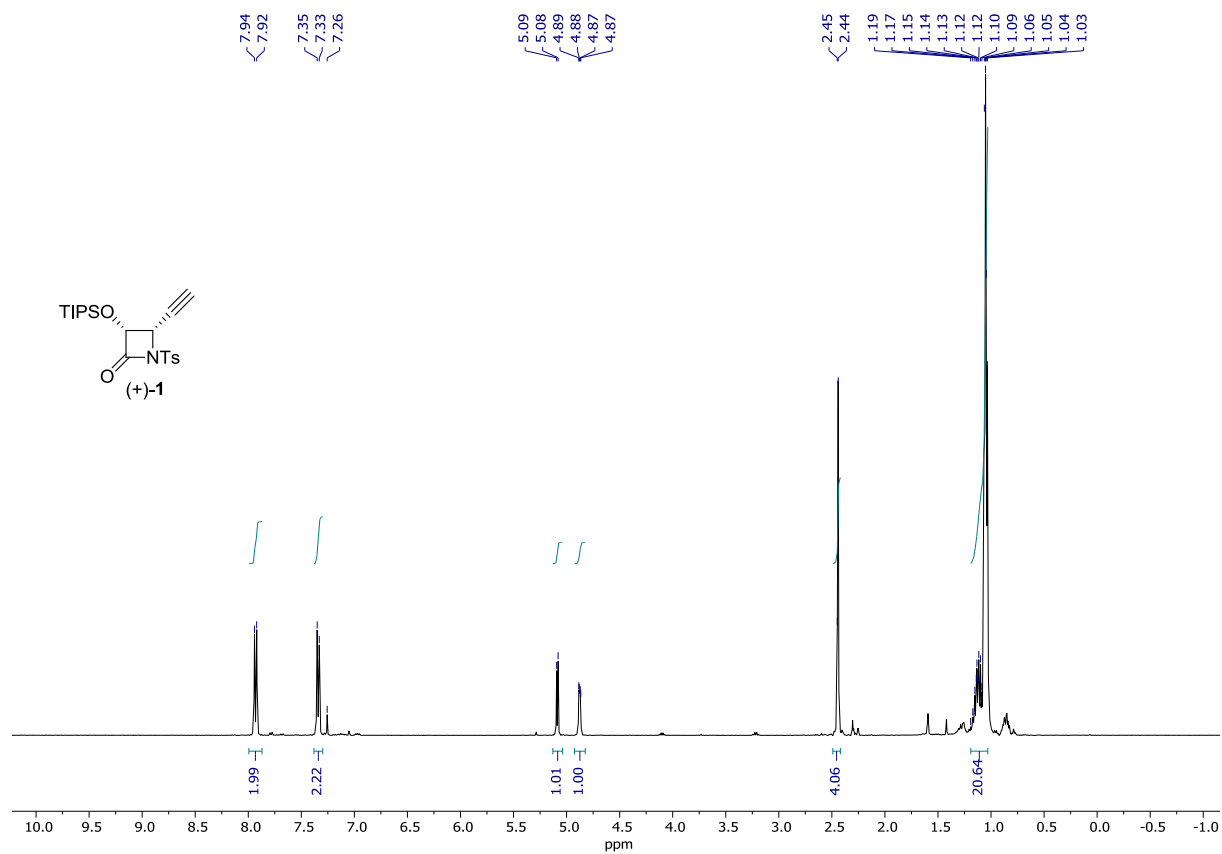




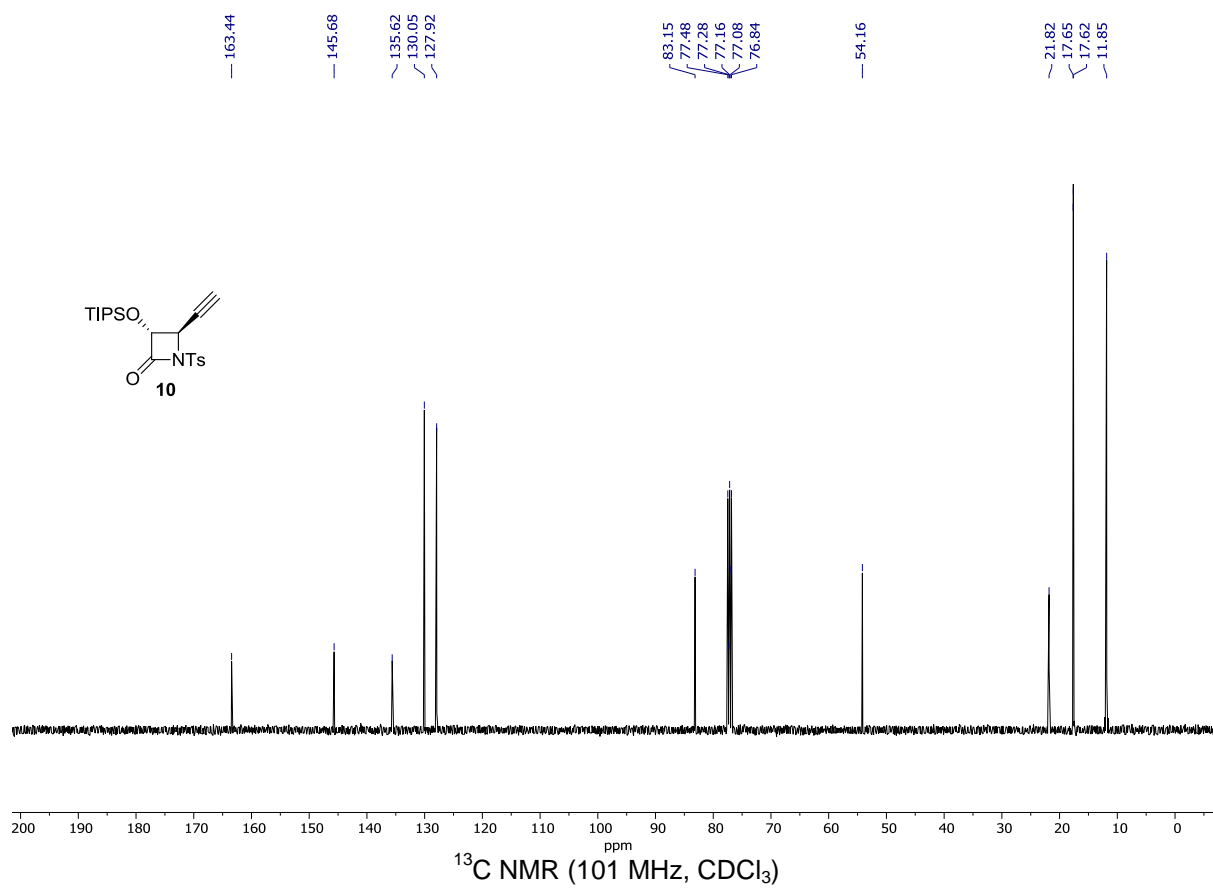
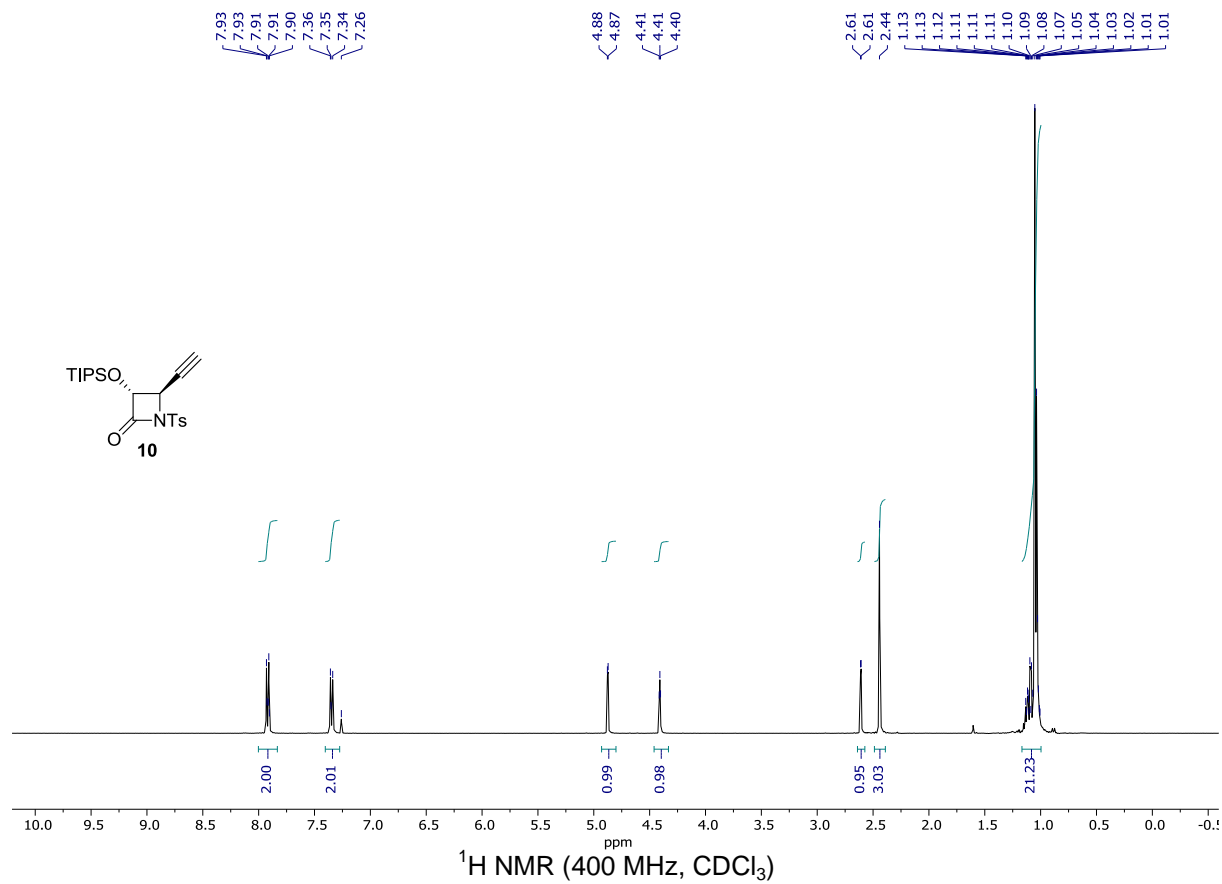




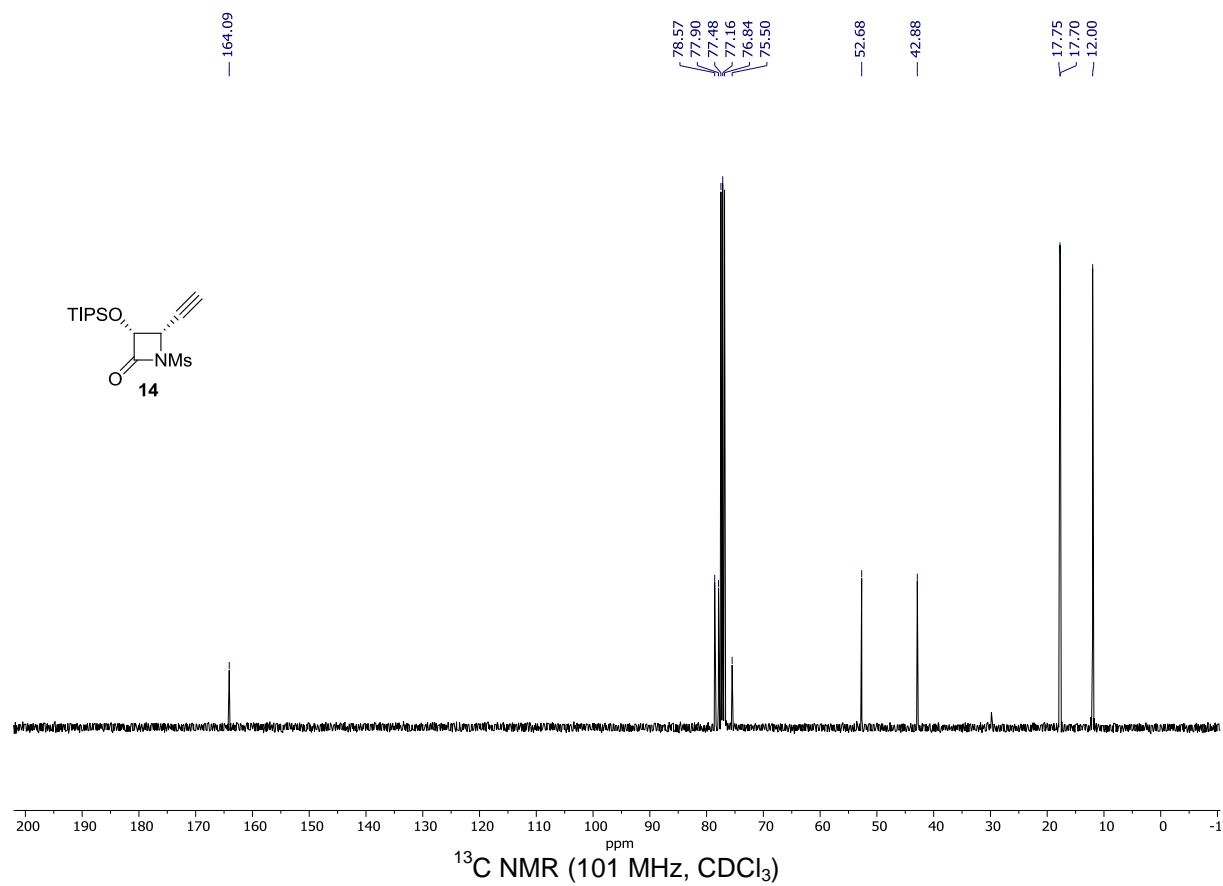
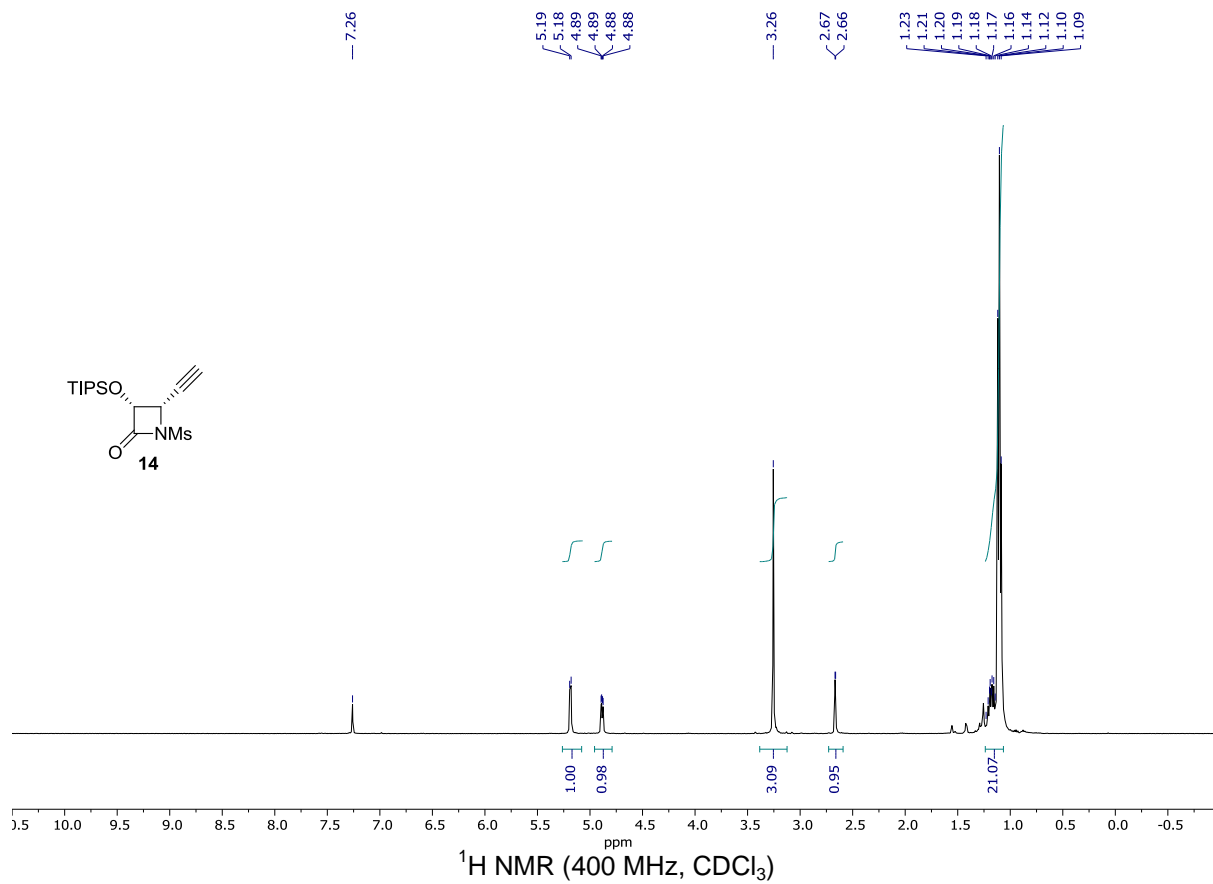


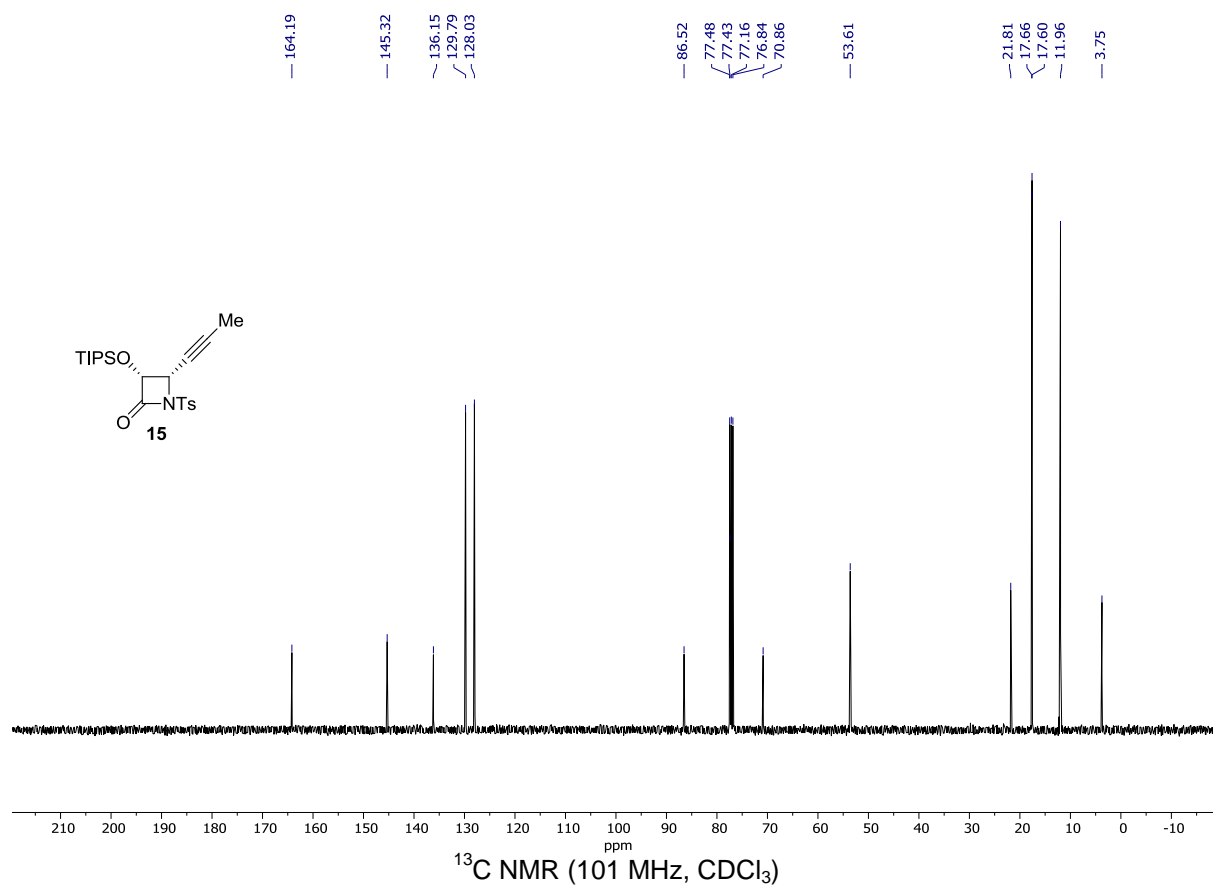
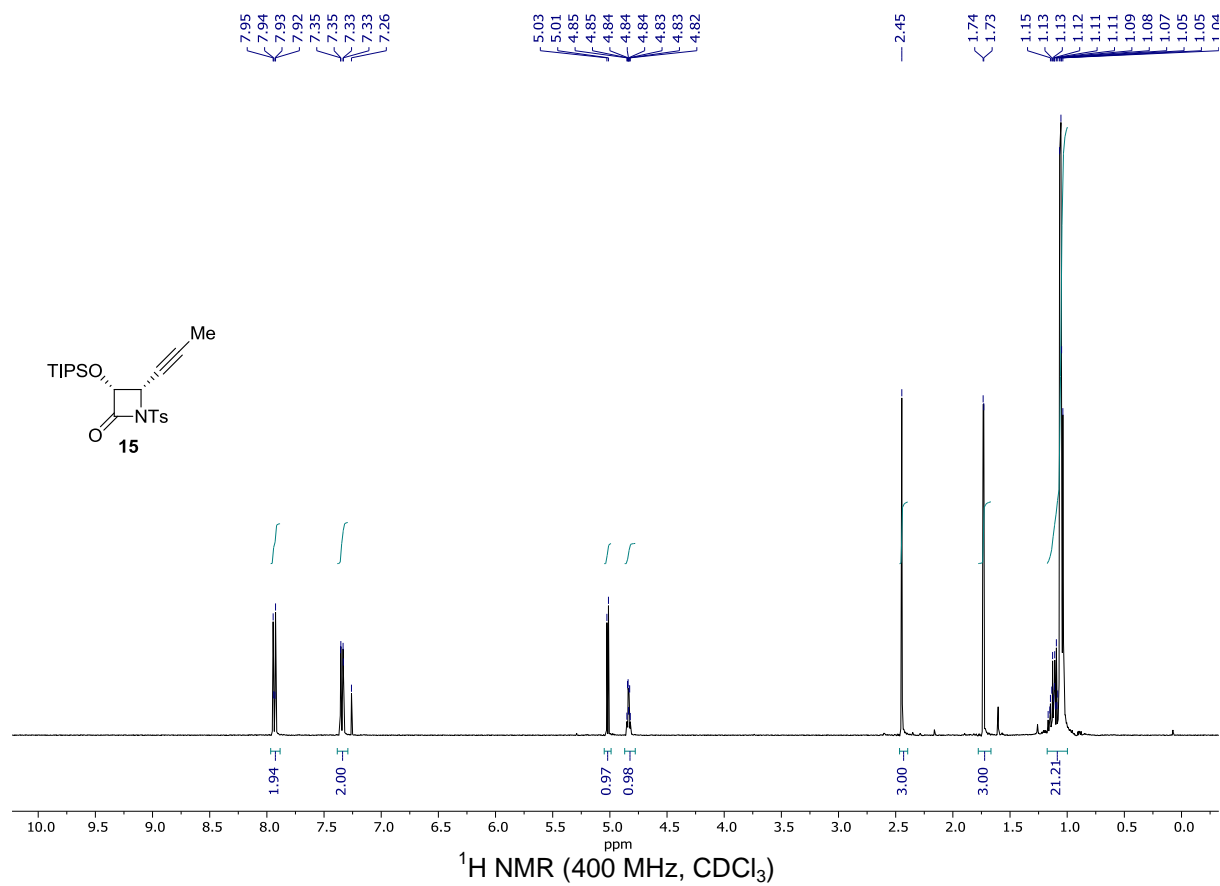


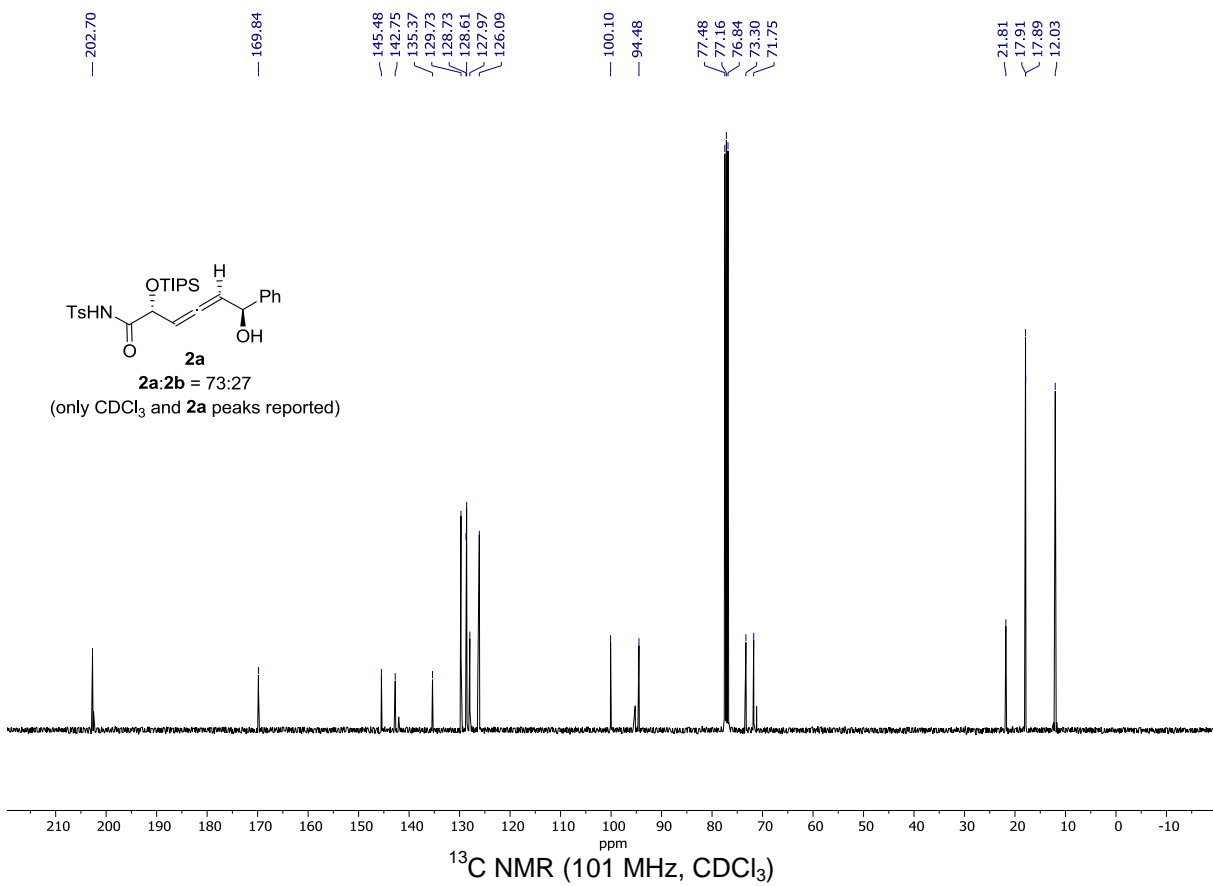
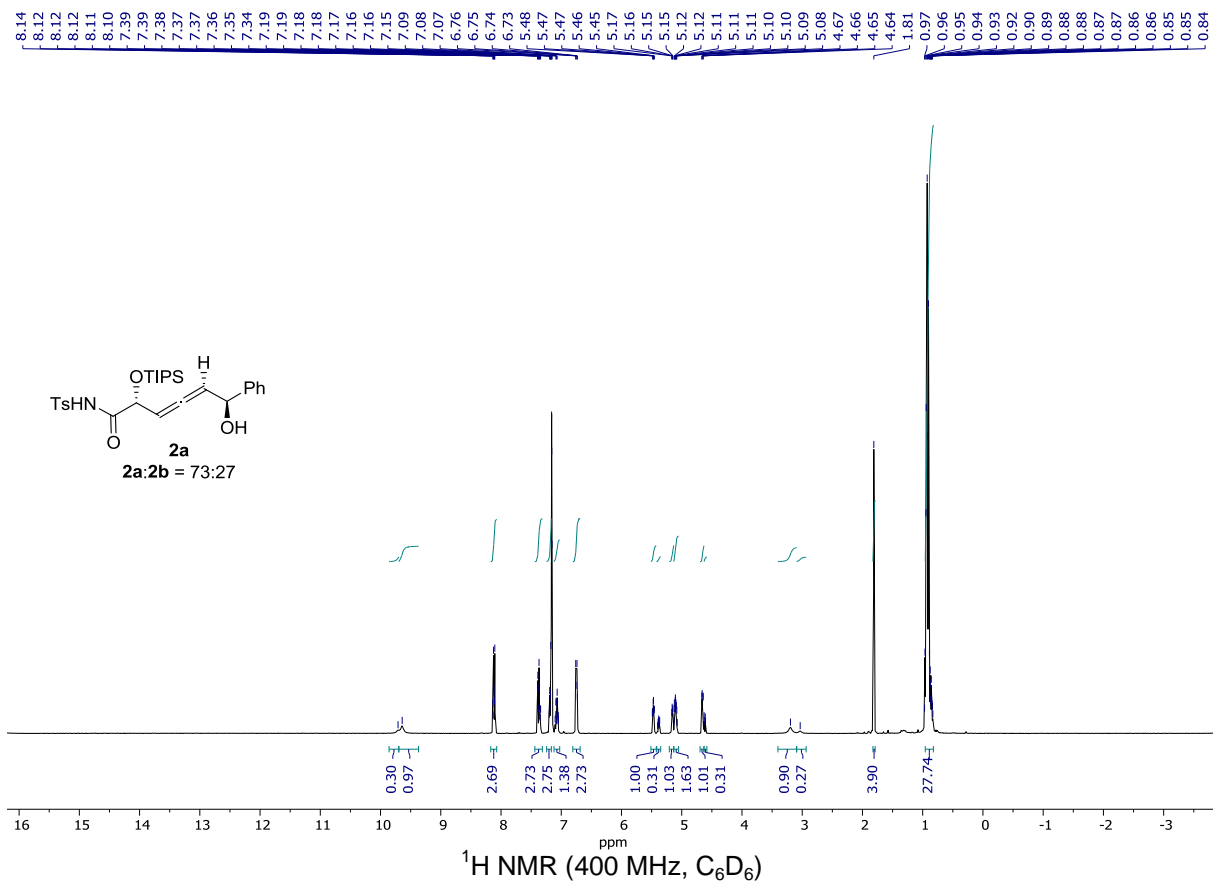
$^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )

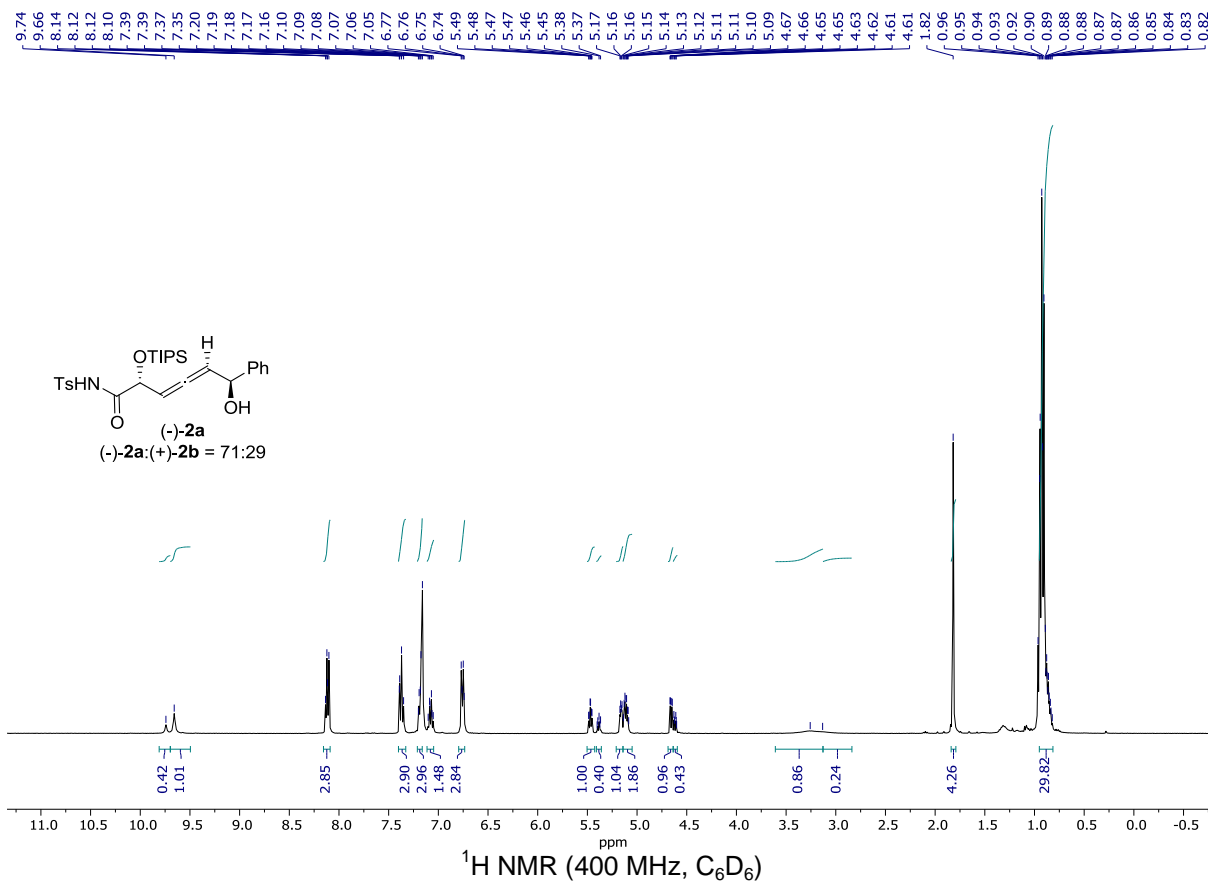


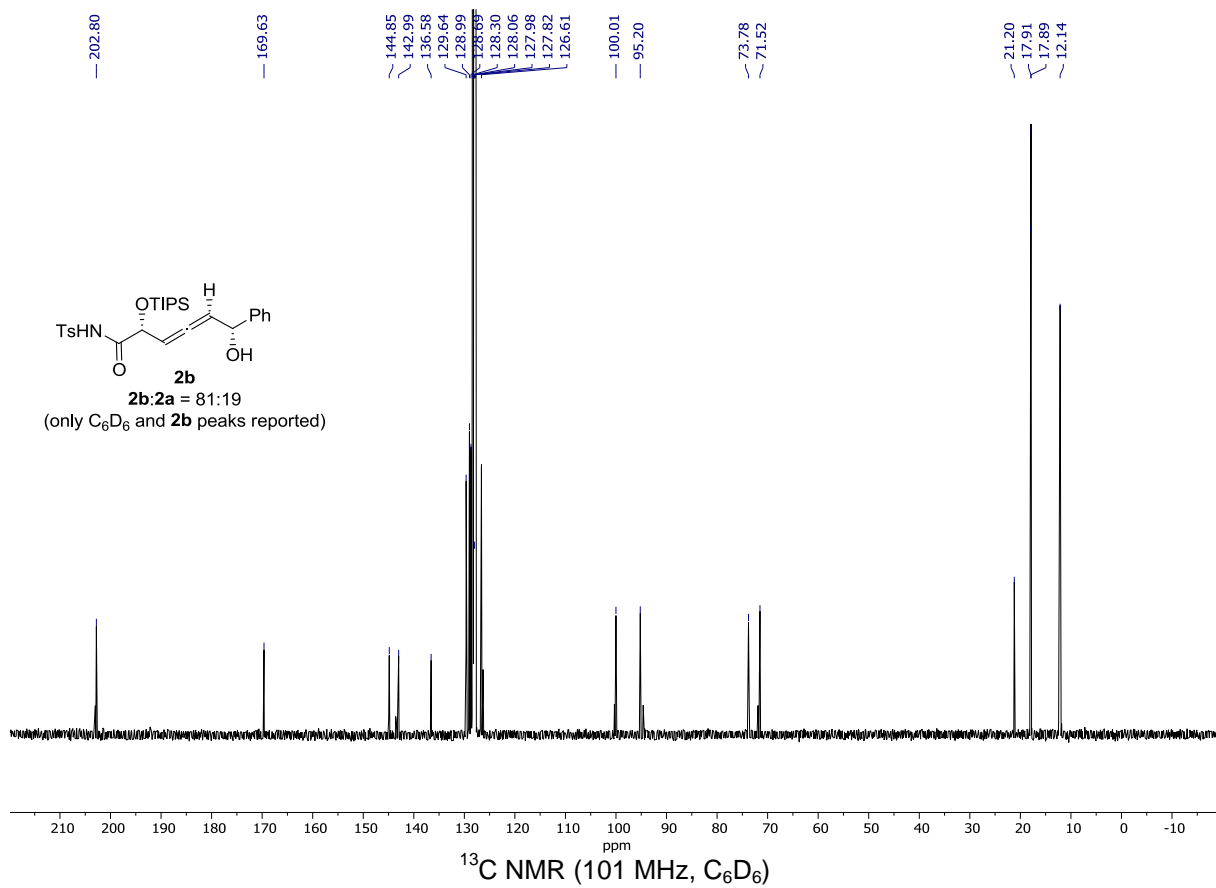
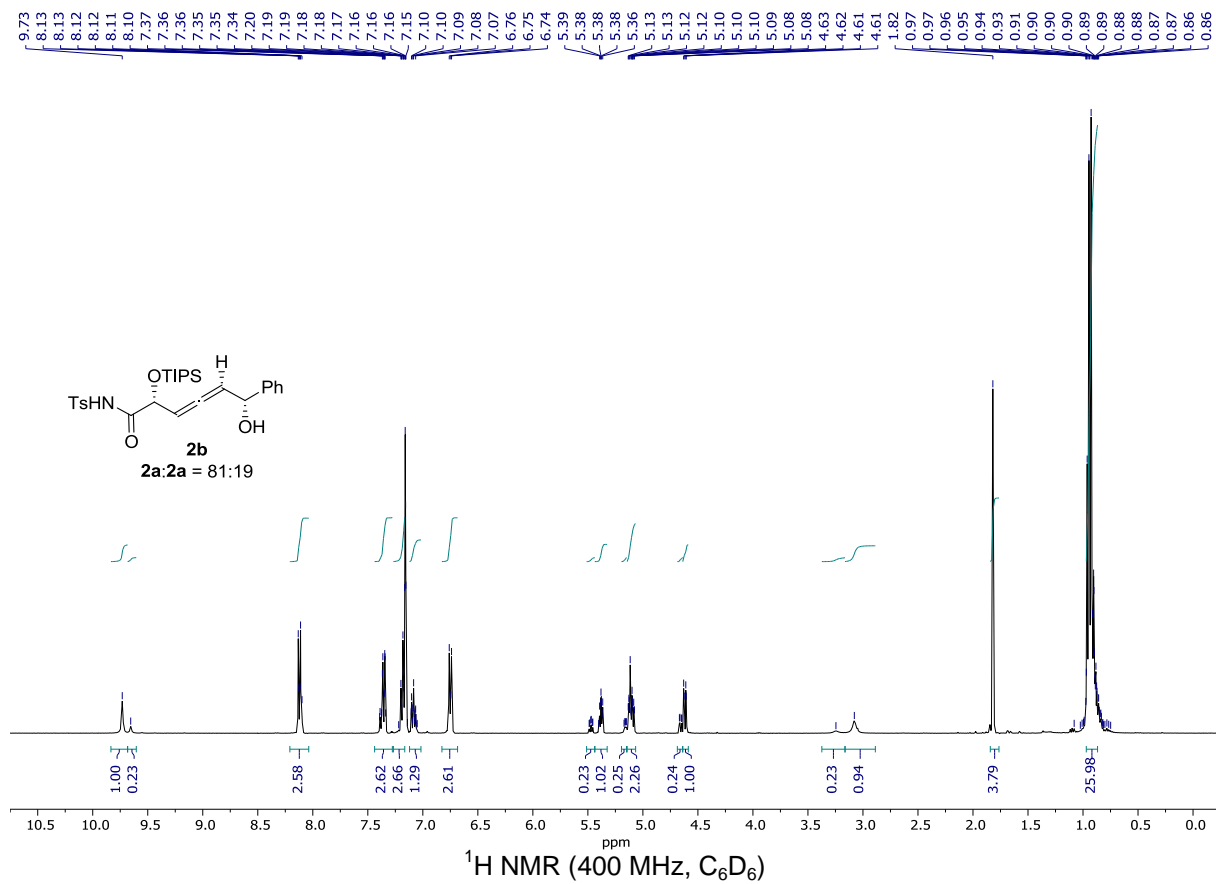


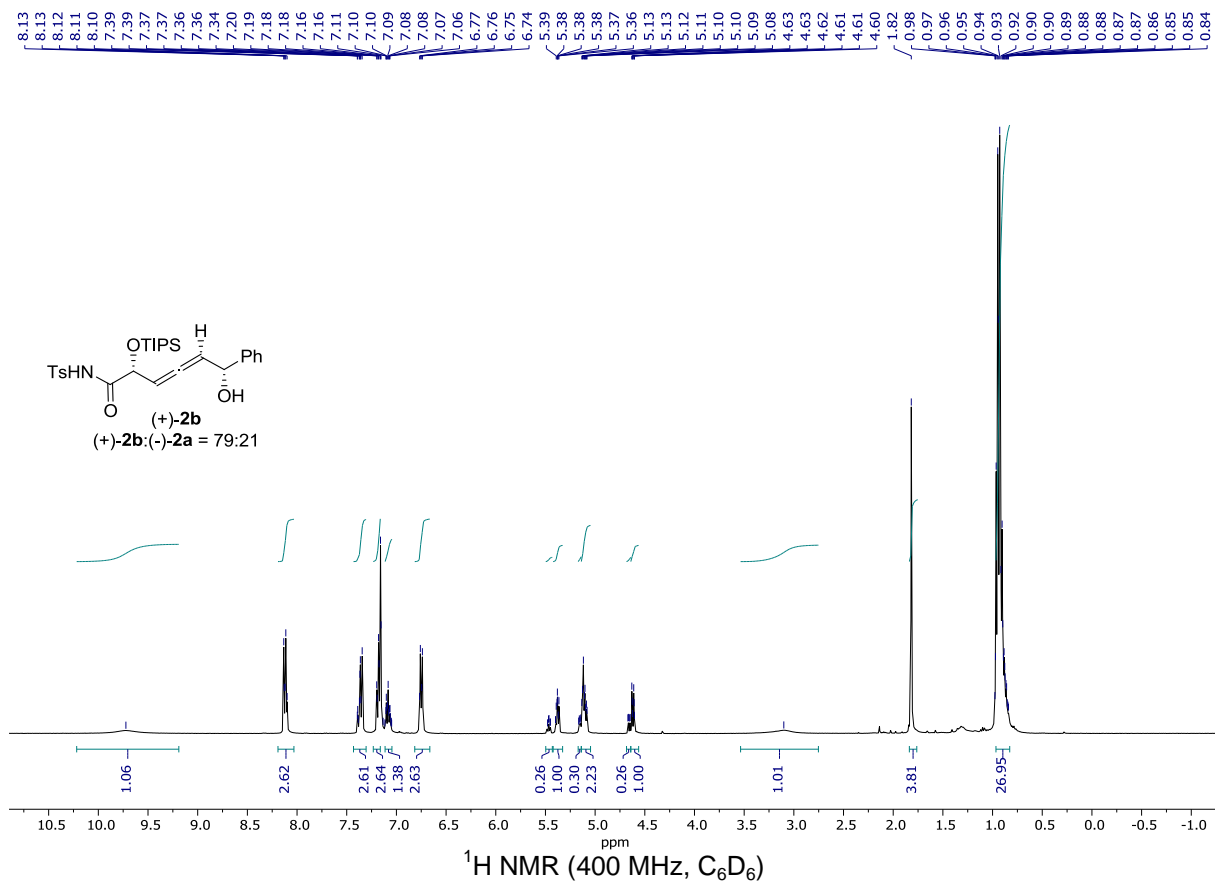


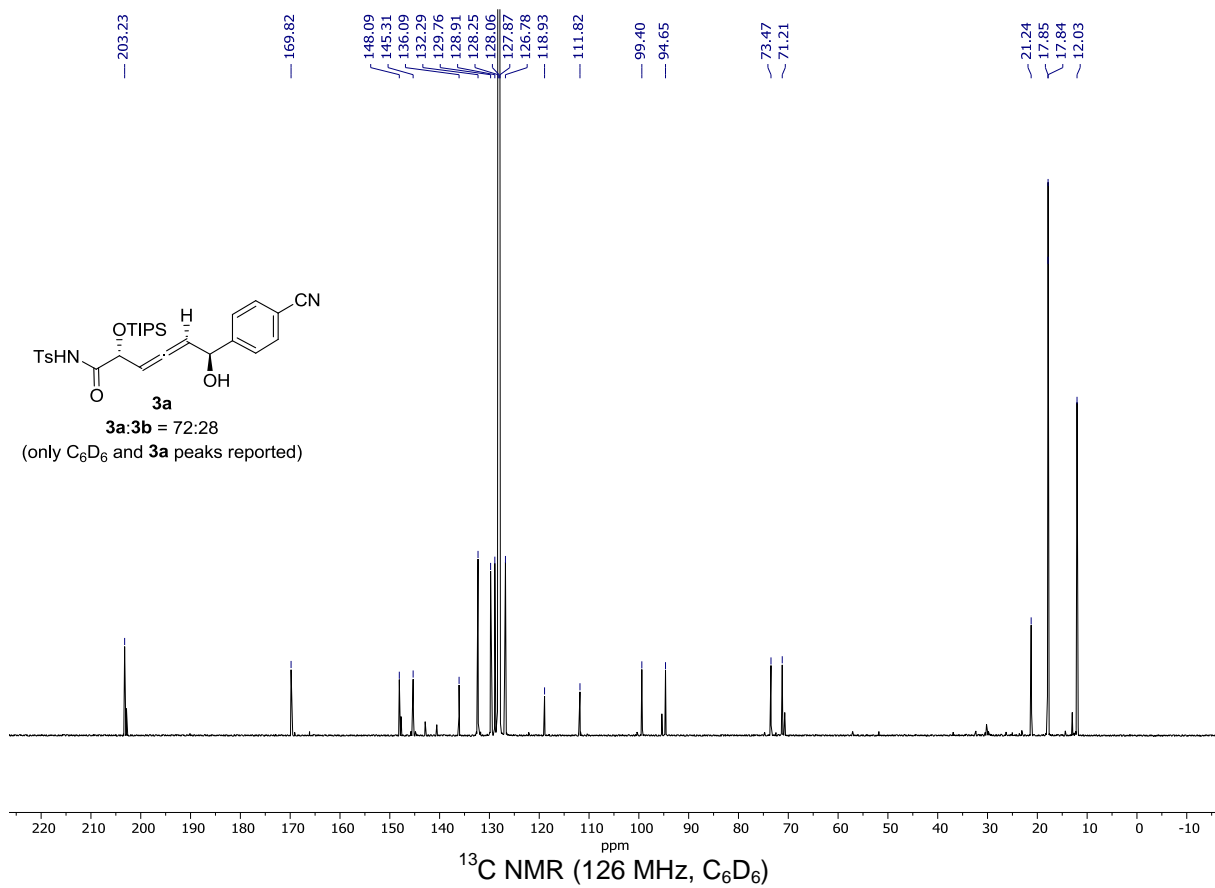
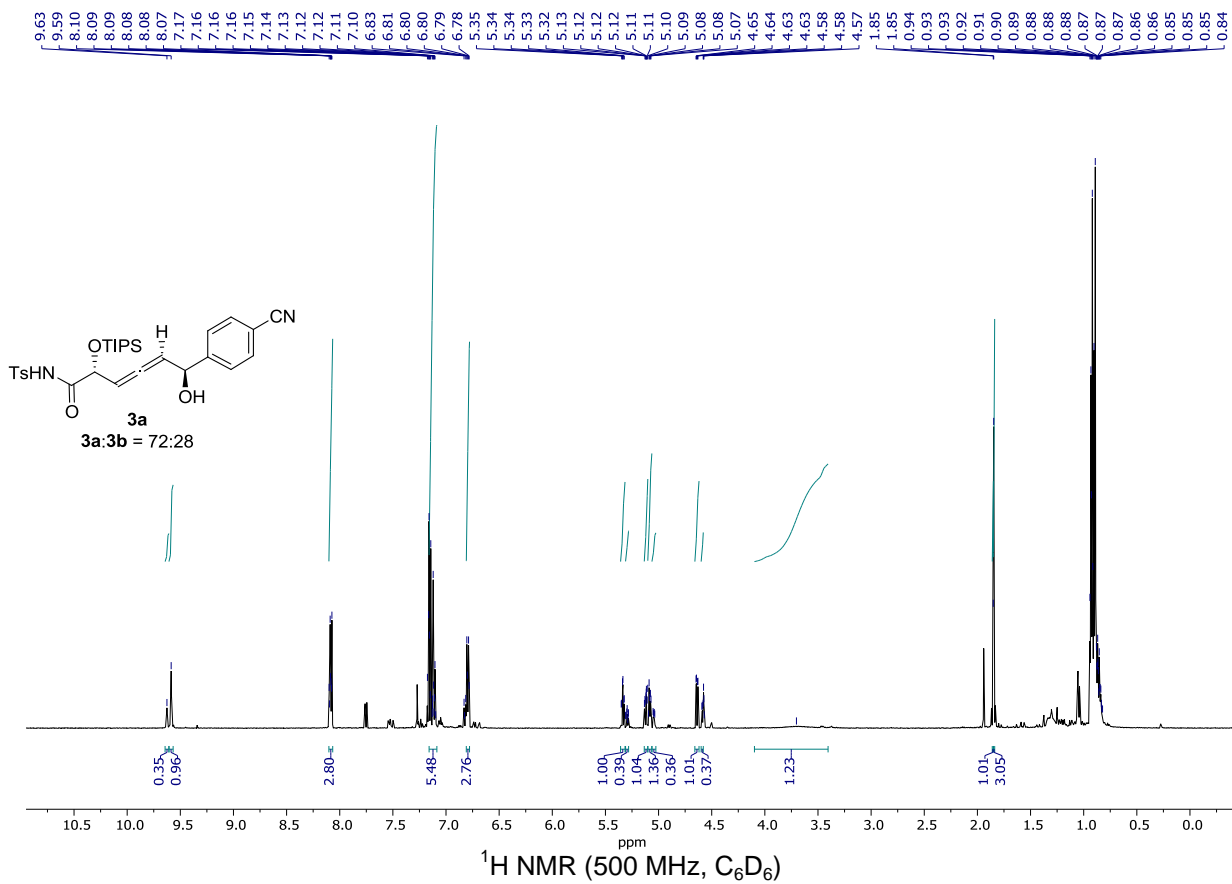




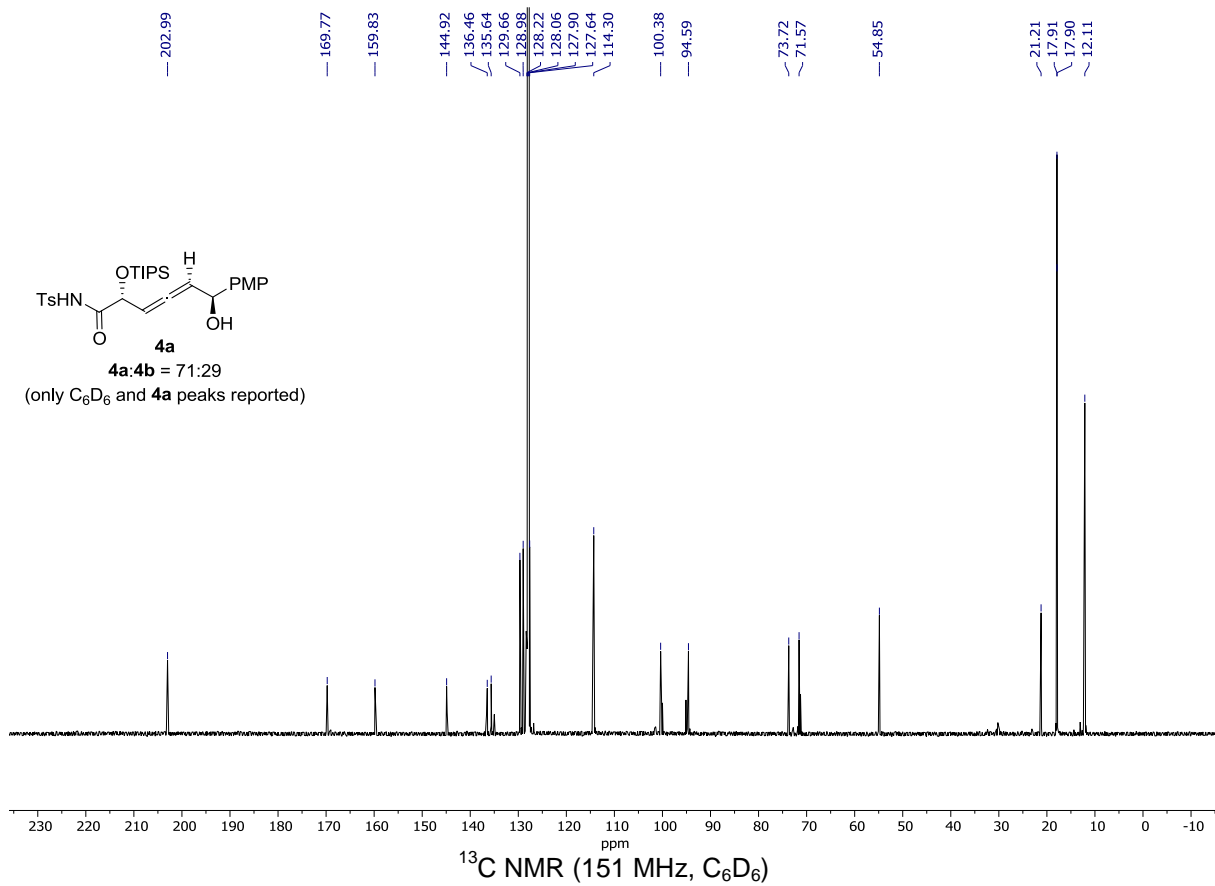
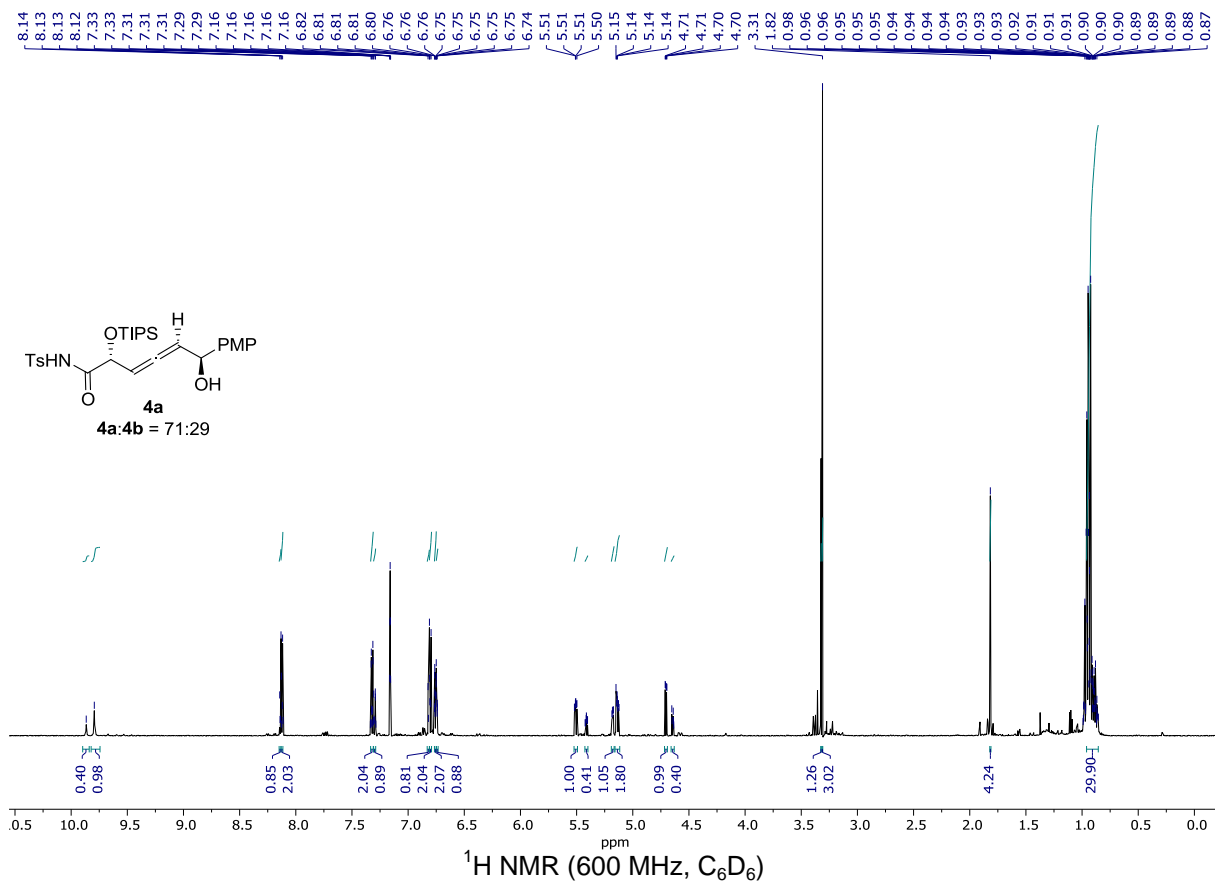




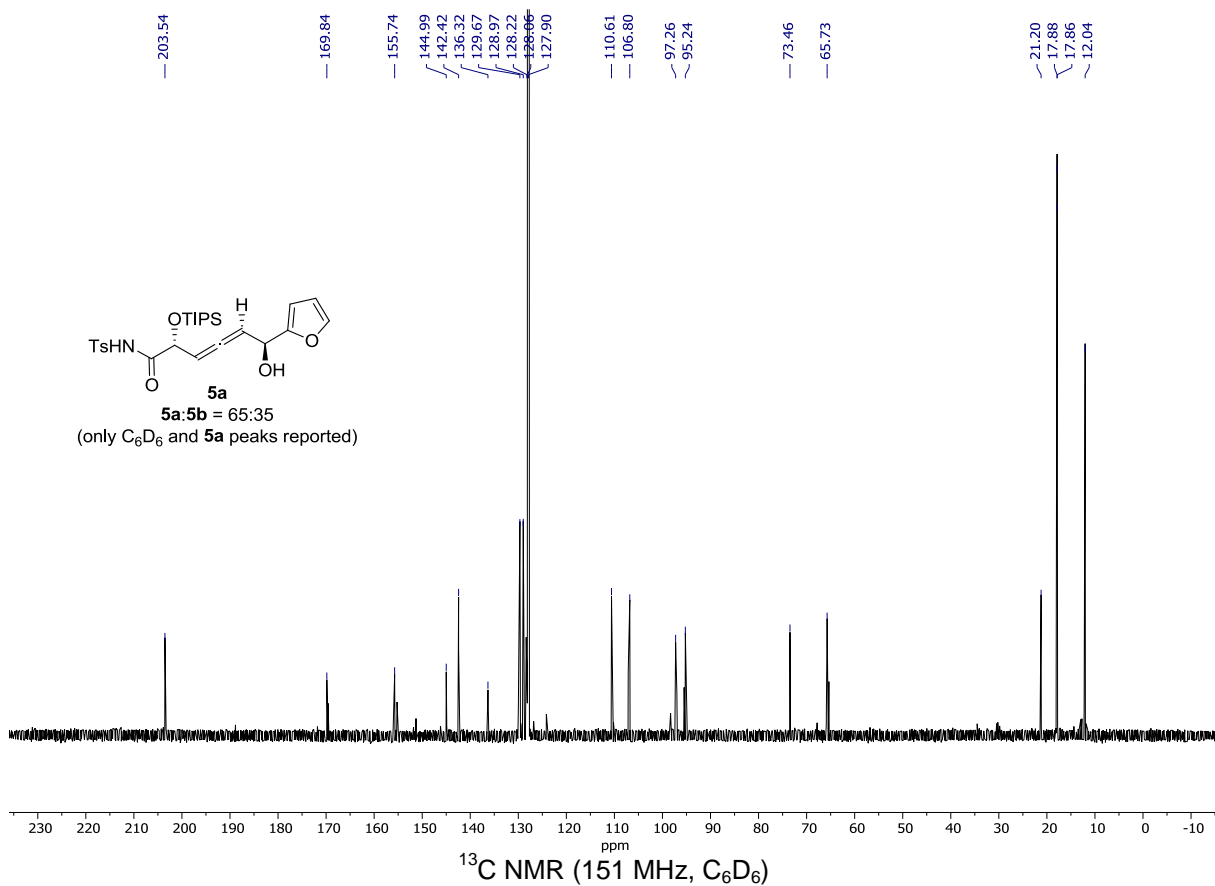
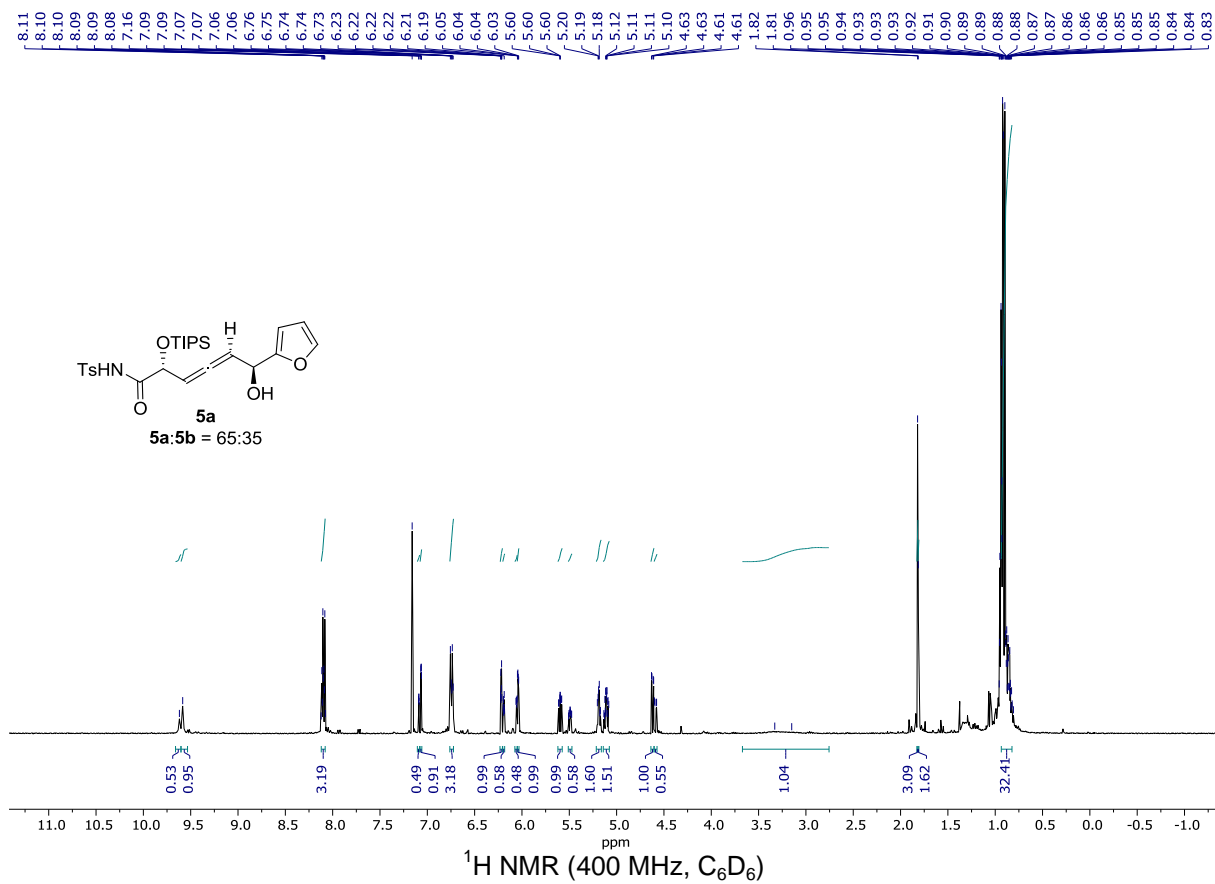


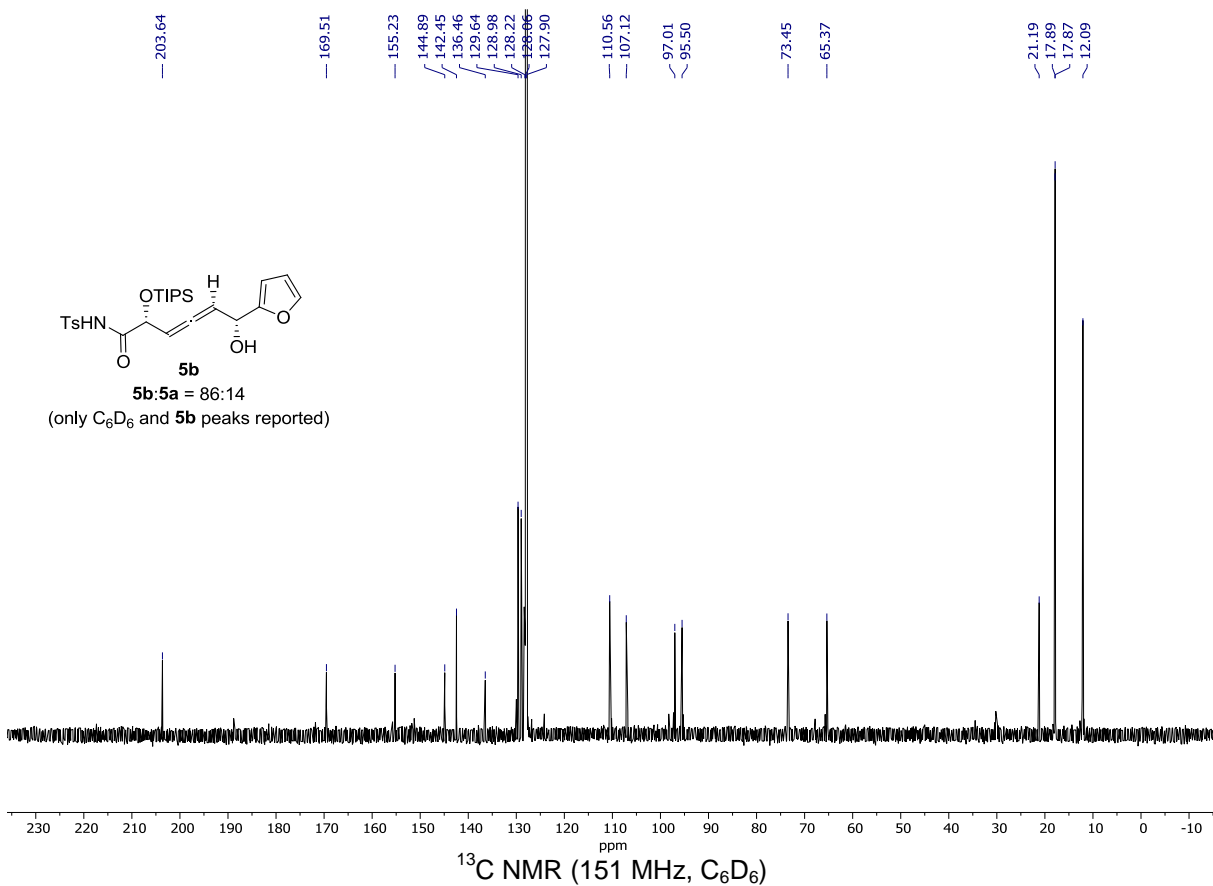
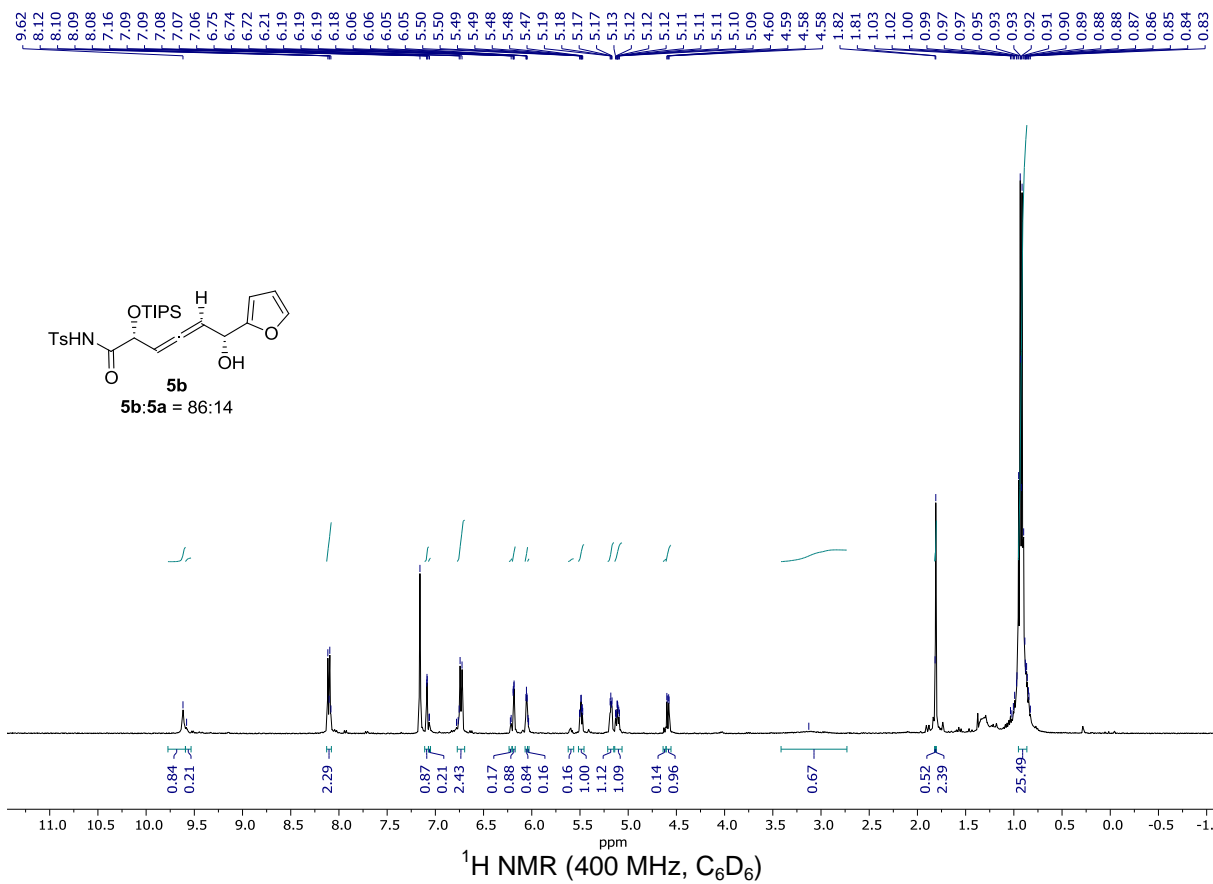


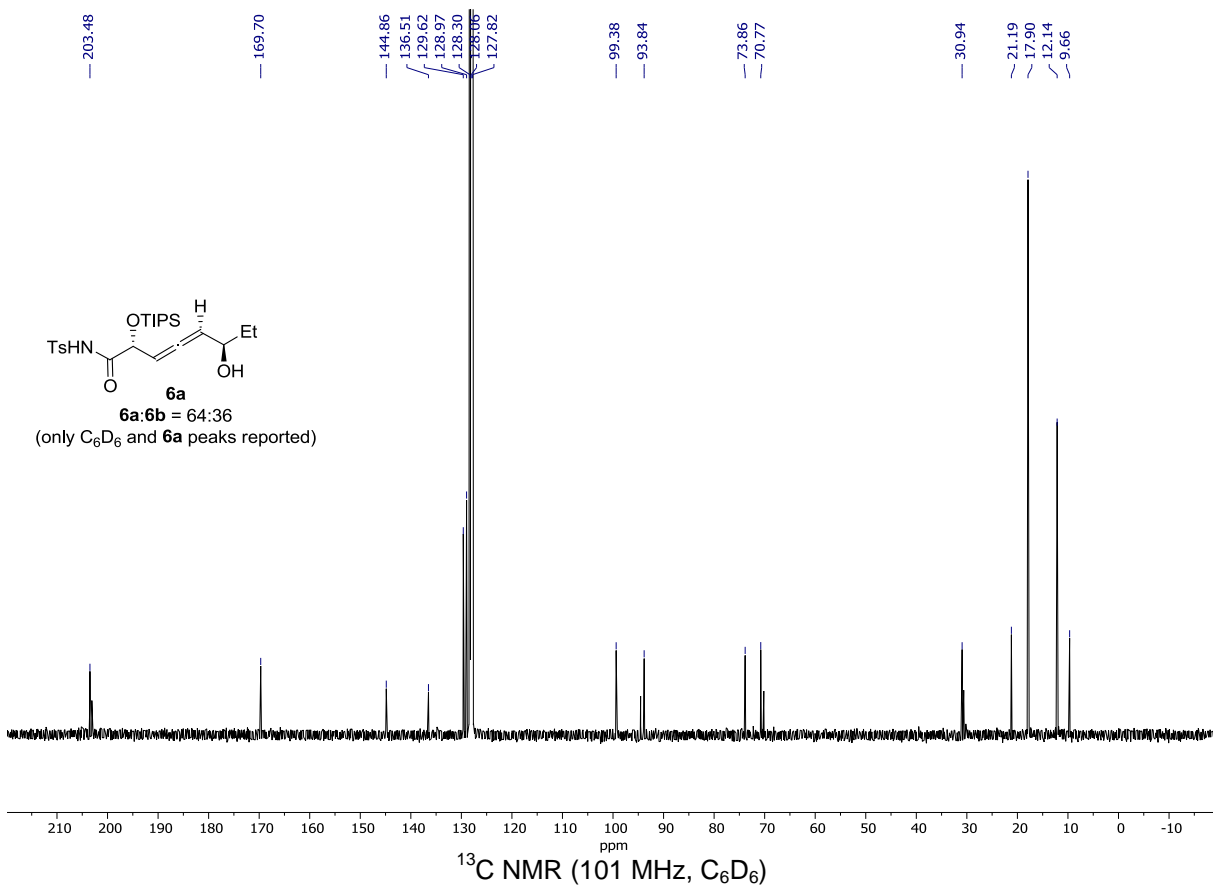
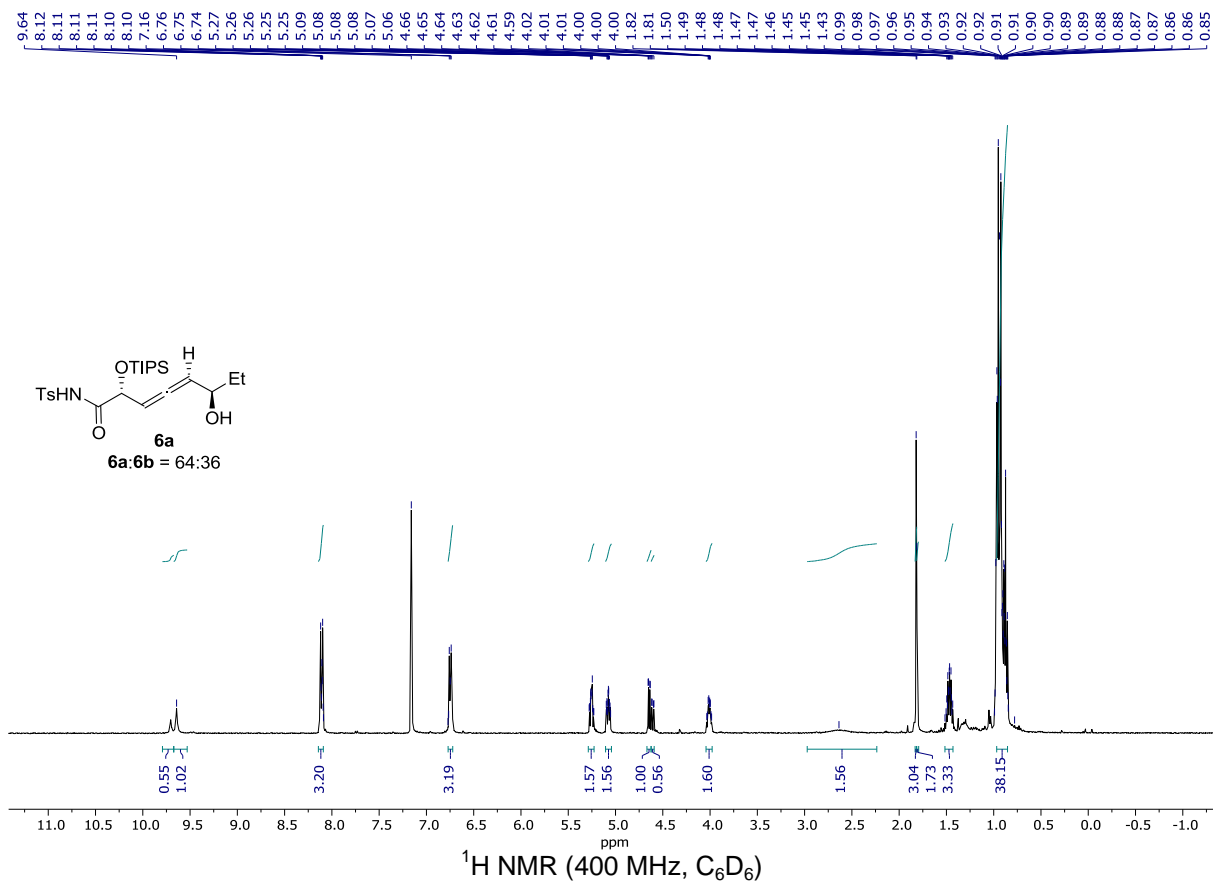


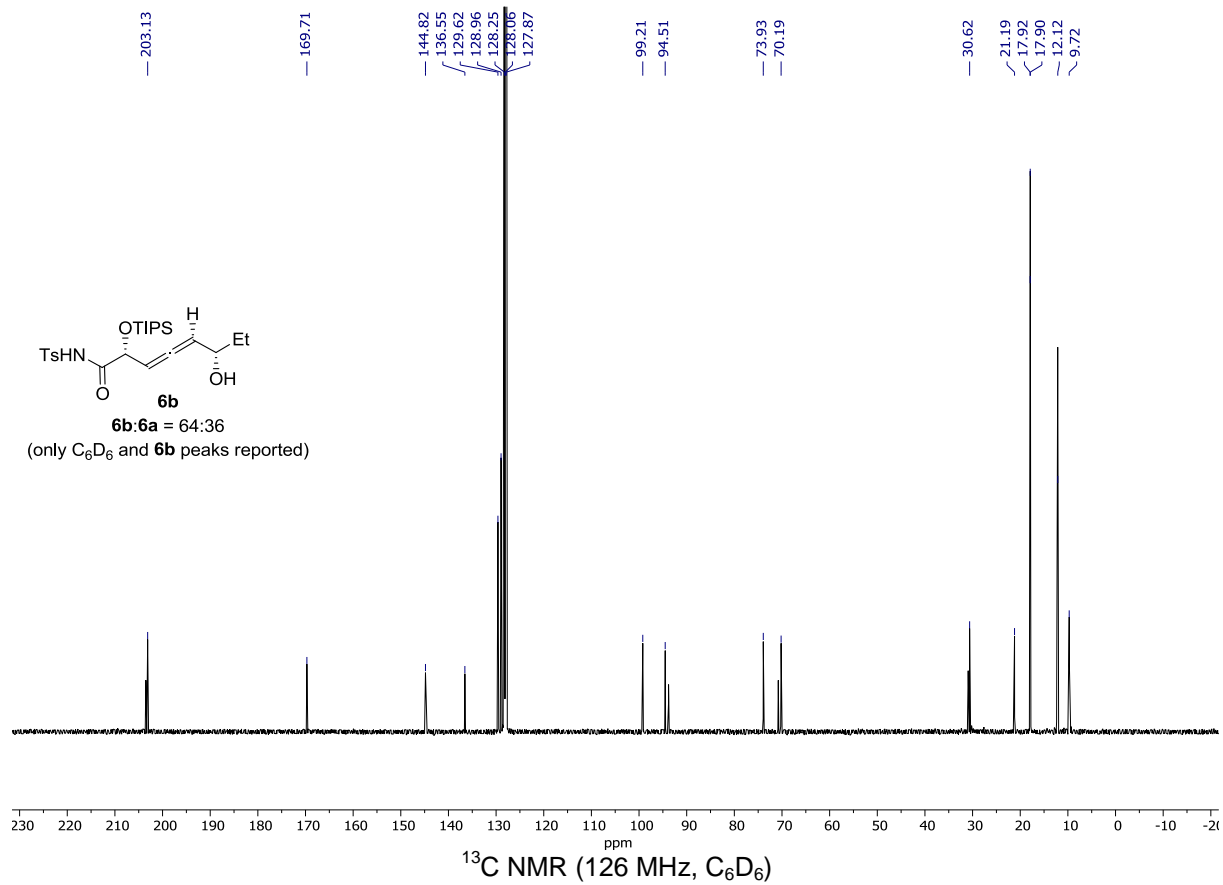
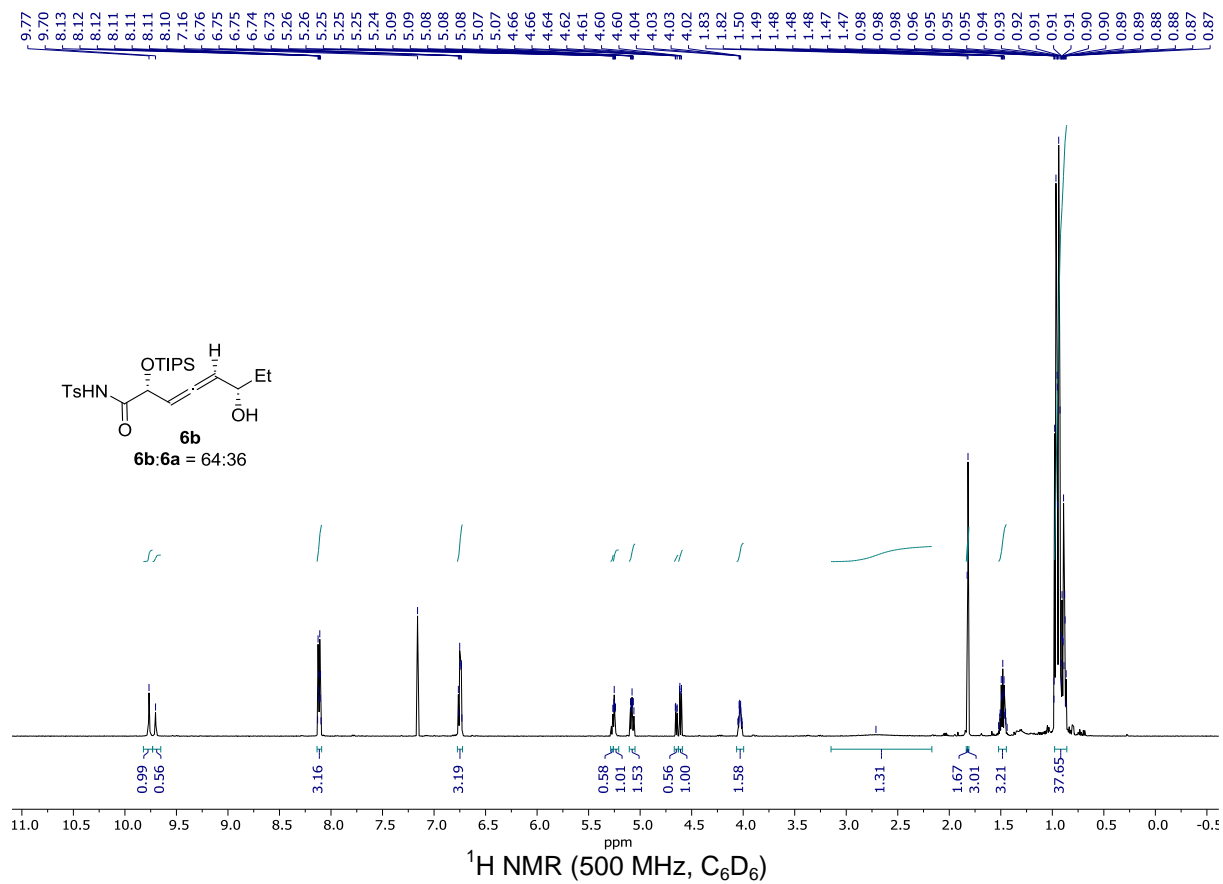


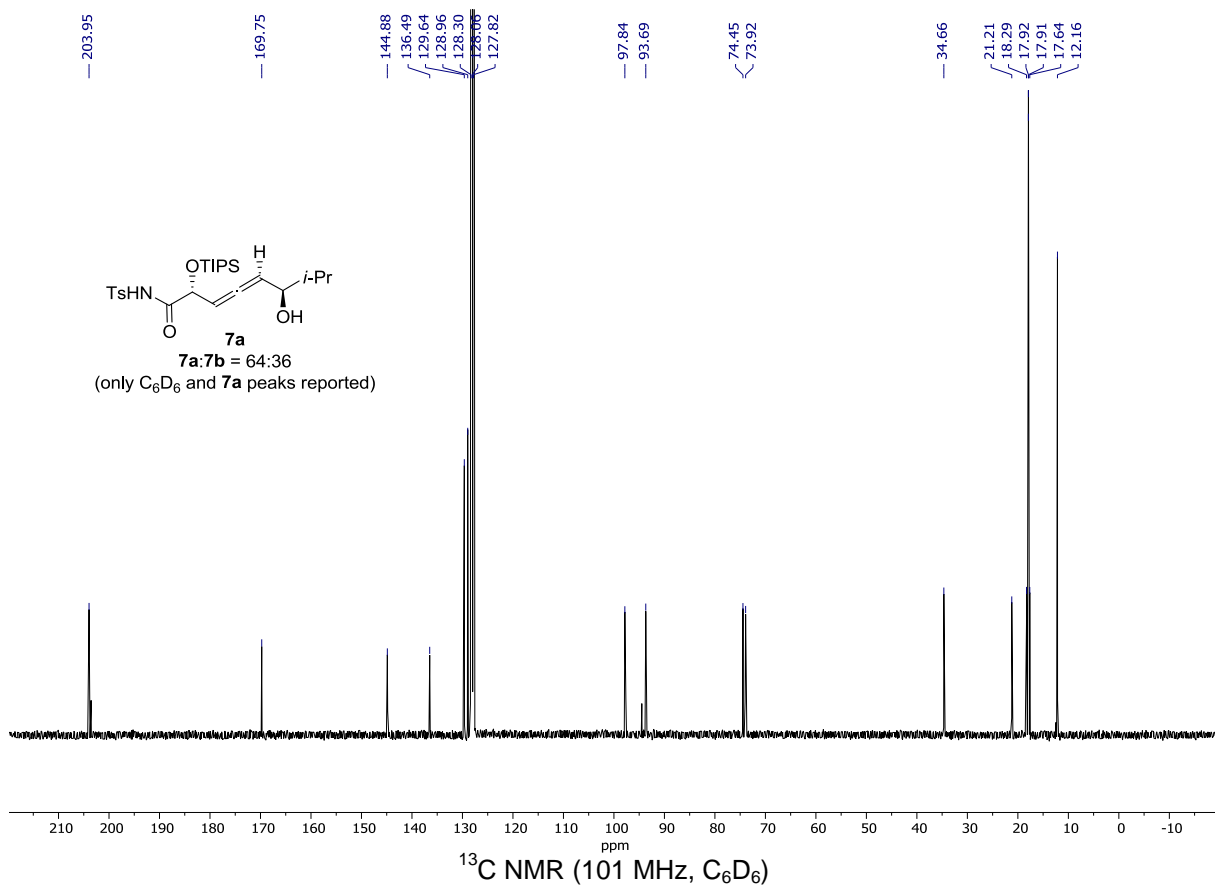
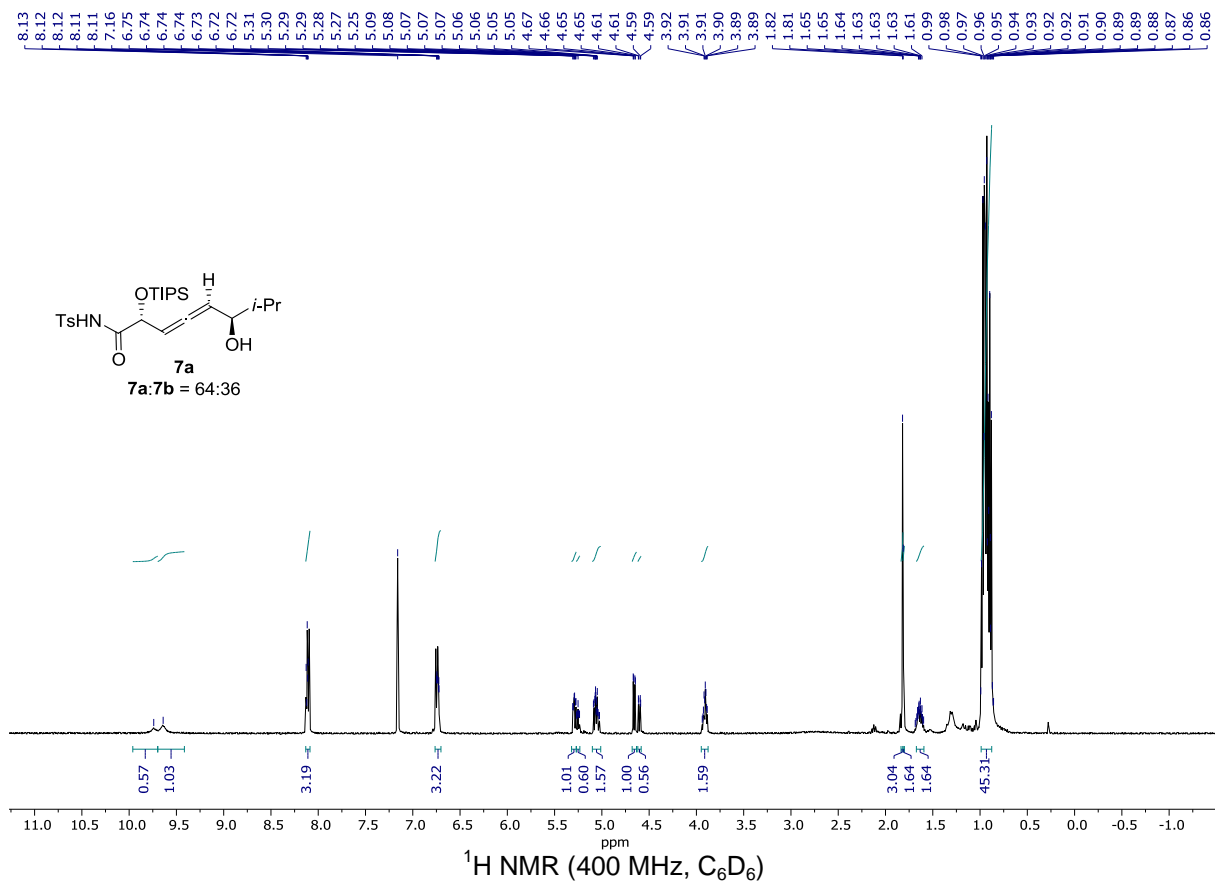


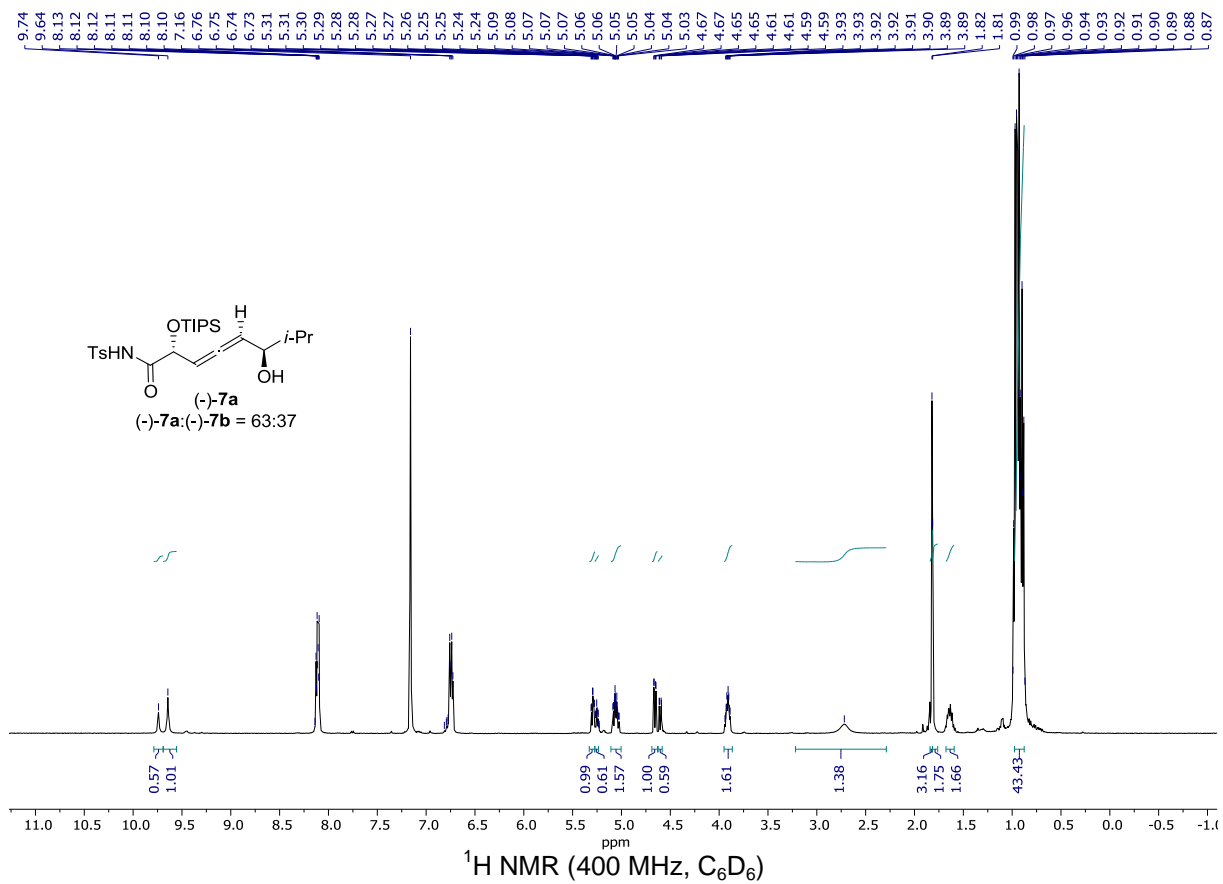


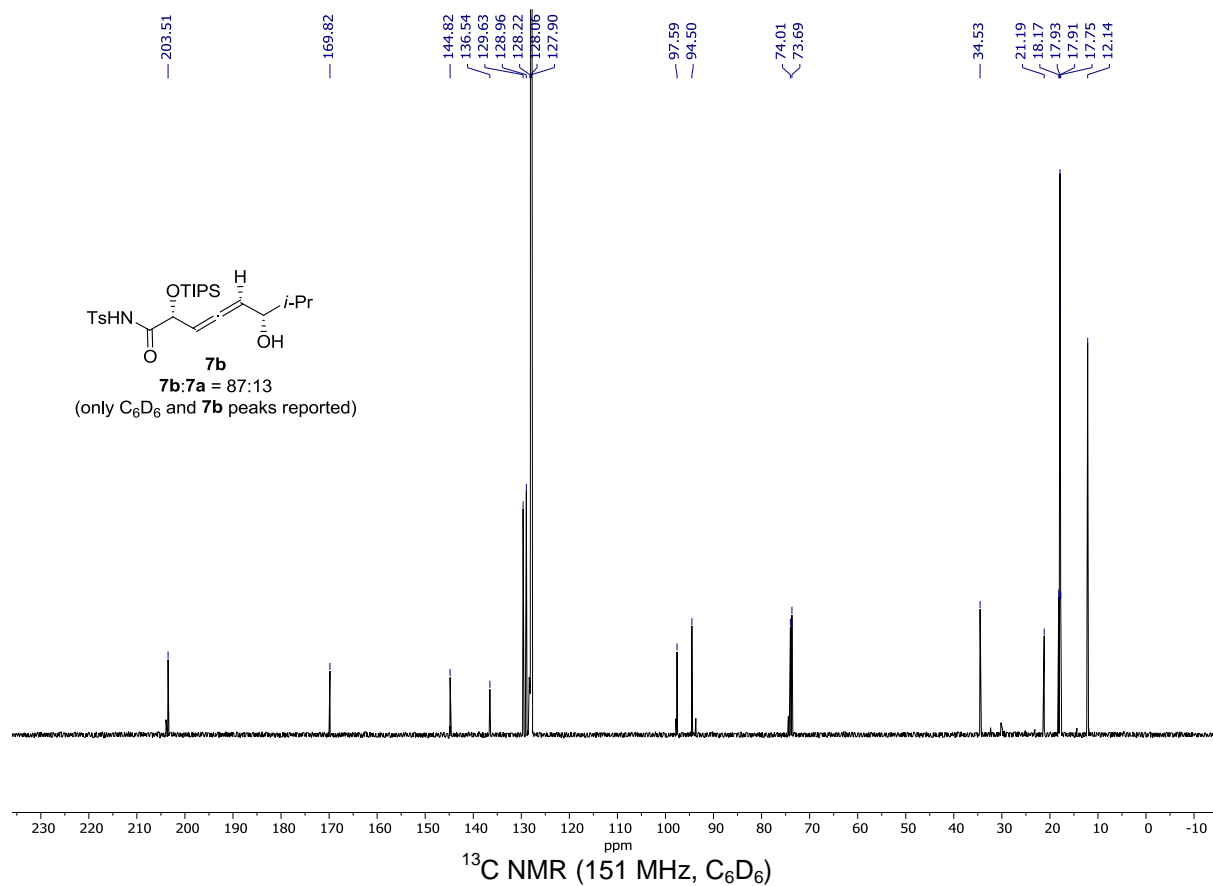
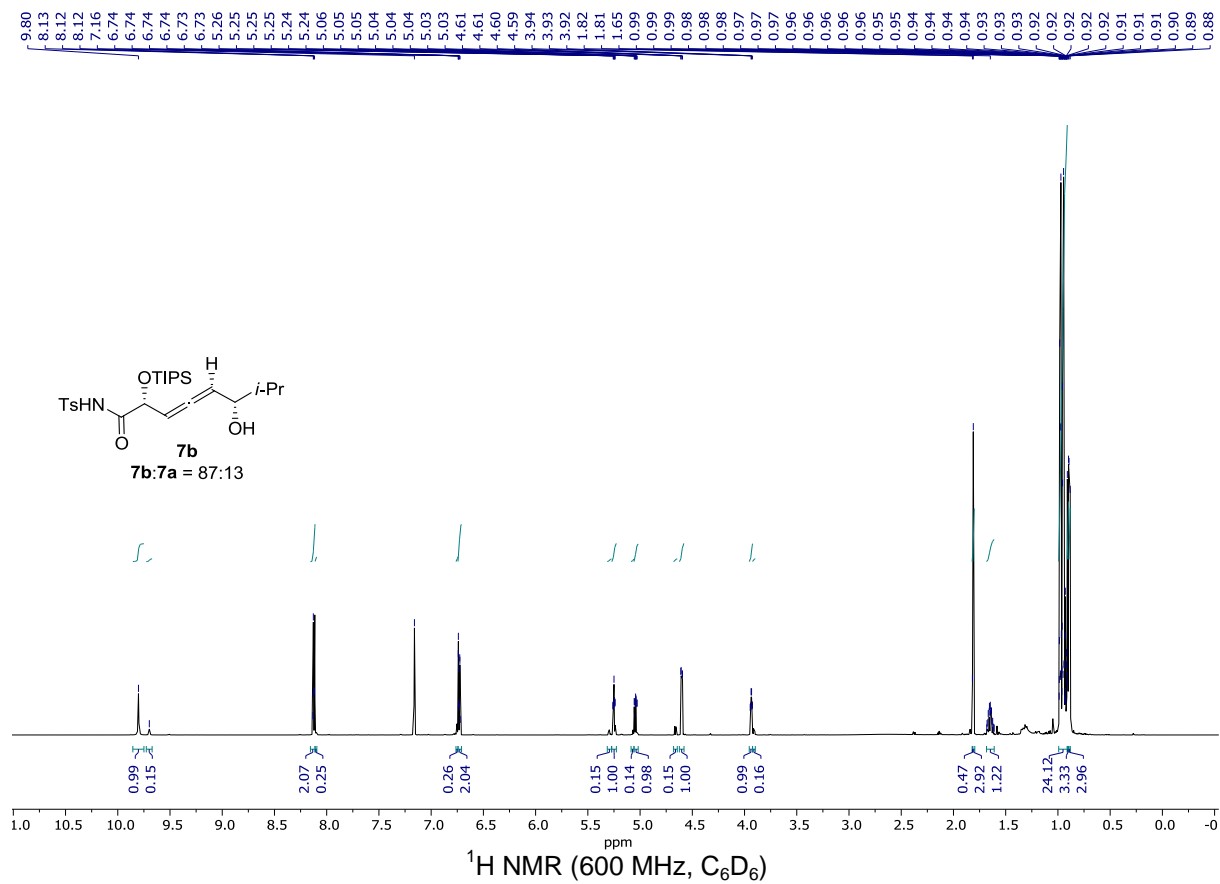


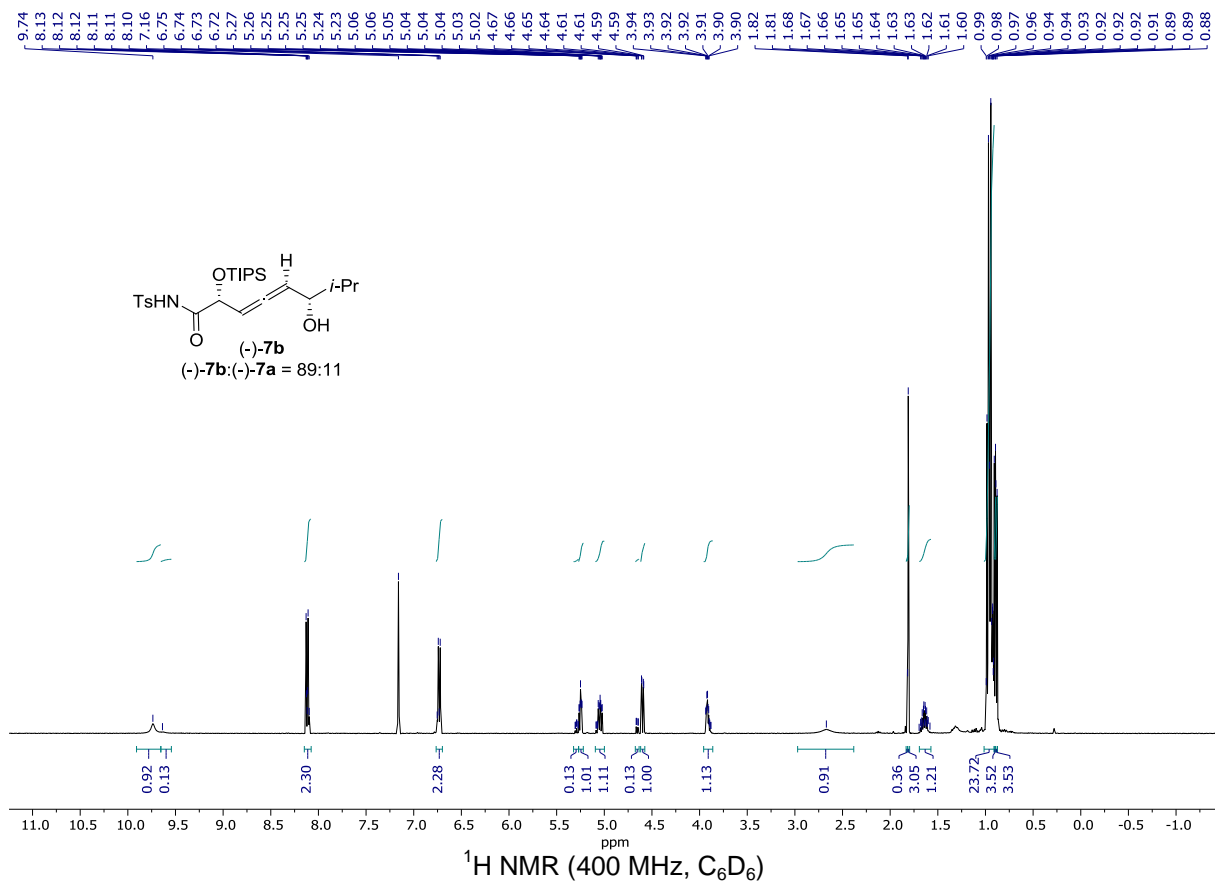


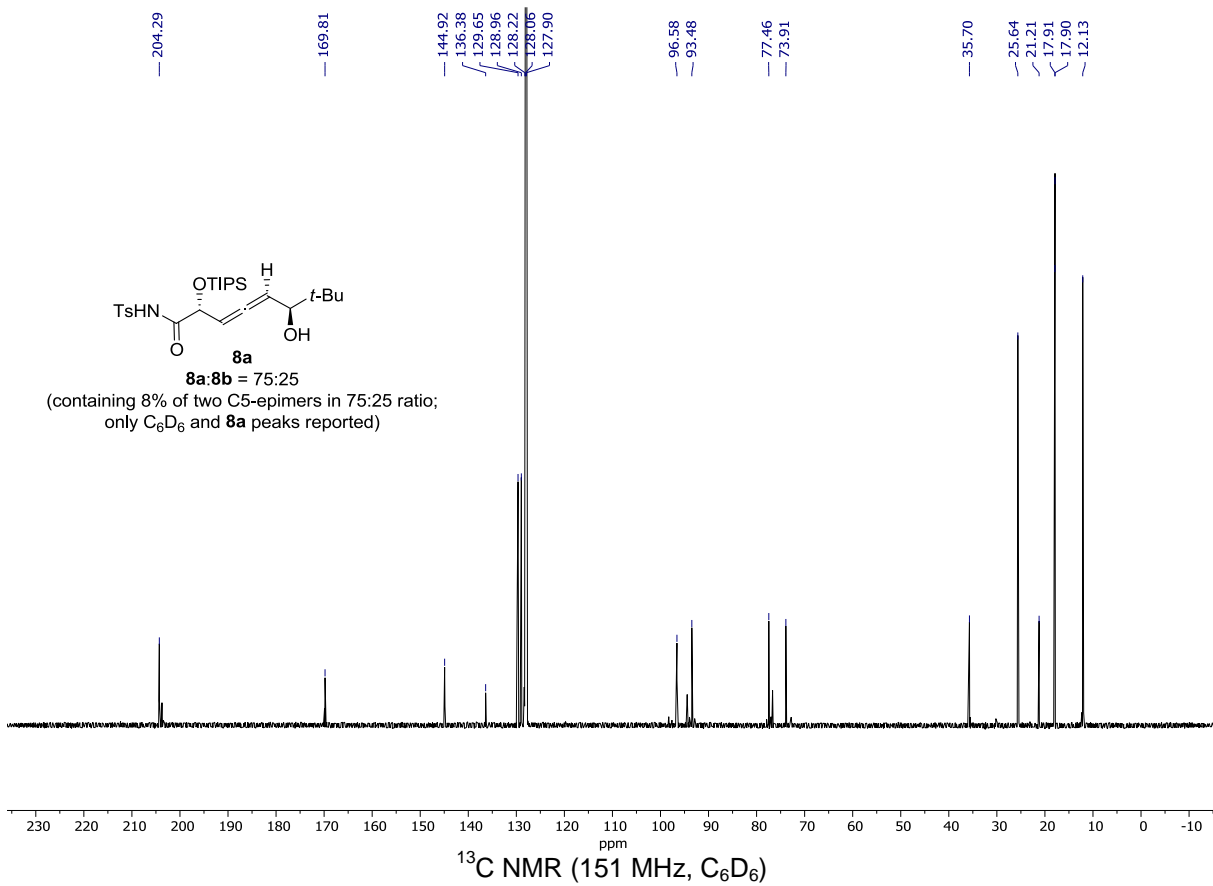
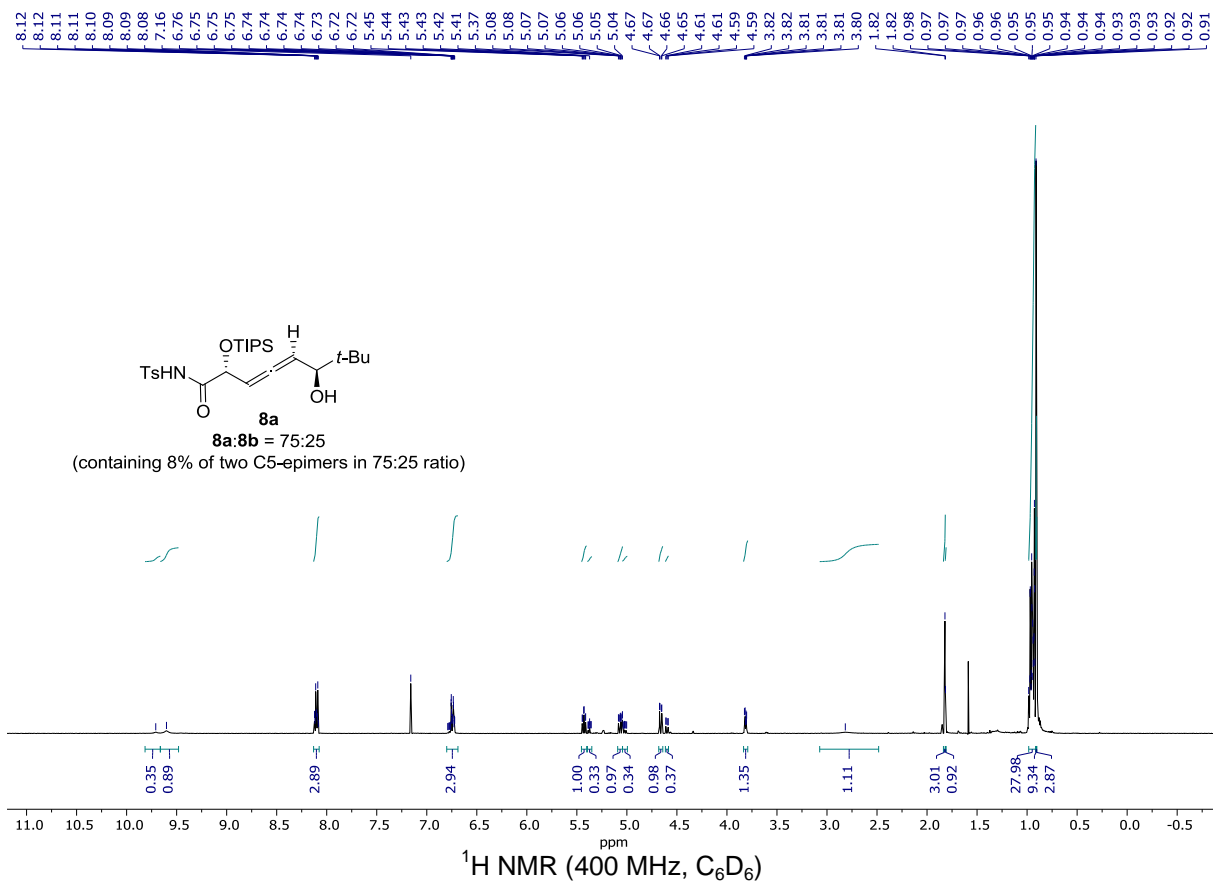


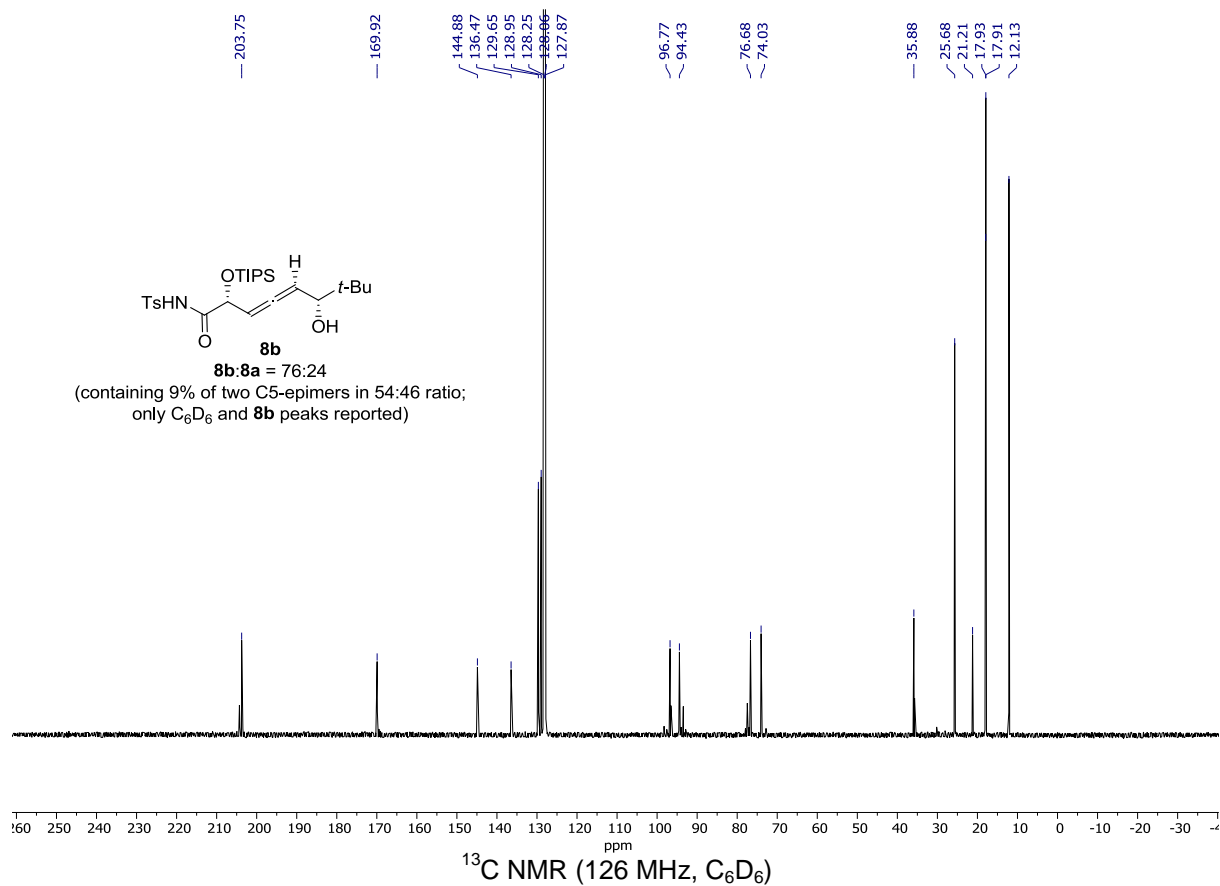
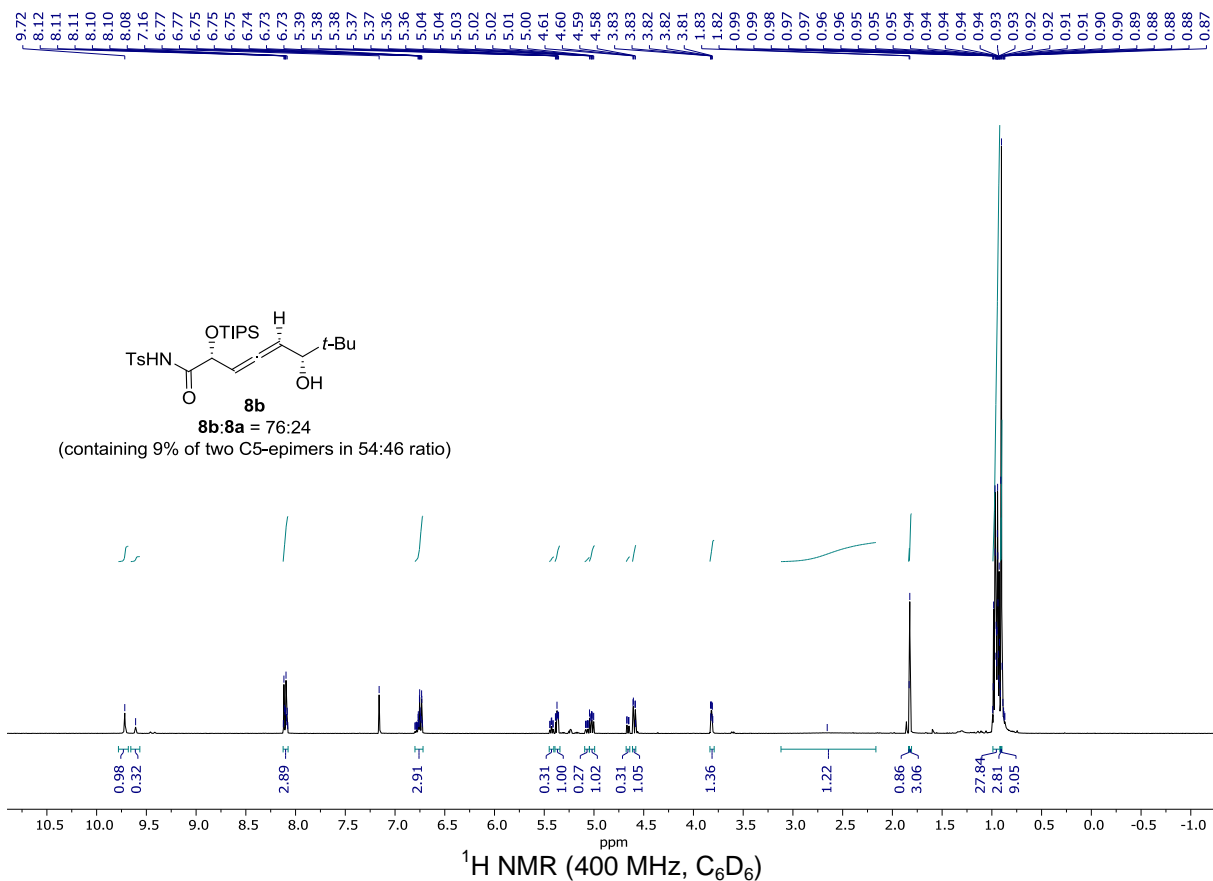


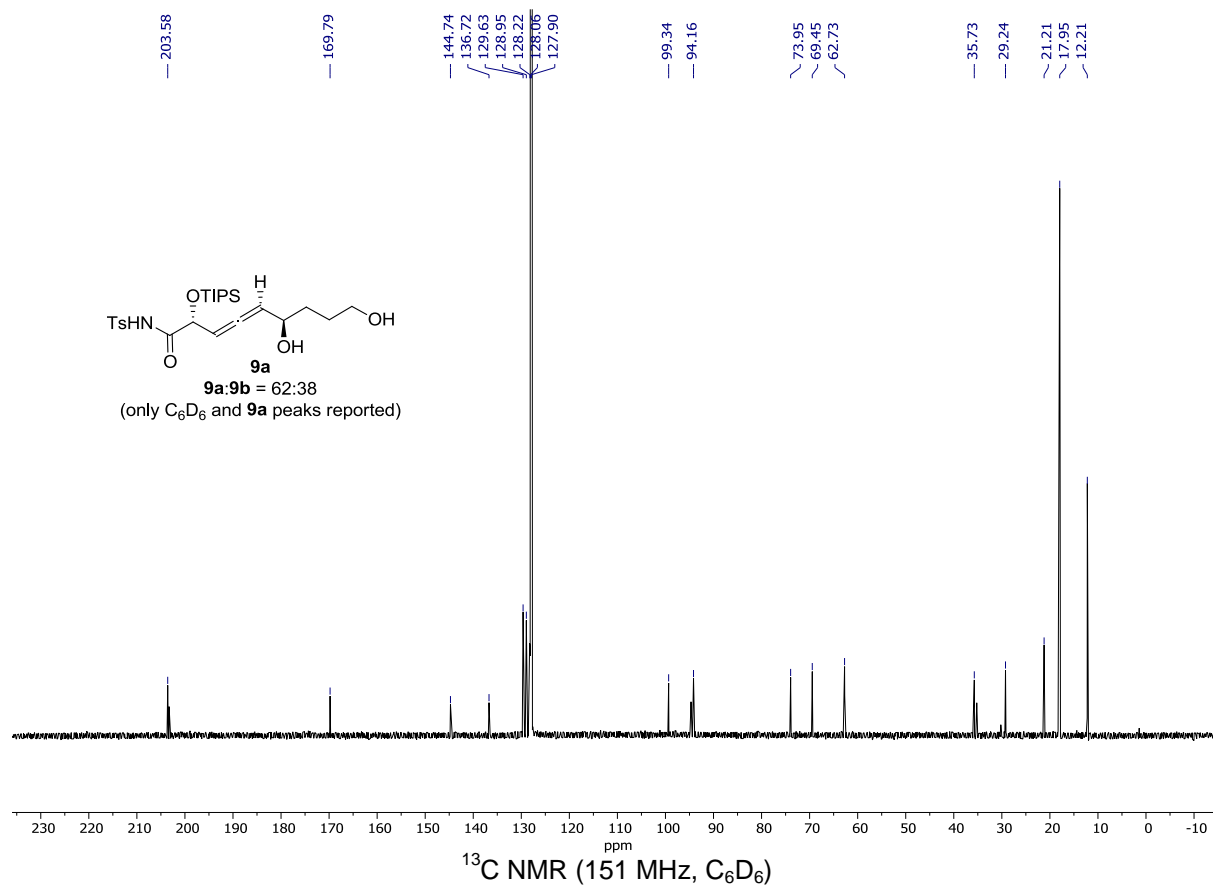
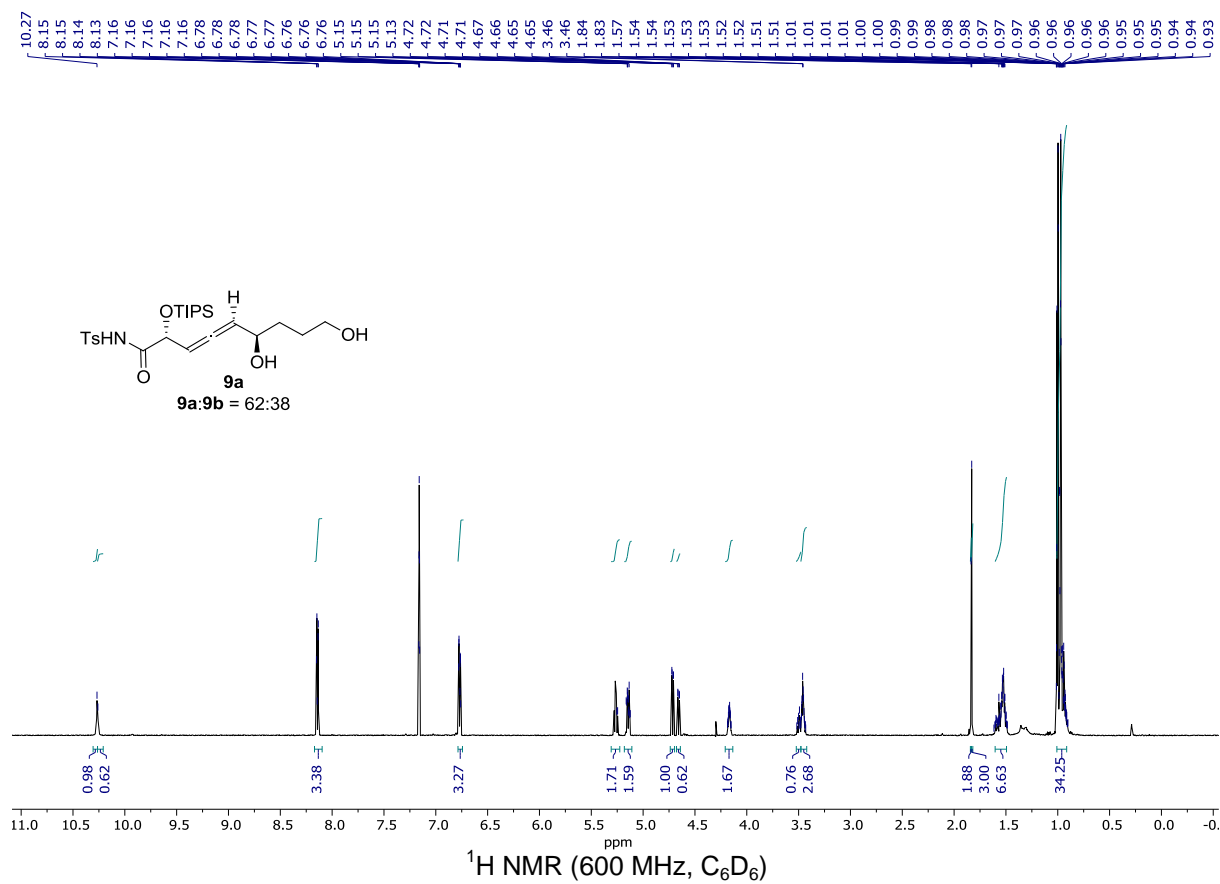


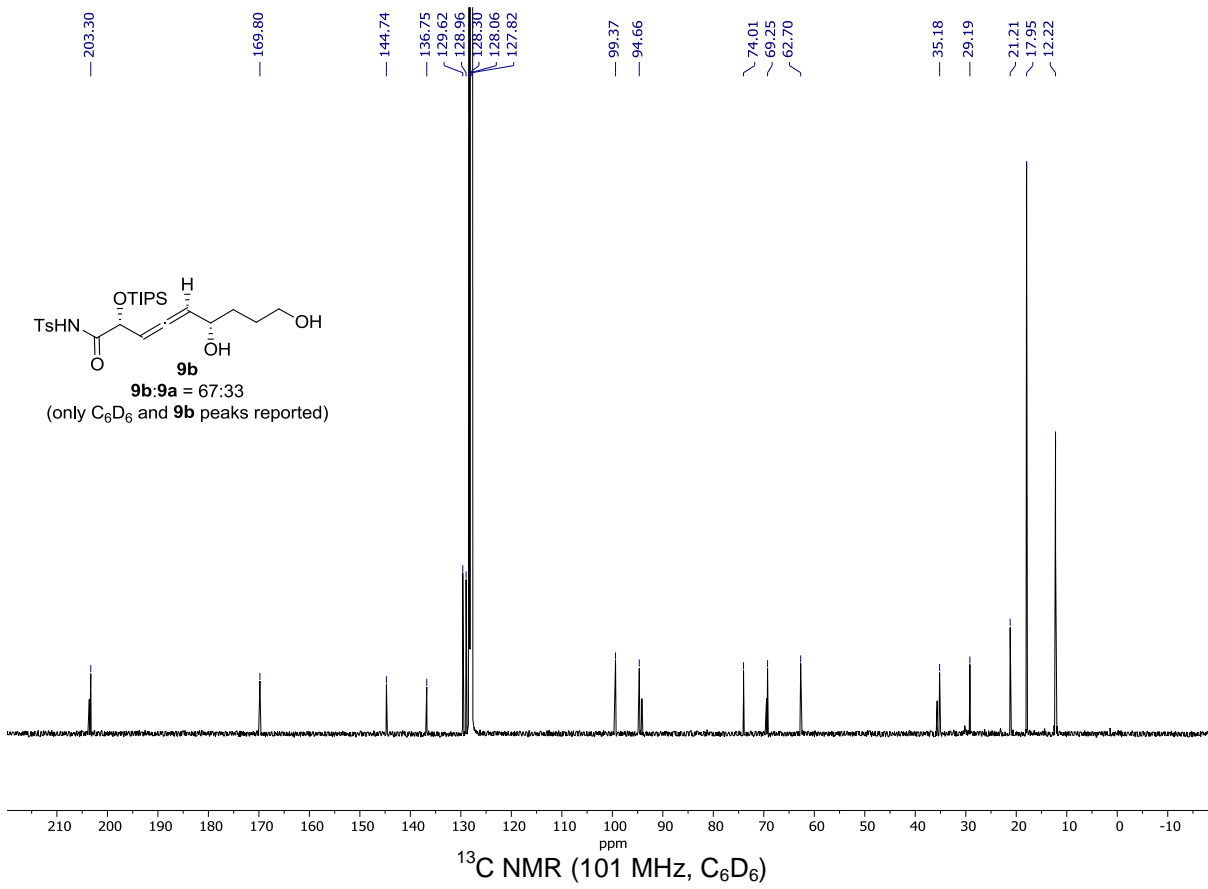
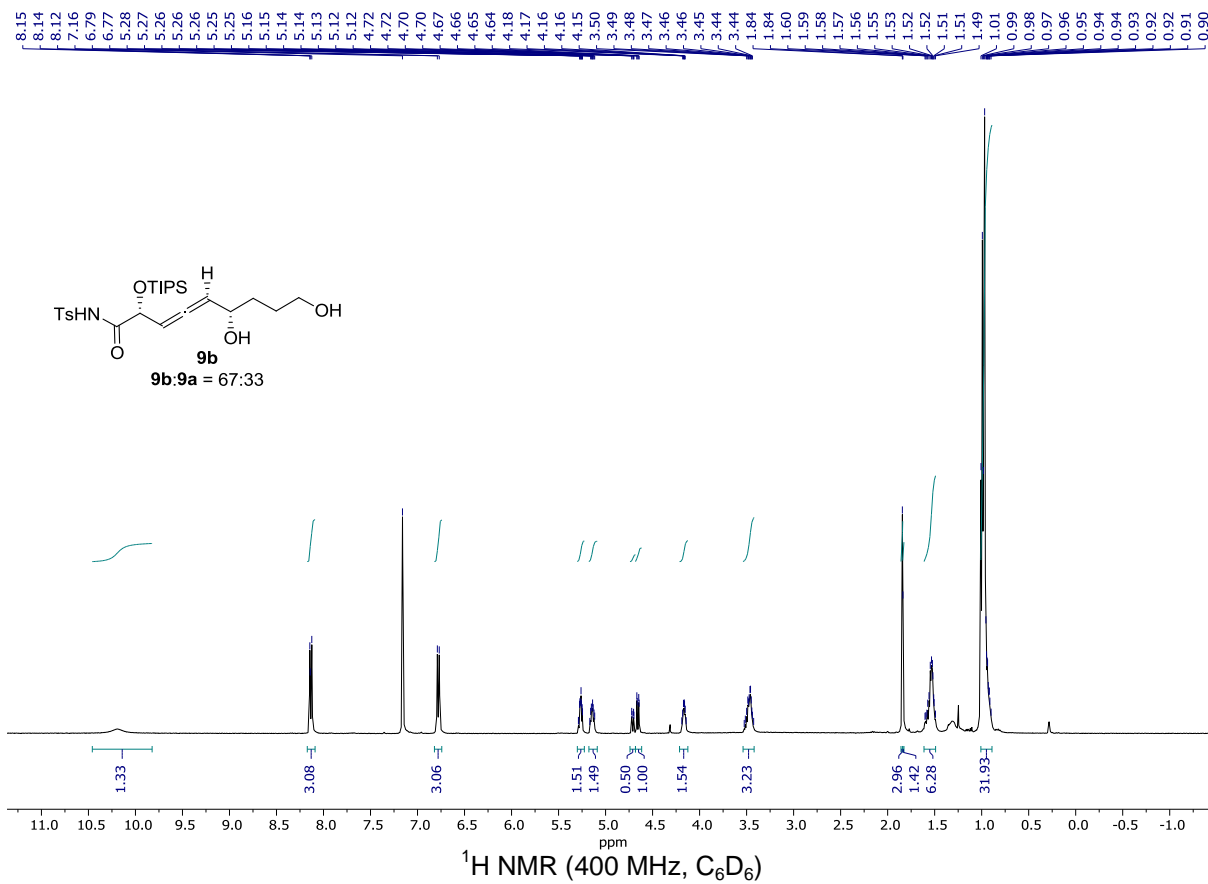


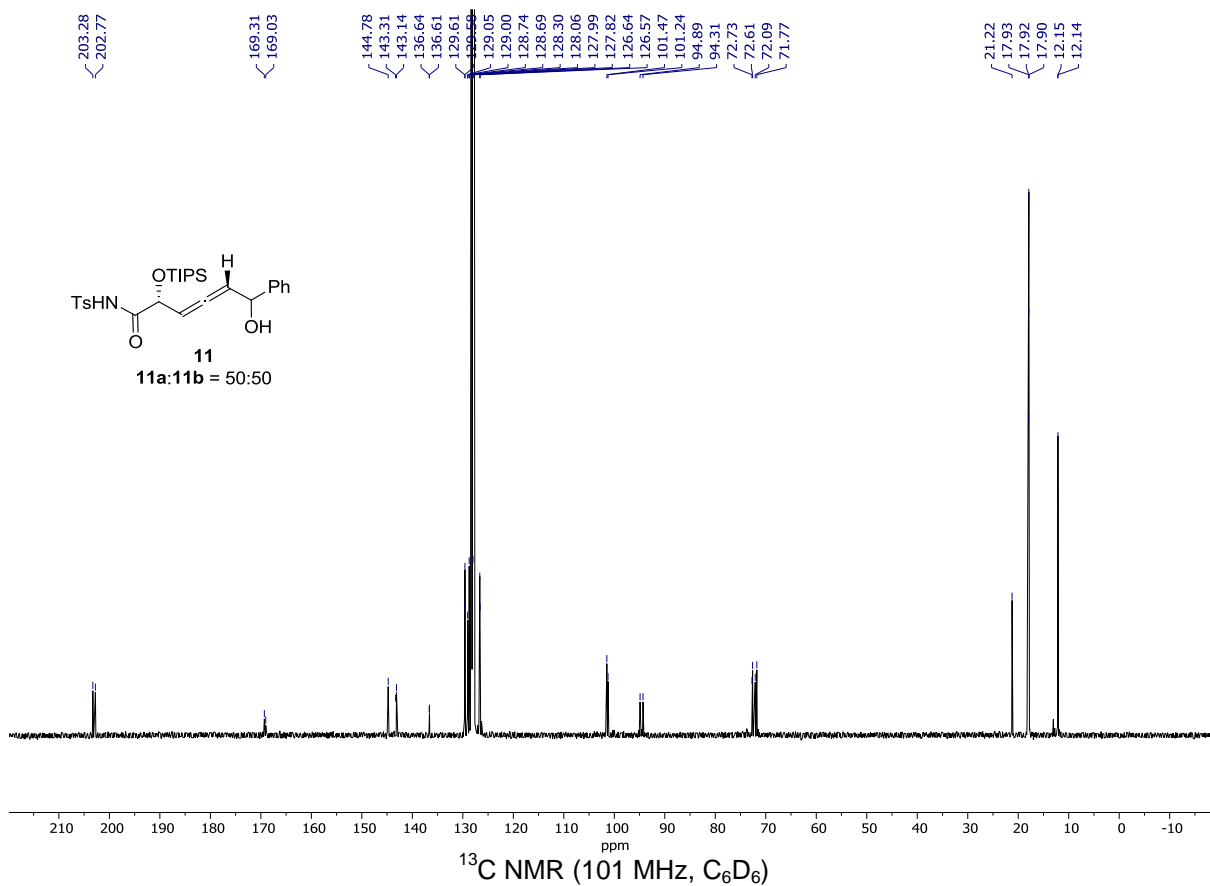
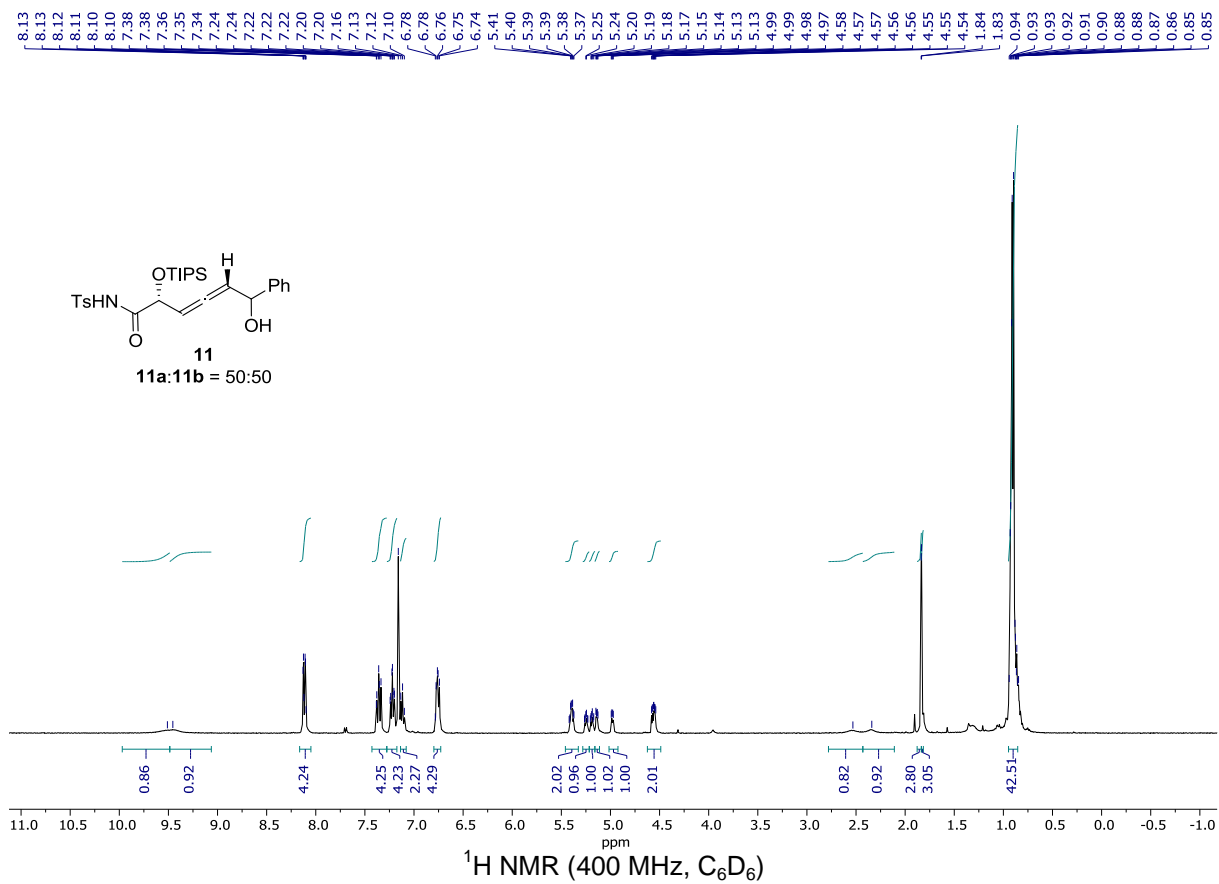


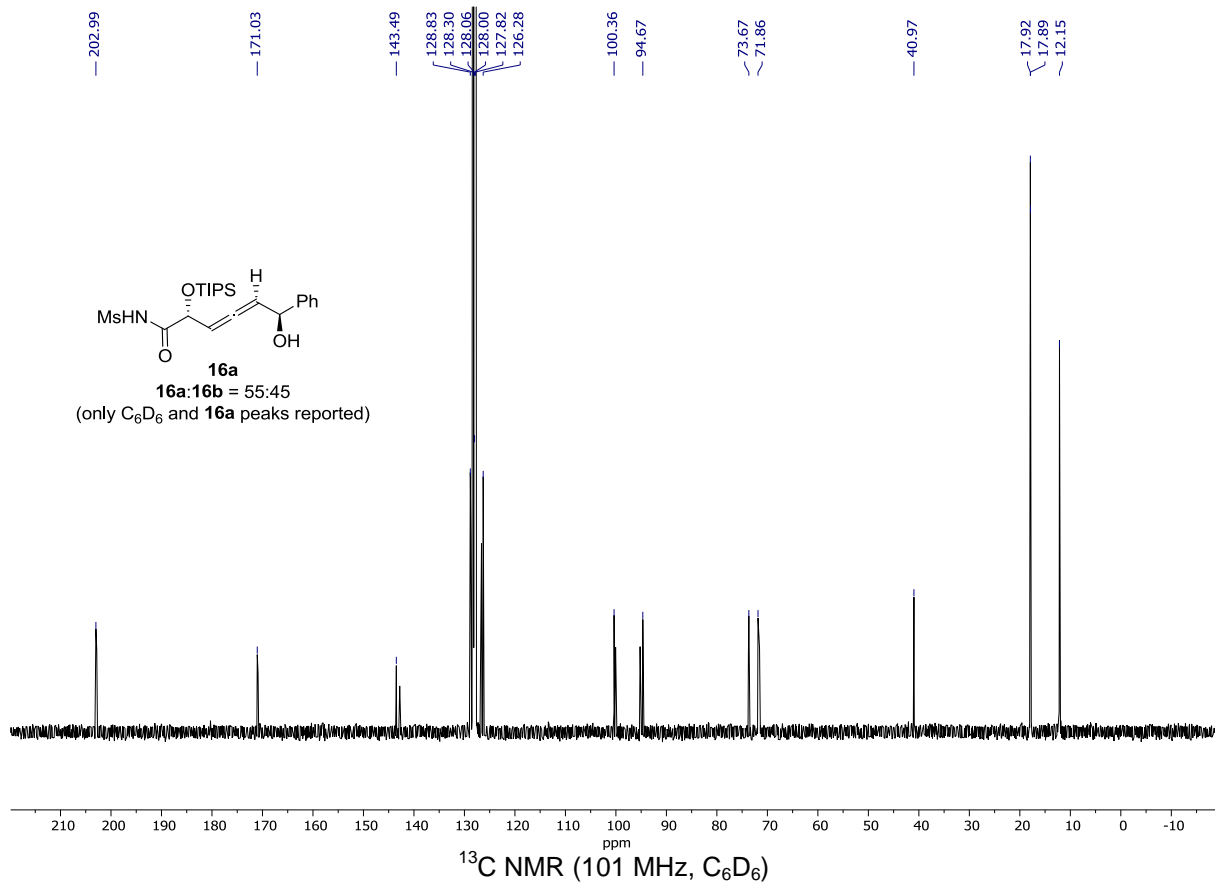
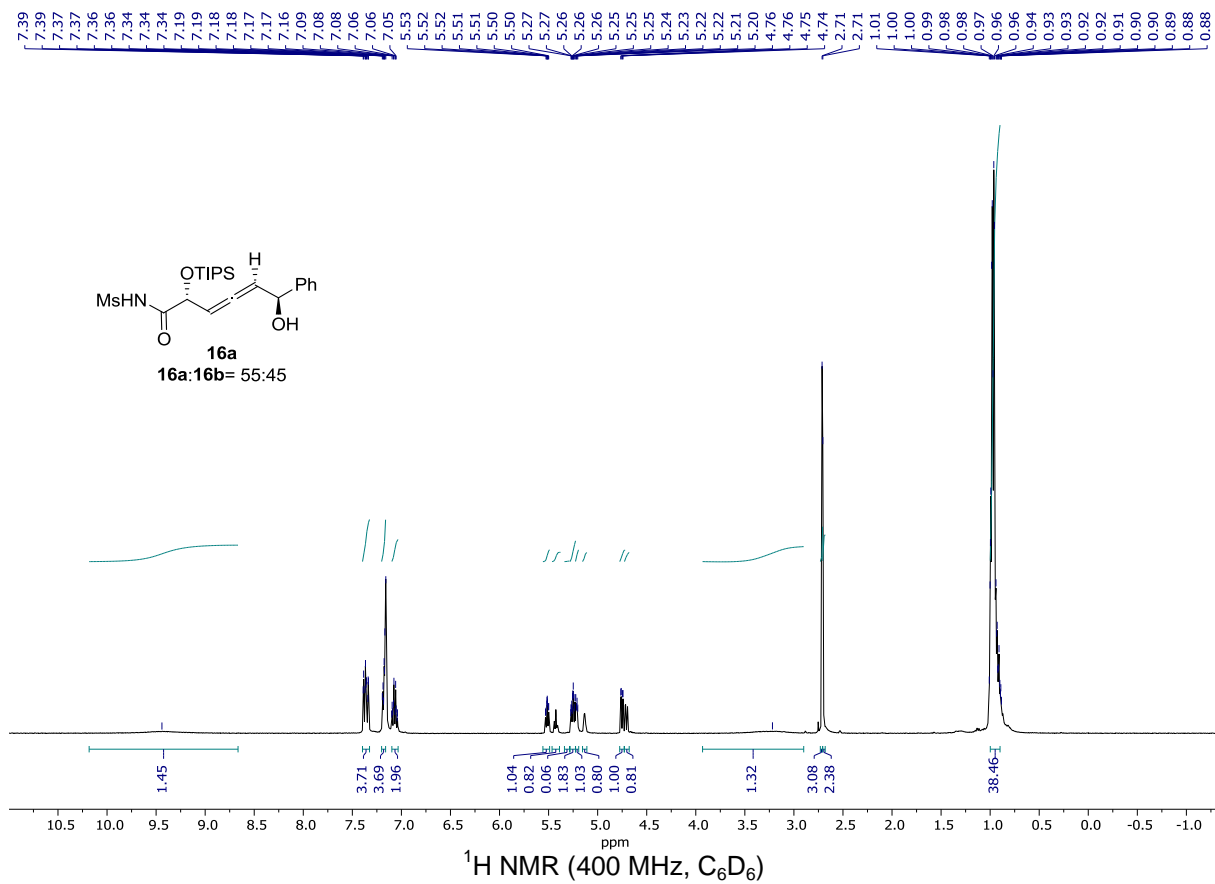


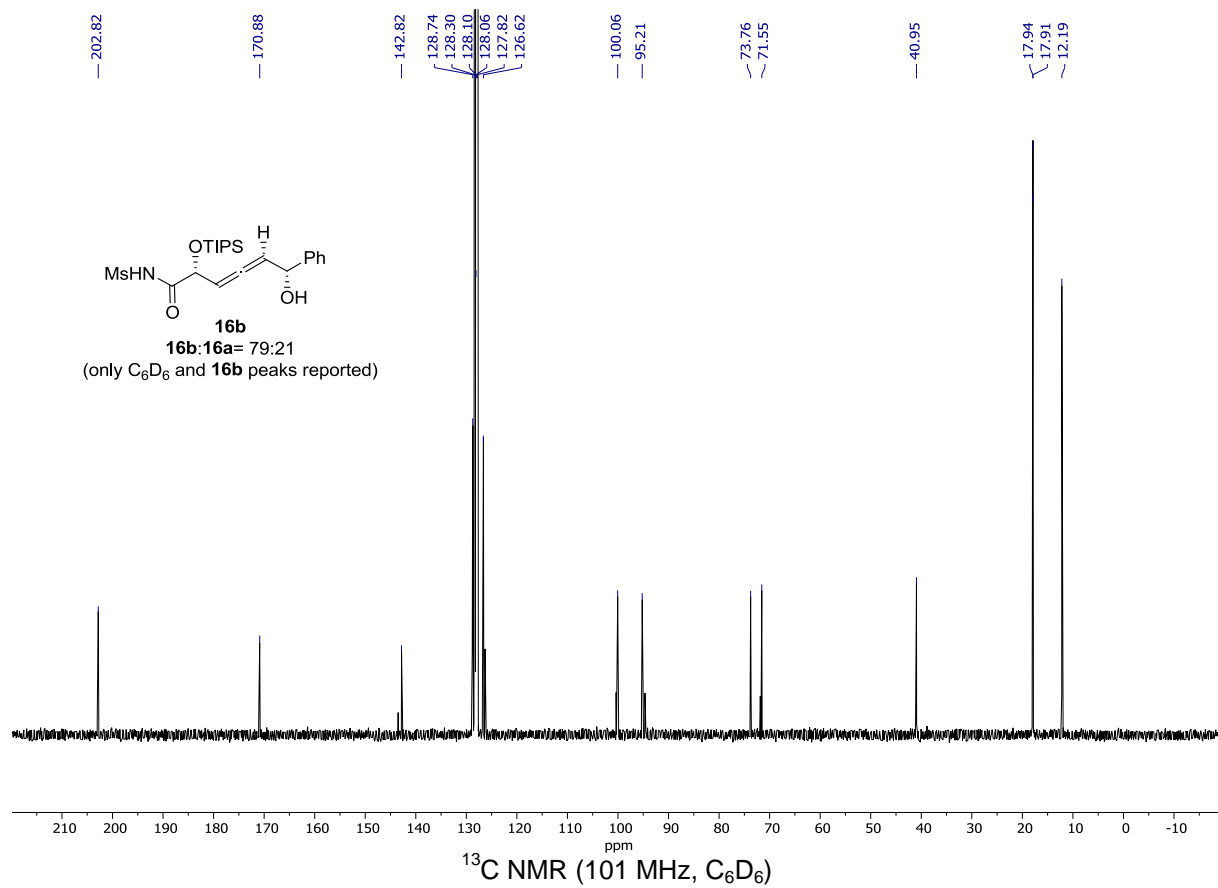
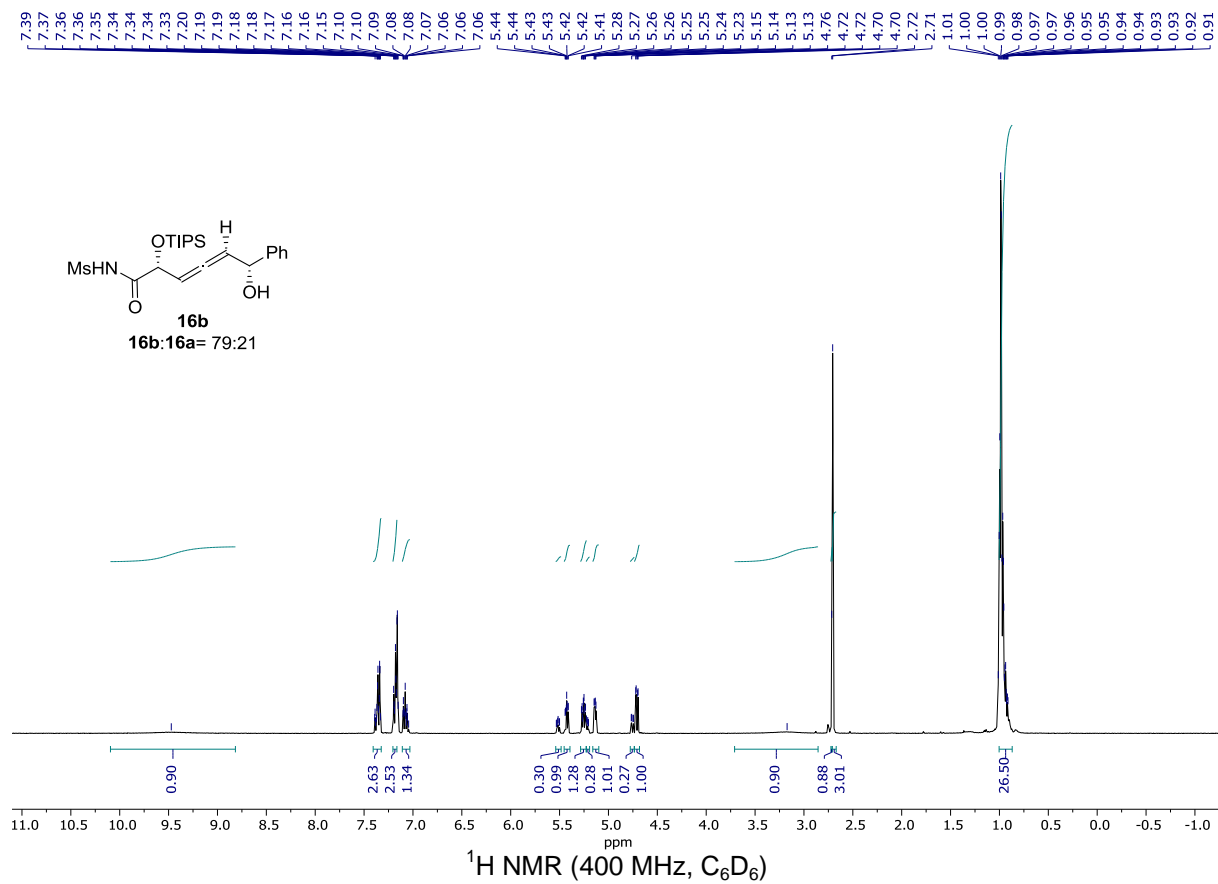


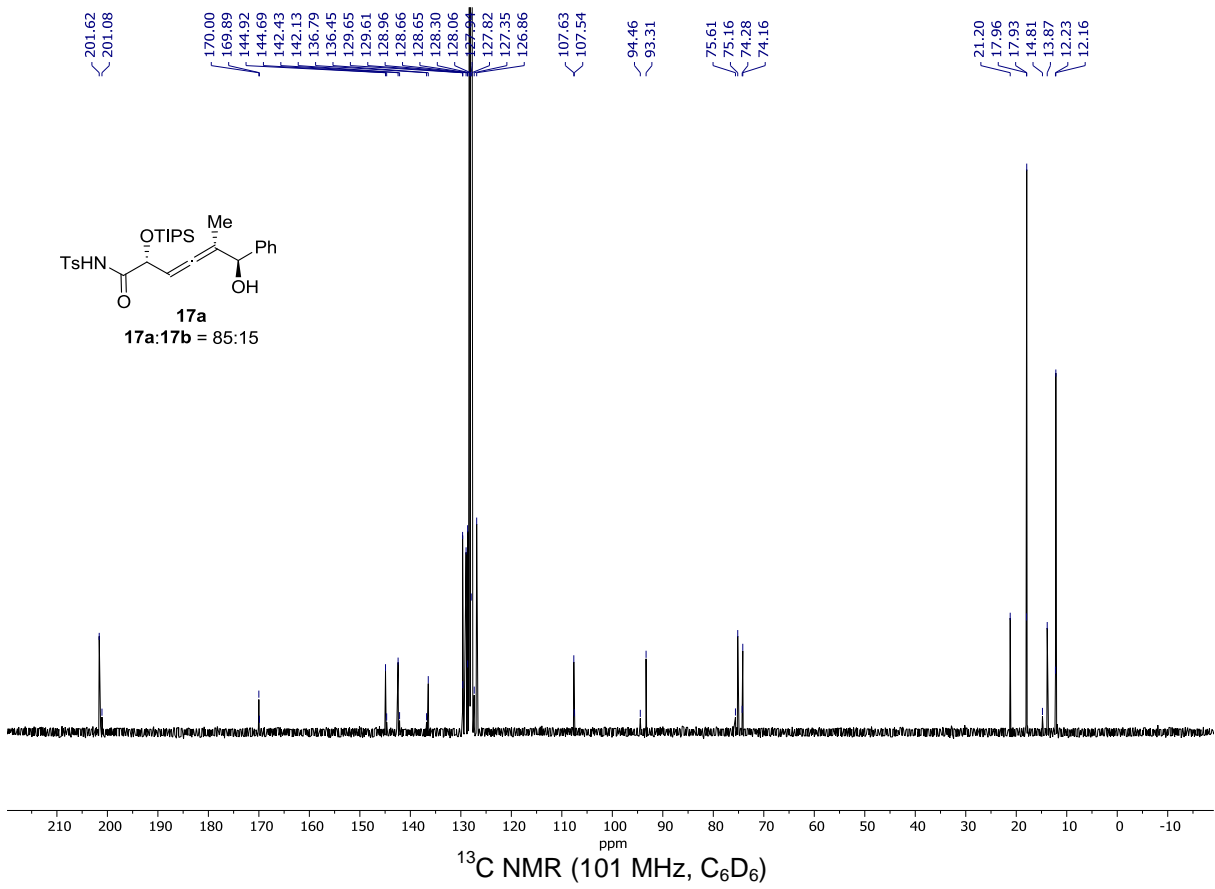
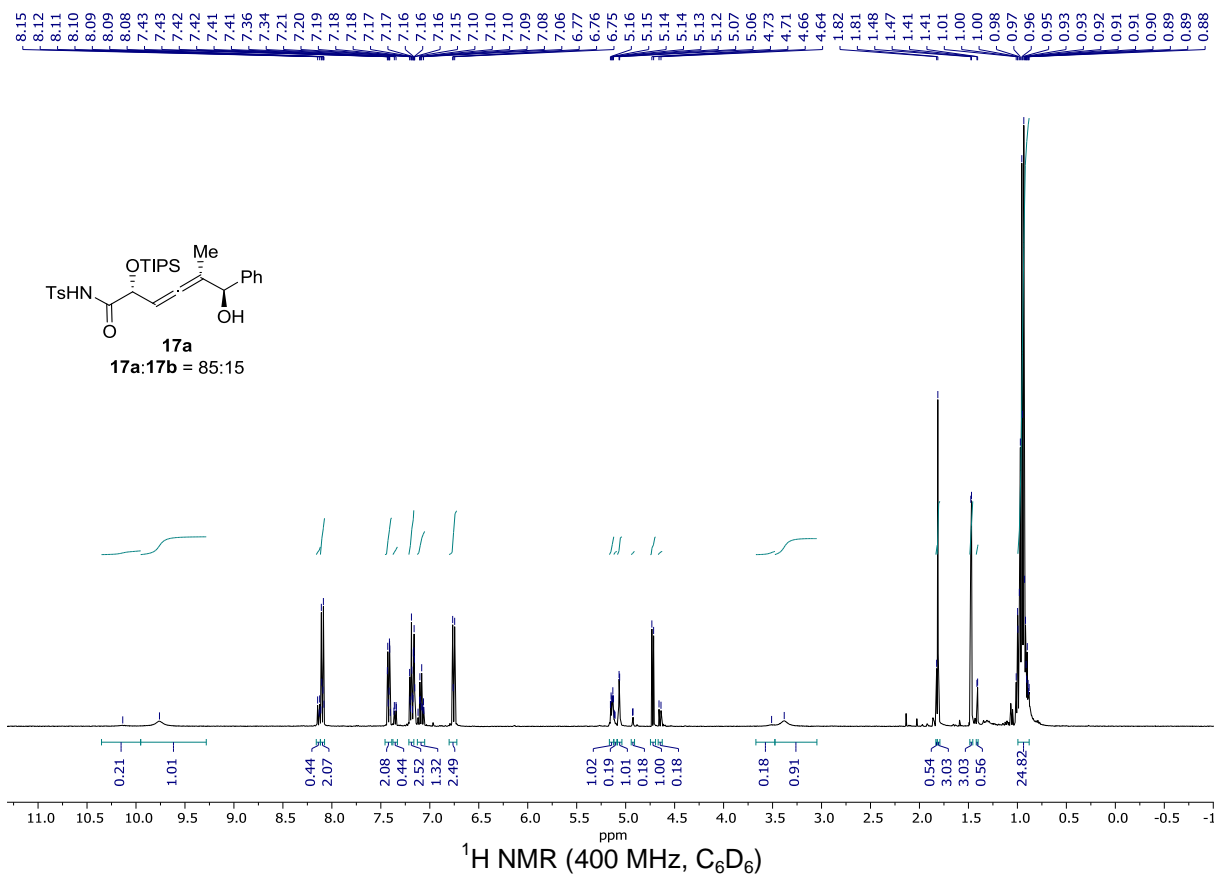


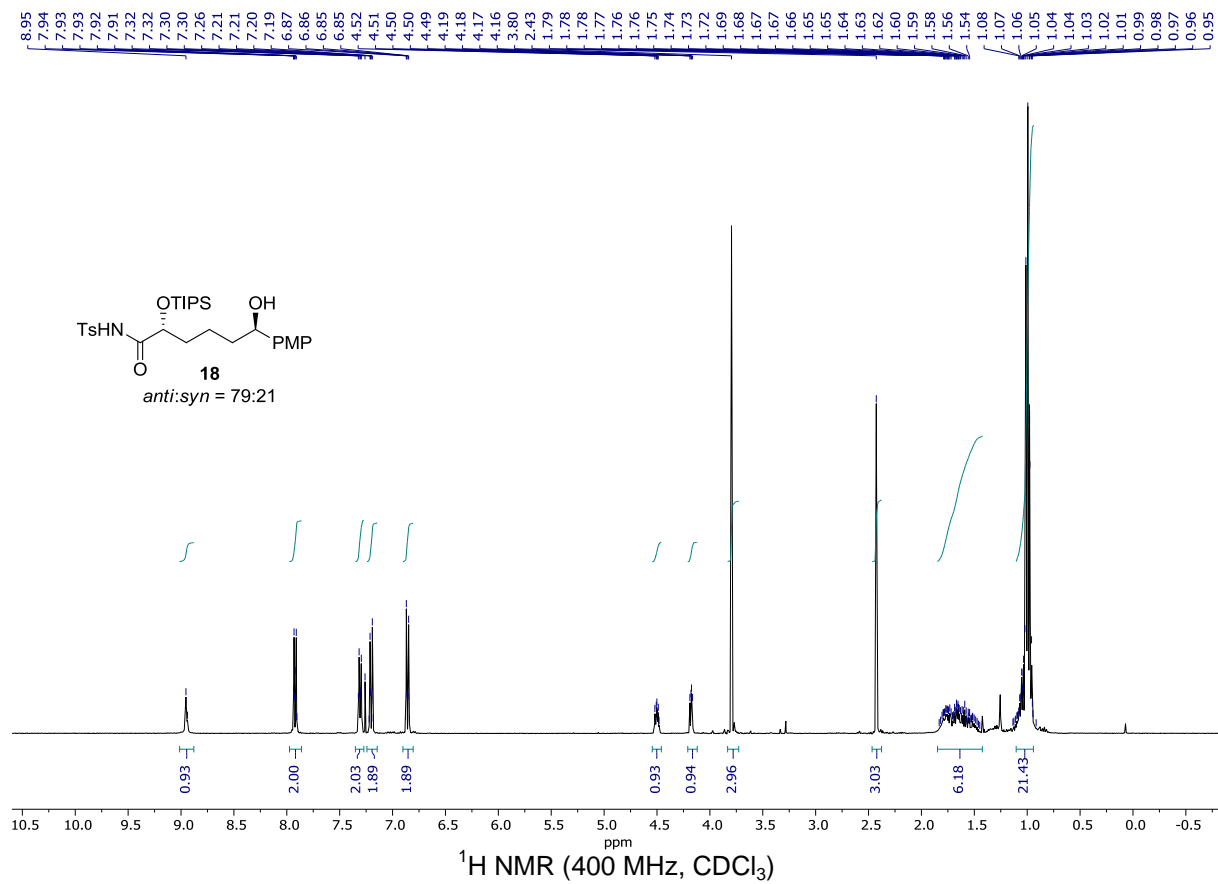


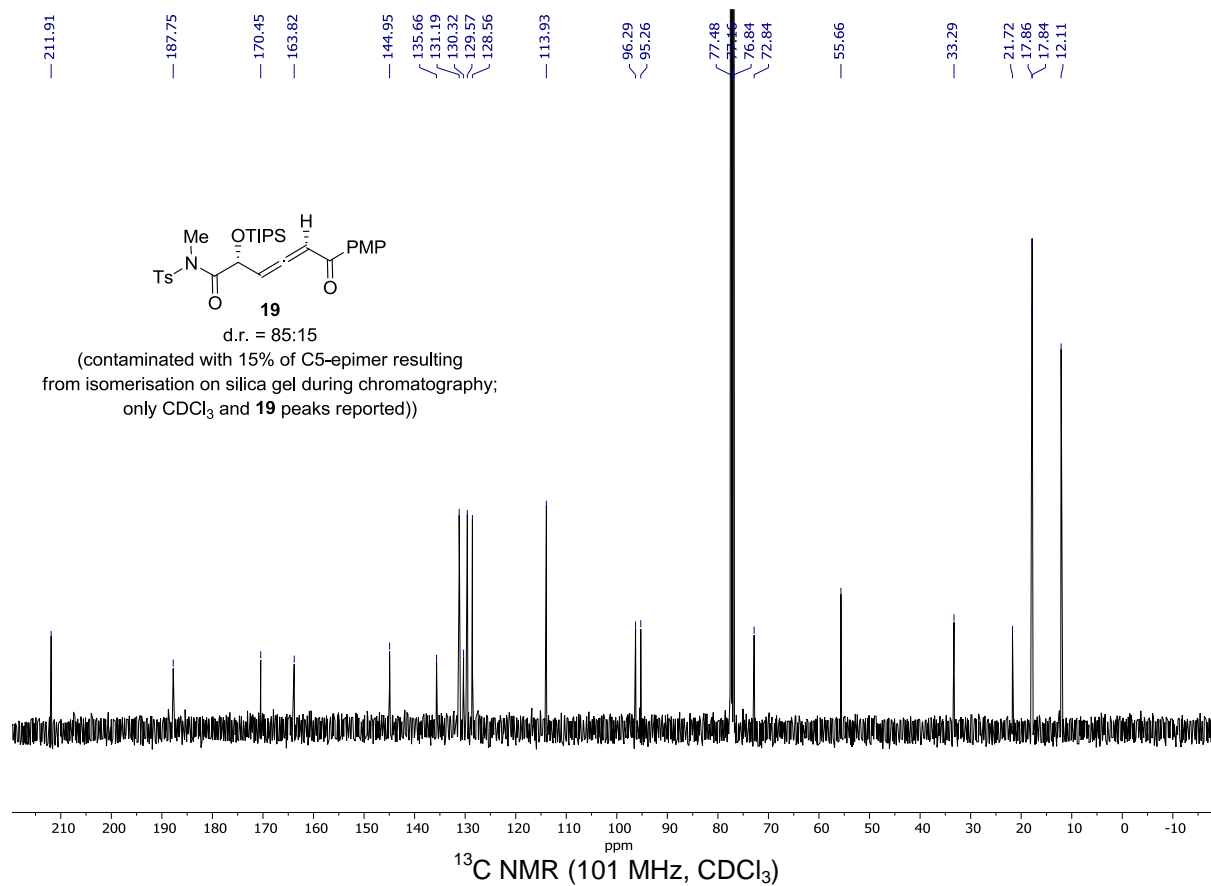
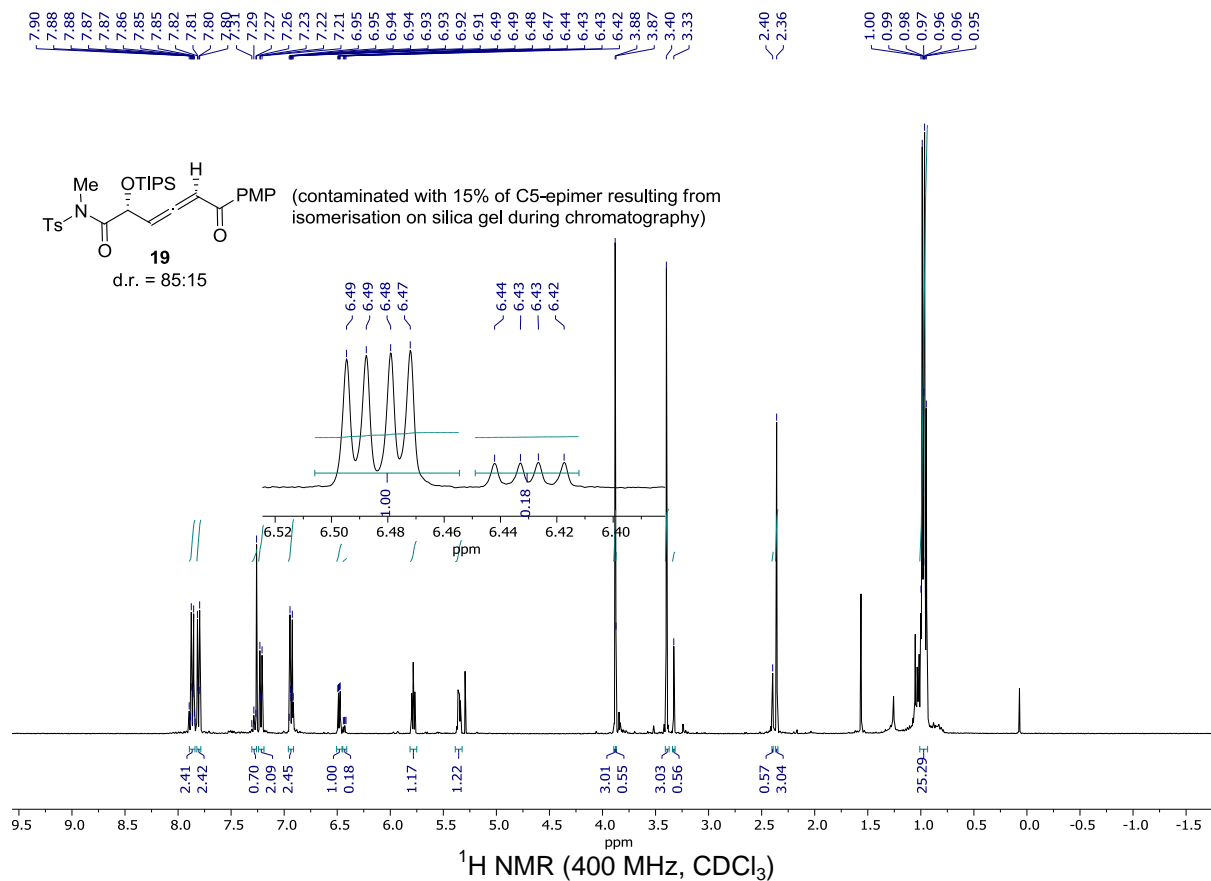


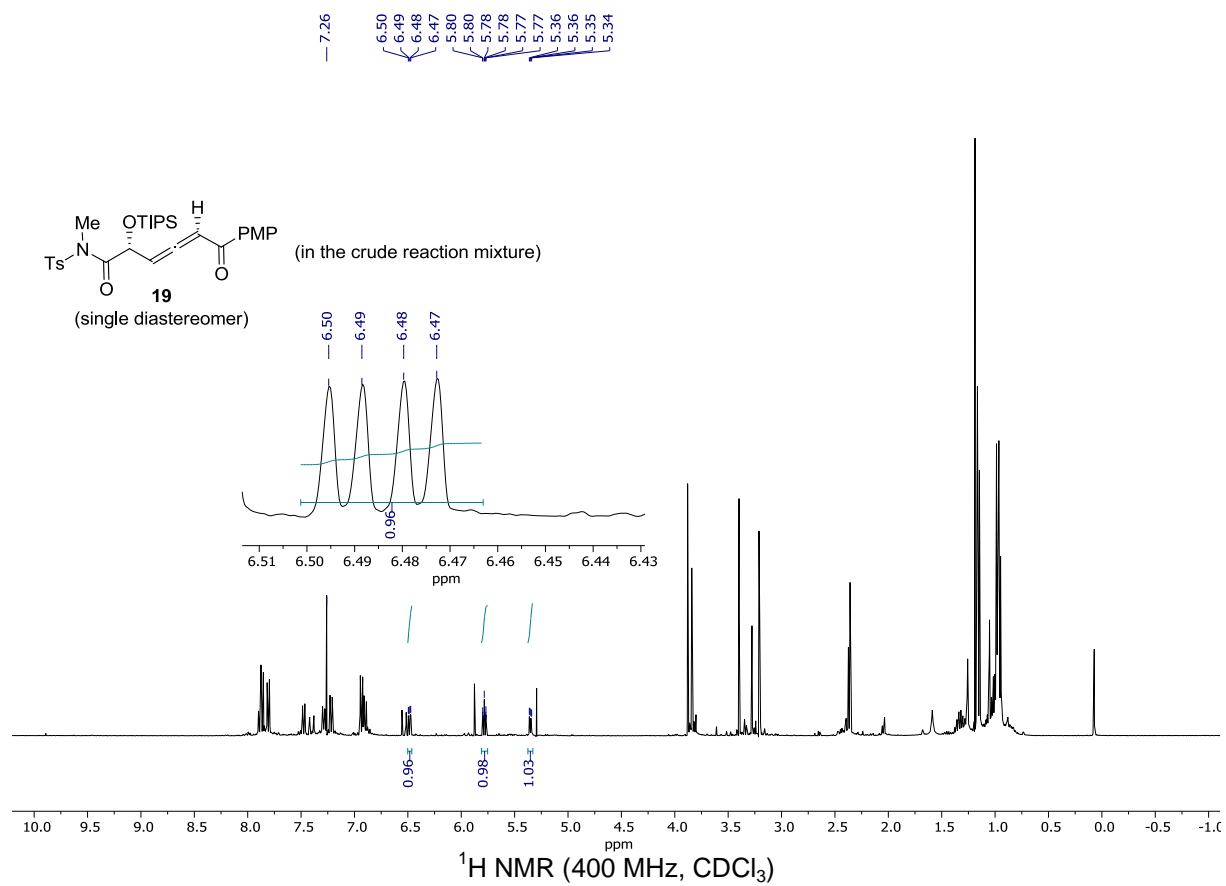


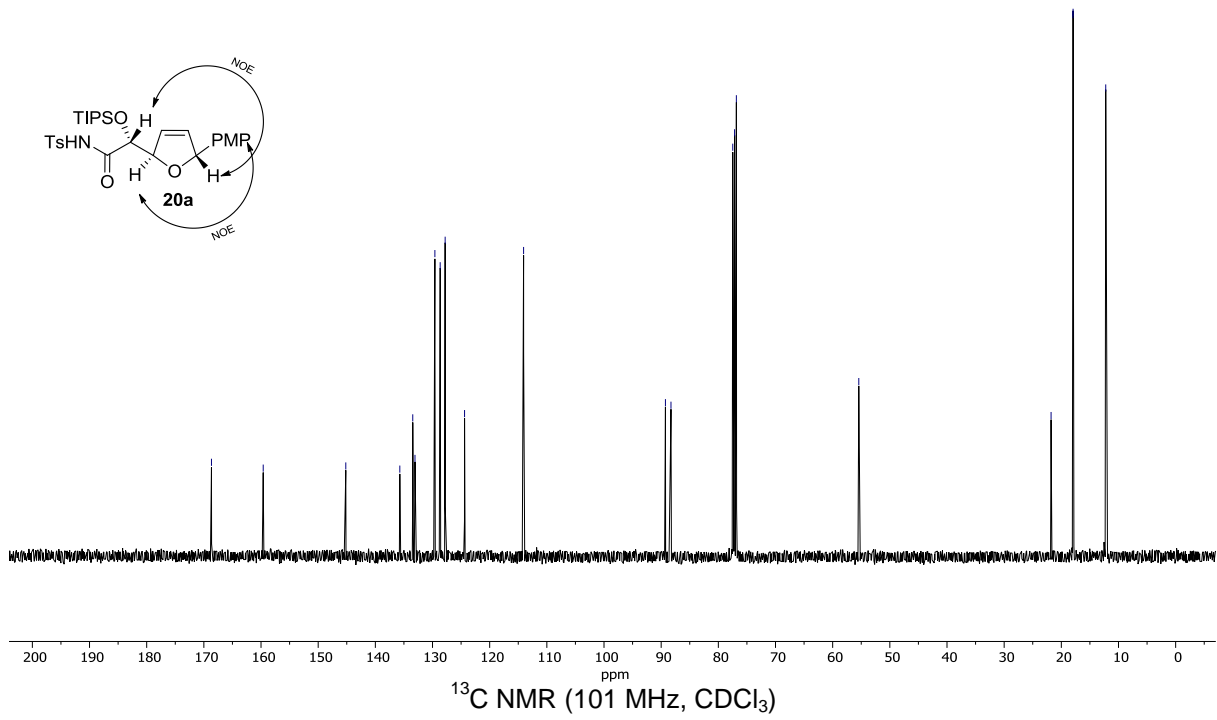
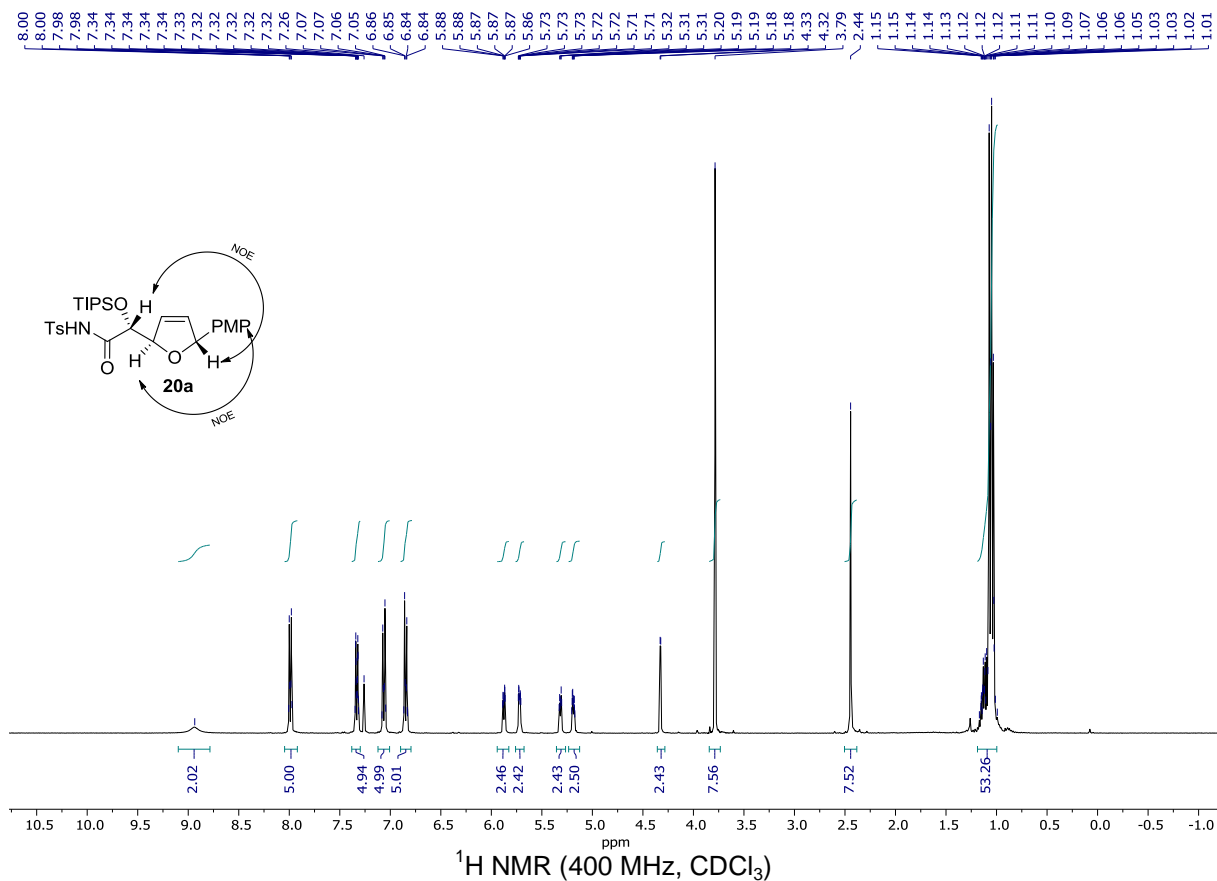


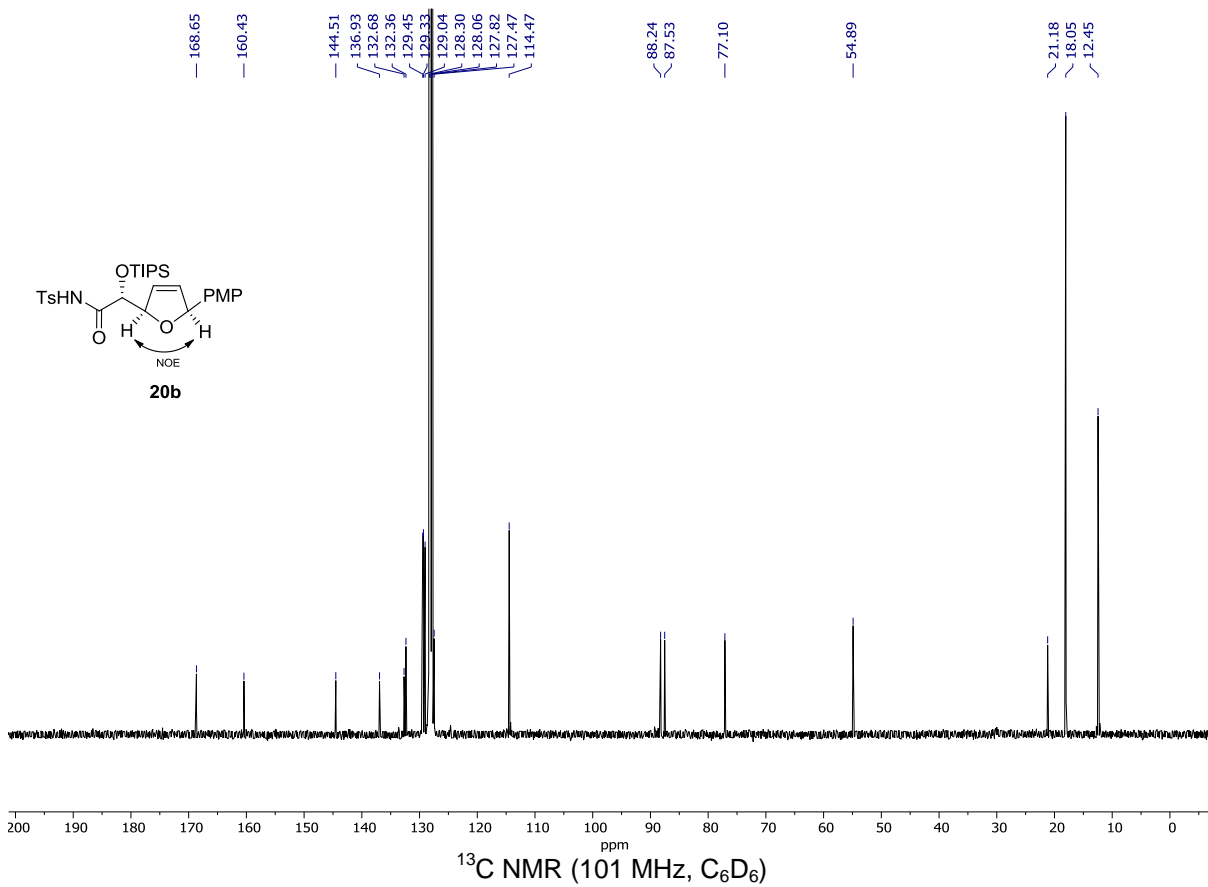
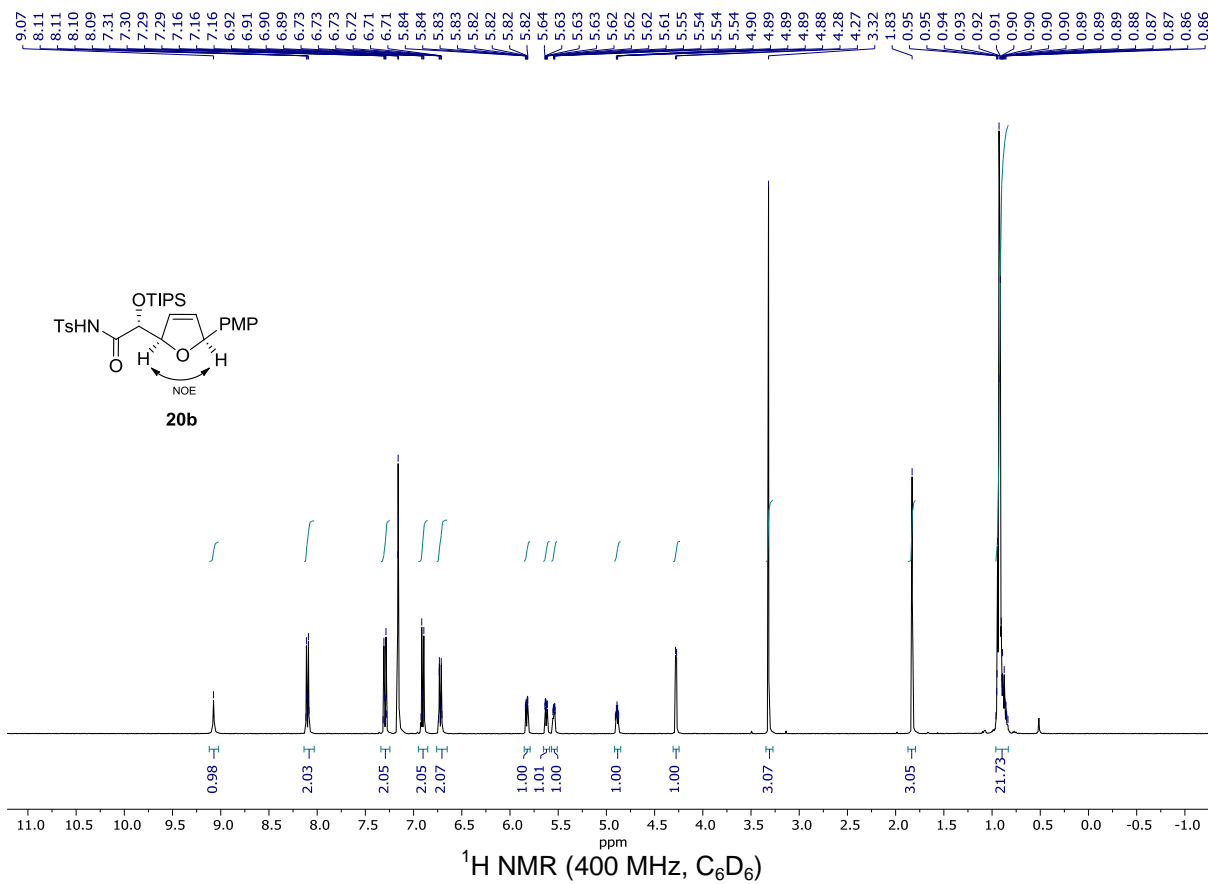




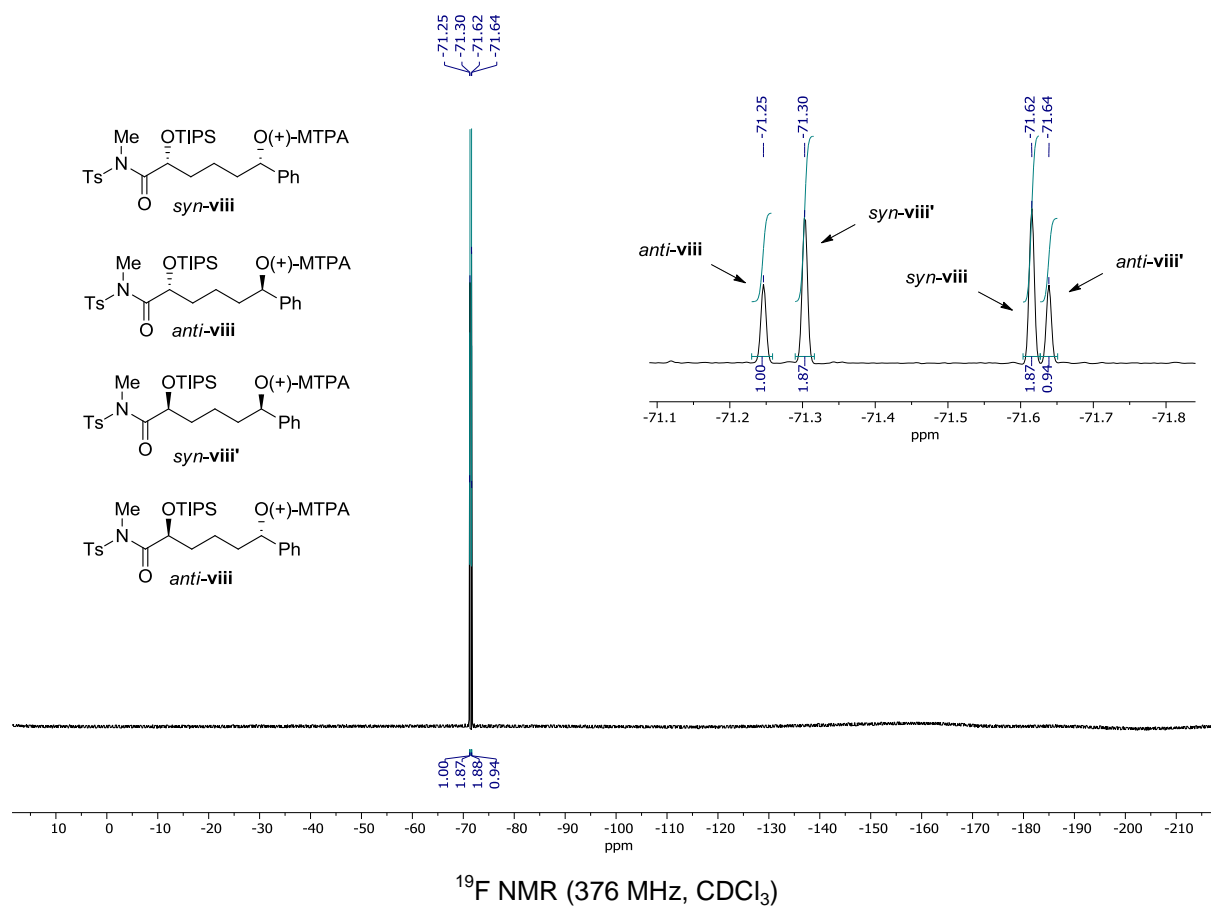
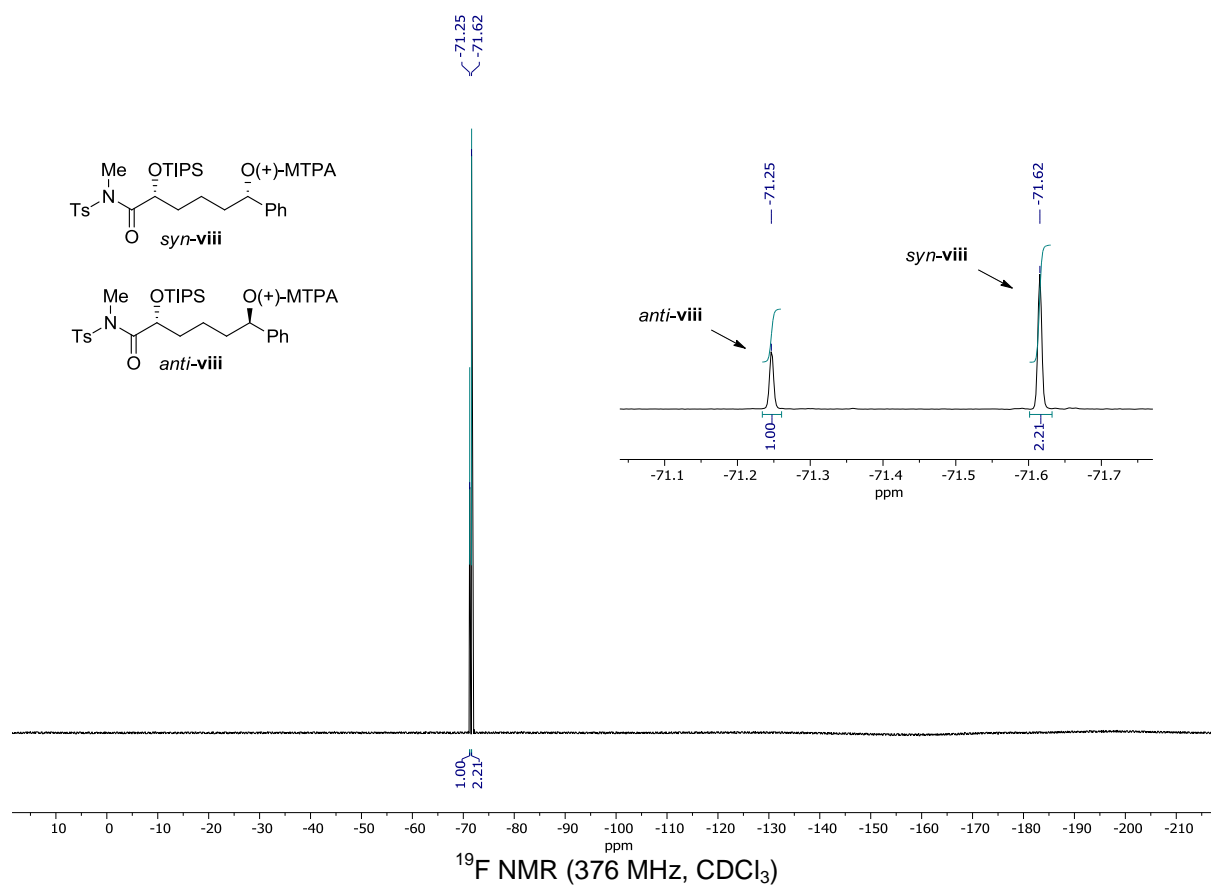


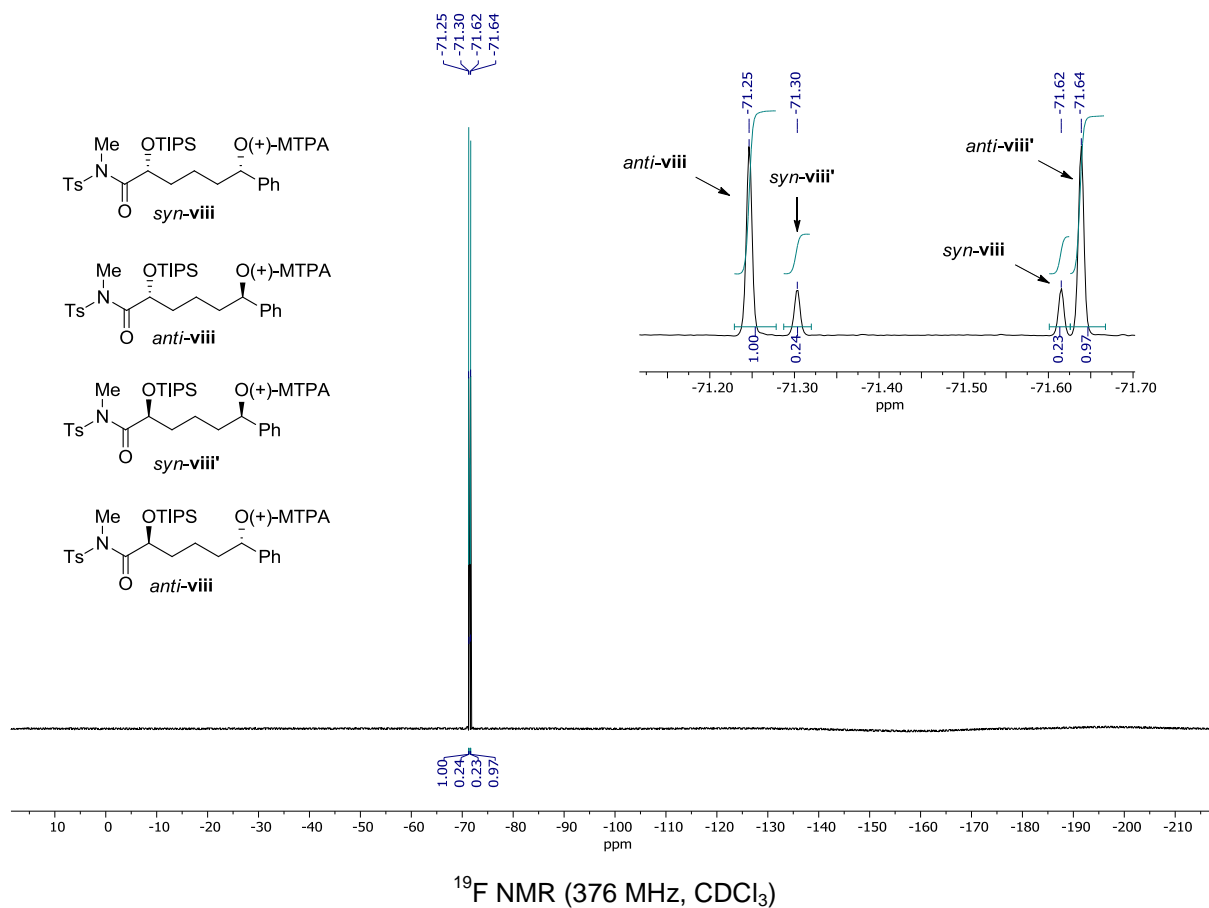
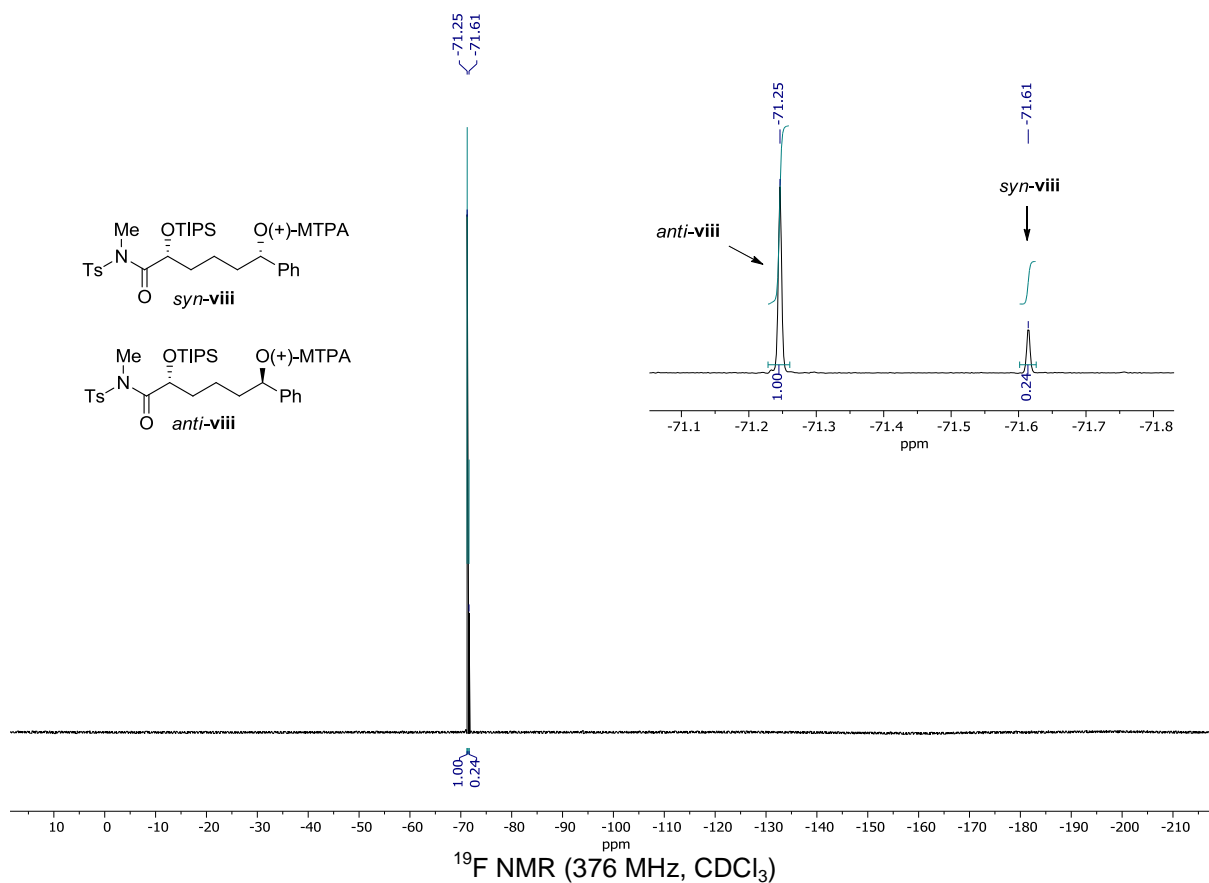


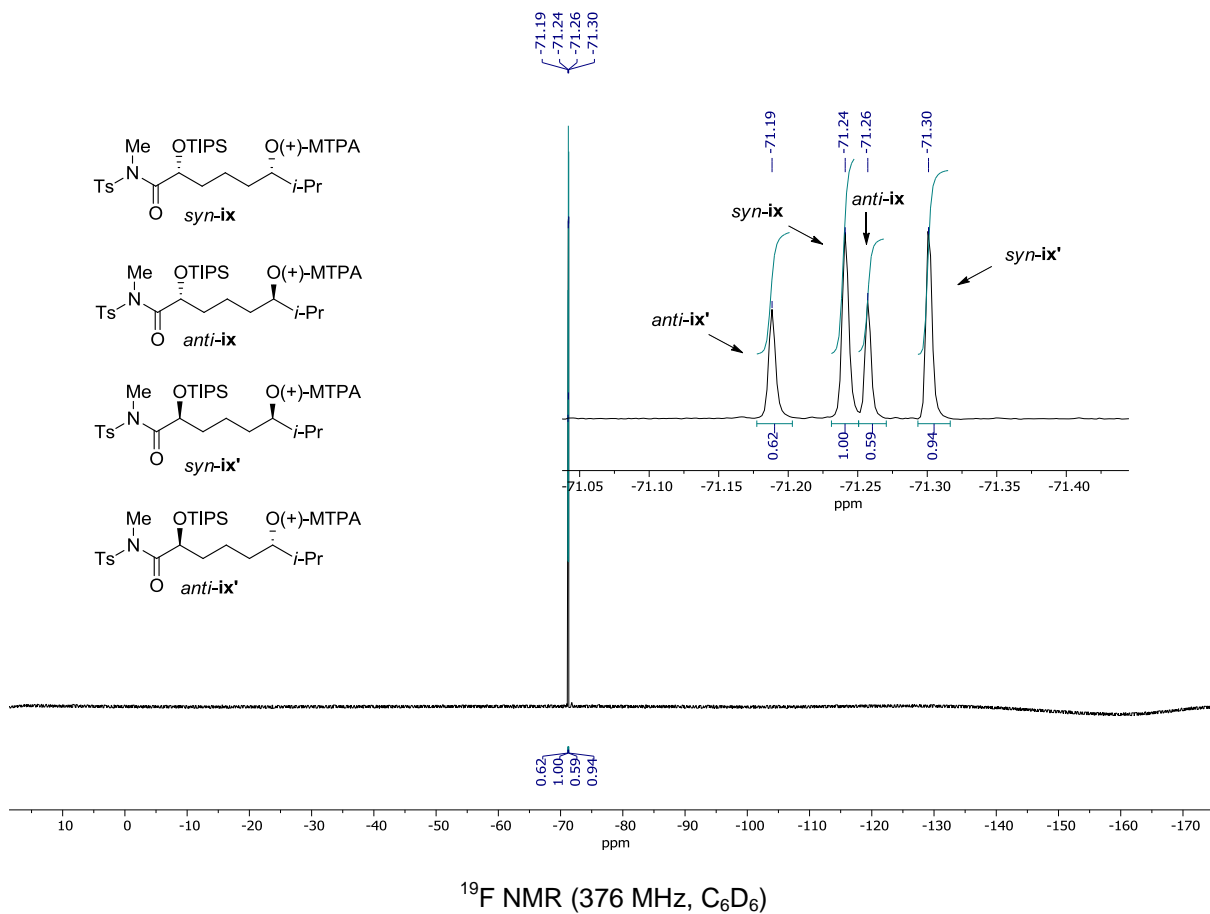
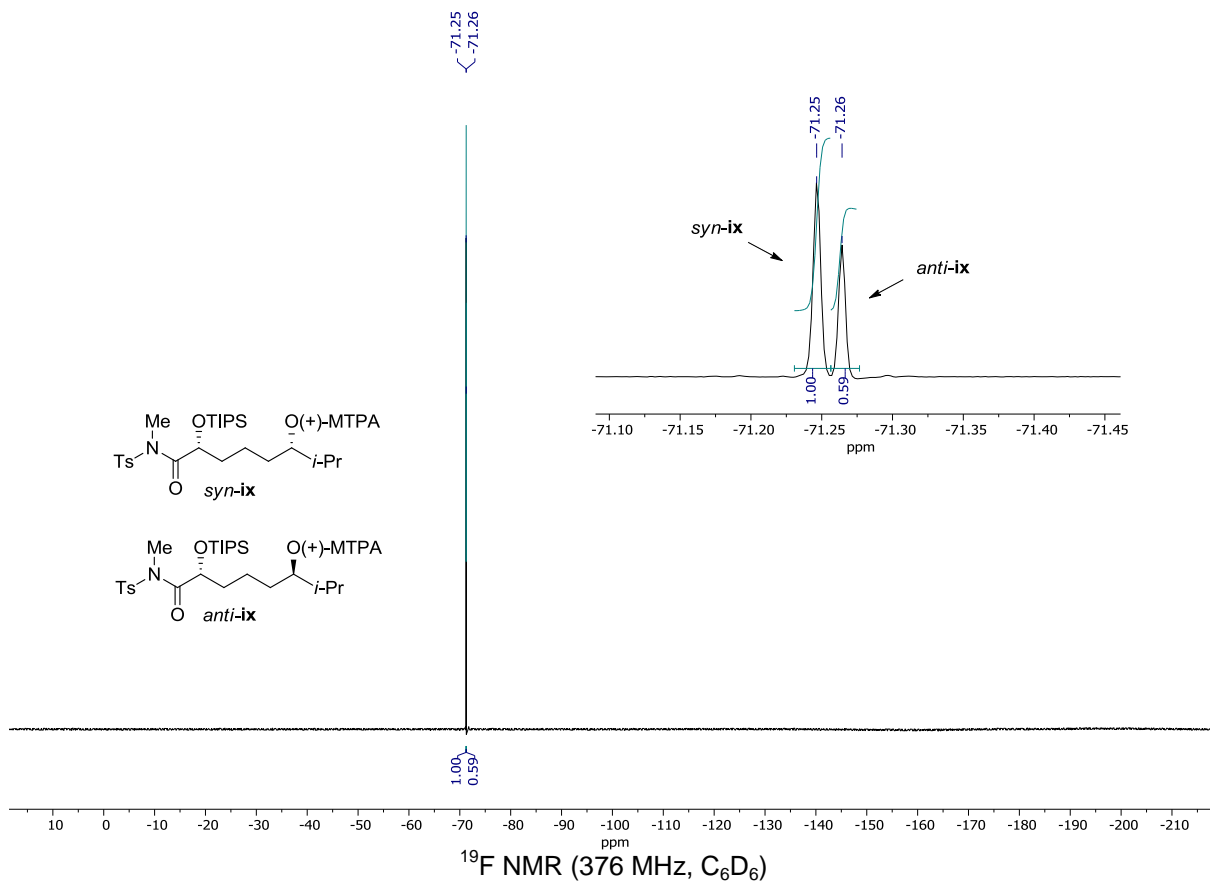




#### 4. $^{19}\text{F}$ NMR spectra of Mosher's esters **viii**, **viii/viii'**, **ix**, **ix/ix'**





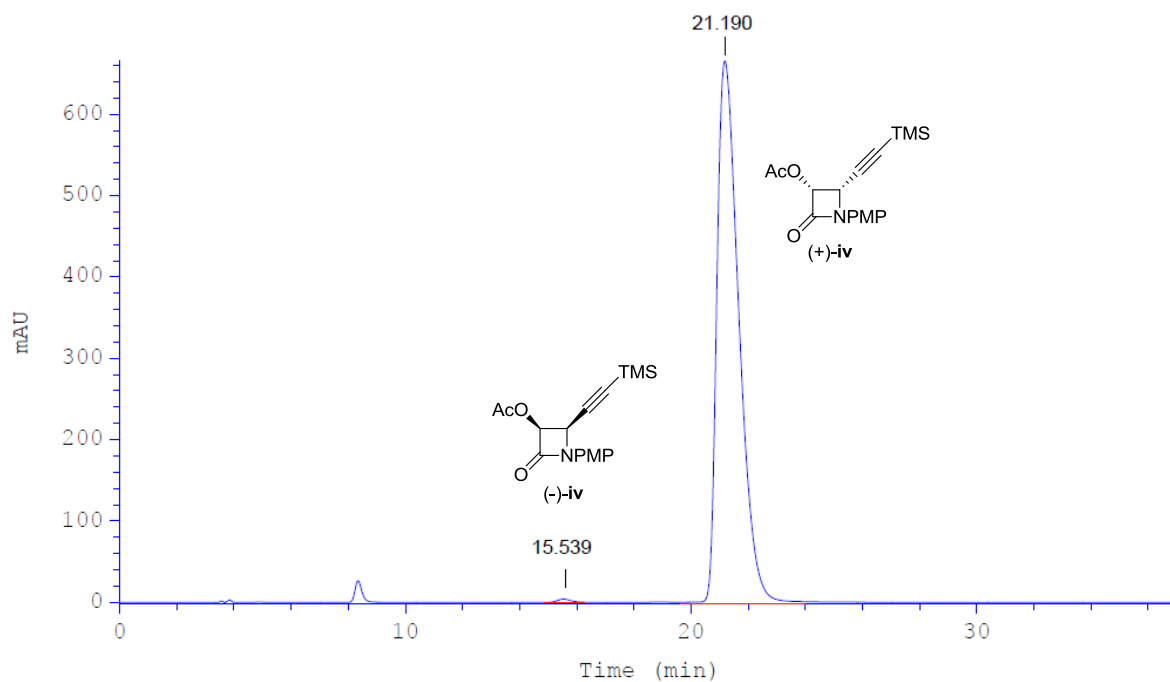




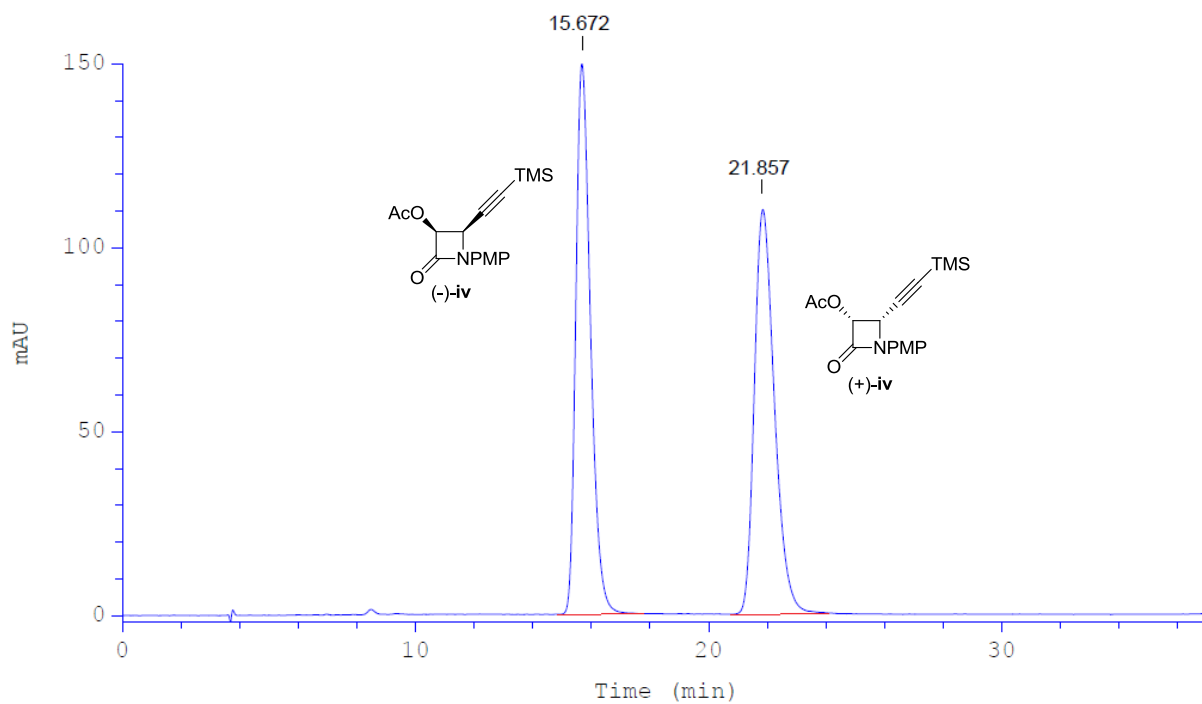
## 5. HPLC chromatograms of (+)-iv, iv, (-)-v and v.

HPLC (Daicel Chiralpak ASH column), hexane/*i*-PrOH = 93:7, flow rate 1.0 mL/min,  $\lambda = 261$  nm).

	Ret.time [min]	Start [min]	End [min]	Area [mAU*min]	Height [mAU]	% Area	Width [min]
1	15.539	14.73	16.71	2.22142	3.94944	0.3760	0.506
2	21.190	19.69	23.91	588.596	665.106	99.6240	0.826

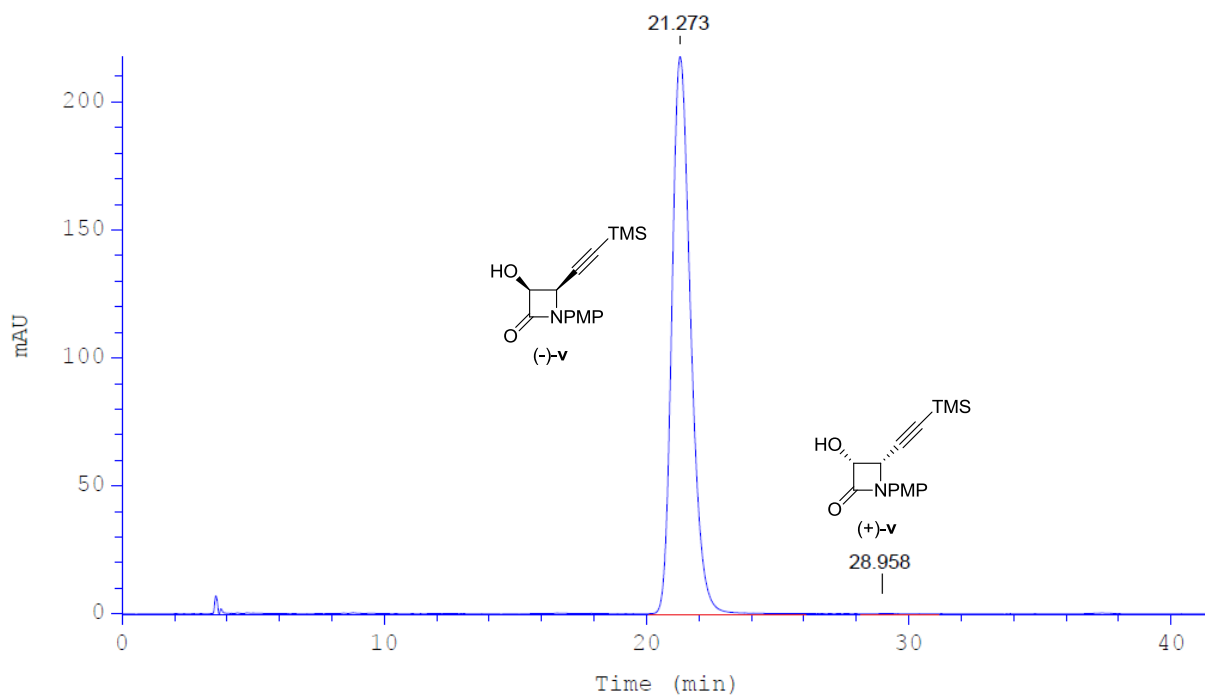


	Ret.time [min]	Start [min]	End [min]	Area [mAU*min]	Height [mAU]	% Area	Width [min]
1	15.672	14.92	17.59	86.9419	149.527	50.0925	0.533
2	21.857	20.87	23.79	86.6209	109.829	49.9075	0.724

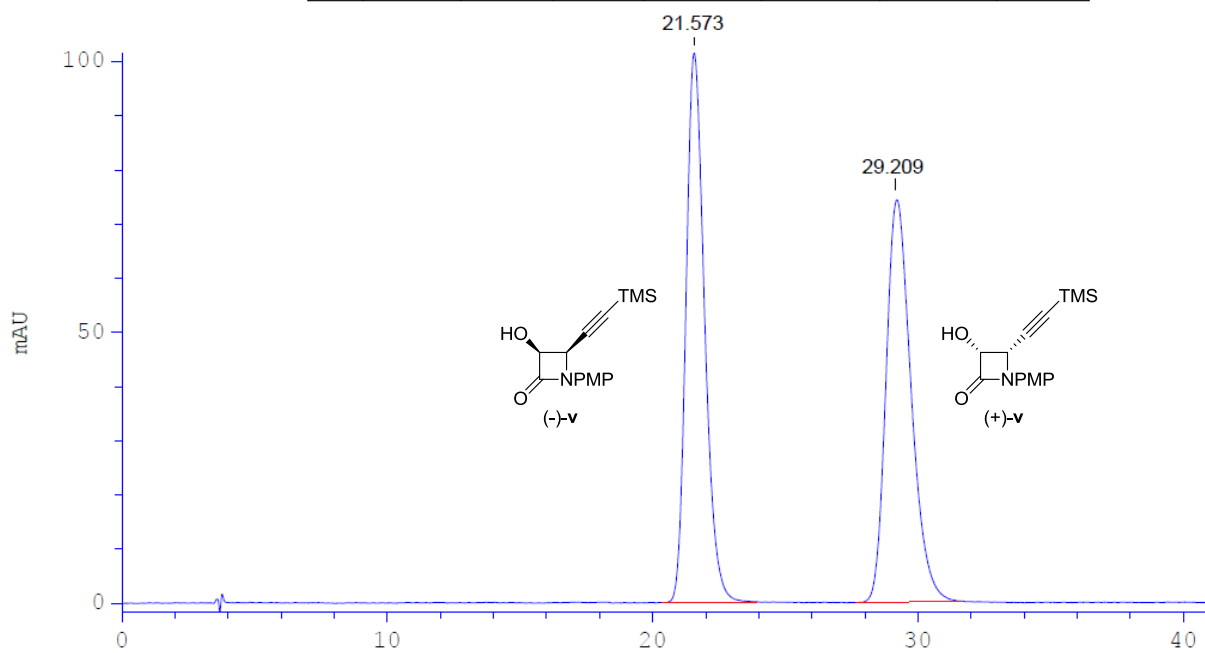


HPLC (Daicel Chiralpak ASH column), hexane/*i*-PrOH = 93:7, flow rate 1.0 mL/min,  $\lambda = 261$  nm).

	Ret.time [min]	Start [min]	End [min]	Area [mAU*min]	Height [mAU]	% Area	Width [min]
1	21.273	20.13	26.01	180.388	217.555	99.9729	0.761
2	28.958	28.17	31.41	0.0488809	0.130983	0.0271	0.537



	Ret.time [min]	Start [min]	End [min]	Area [mAU*min]	Height [mAU]	% Area	Width [min]
1	21.573	20.46	23.86	81.9081	101.336	50.1911	0.740
2	29.209	27.86	31.56	81.2845	74.241	49.8089	1.004



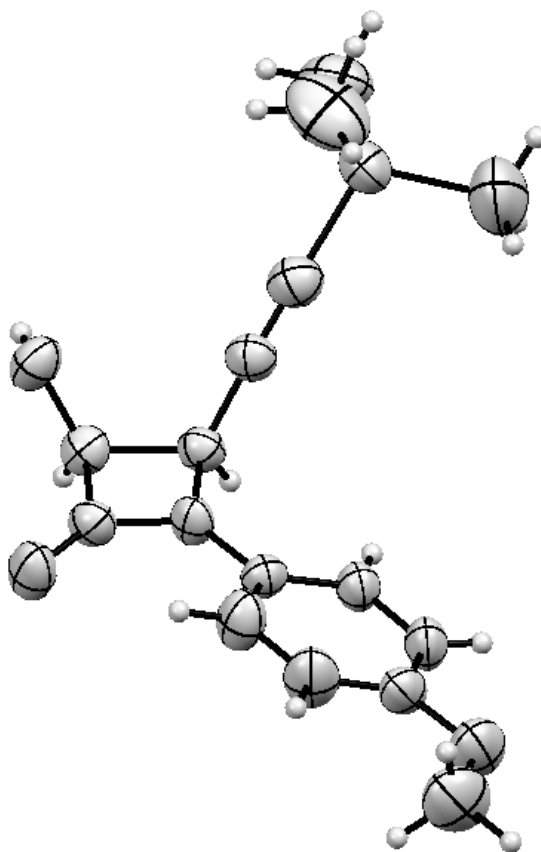
## 6. X-ray crystallographic data for (-)-**v**, **8b** and **20b**.

Samples were prepared by crystallization from benzene ((-)-**v**<sup>20</sup> and **20b**) or hexane (**8b**). The measurements were performed on Bruker X8 APEXII diffractometer using Cu-K $\alpha$  radiation ( $\lambda = 1.54178 \text{ \AA}$ ). Frames were integrated with the Bruker SAINT software package using a narrow-frame algorithm.<sup>1</sup> Data were corrected for absorption effects using the face-indexed numerical method (SADABS).<sup>2</sup> placed in calculated positions and refined as riding on their parent atoms with Uiso = 1.2 Ueq. The structure was solved by direct methods SHELXS-2014<sup>3</sup> and refined with full-matrix least-squares calculations on F2 using SHELX-2014<sup>3</sup>. All non-hydrogen atoms were refined anisotropically.

The structures presented in this article have been deposited with the Cambridge Crystallographic Data Centre. Copies of these data can be obtained free of charge via <http://www.ccdc.cam.ac.uk/conts/retrieving.html> or from the Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge CB2 1EZ, UK; fax:(+44) 1223-336-033; e-mail: [deposit@ccdc.cam.ac.uk](mailto:deposit@ccdc.cam.ac.uk).

### References

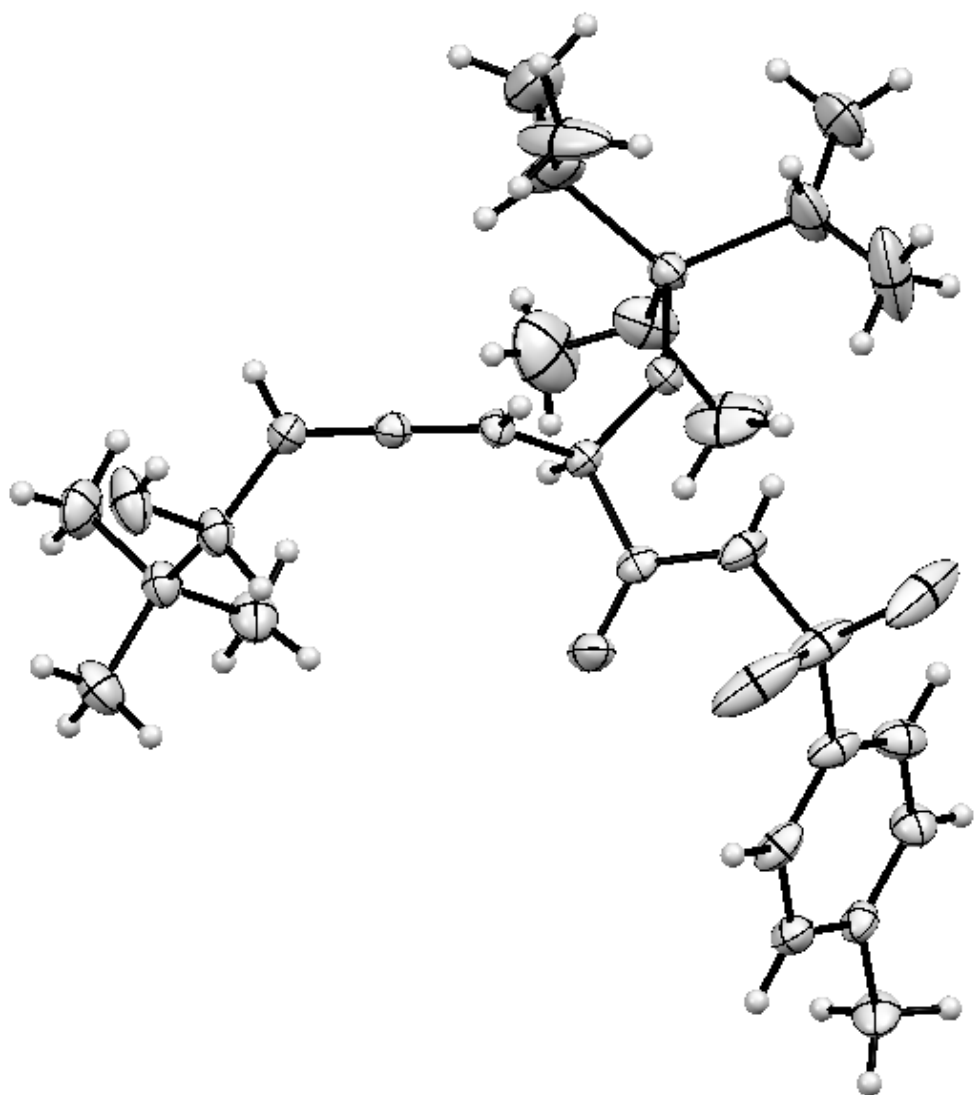
1. Bruker, 2004, APEX2 and SAINT. Bruker AXS Inc., Madison, Wisconsin, USA
2. Bruker, 2008, SADABS. Bruker AXS Inc., Madison, Wisconsin, USA.
3. G. M. Sheldrick, SHELXL-2014. Program for the Refinement of Crystal Structures from Diffraction Data, University of Göttingen, Germany (2014).



**Figure S1.** ORTEP diagram (50% probability) of (-)-**v**

**Table S1.** Crystal data and structure refinement details for (-)-**v**

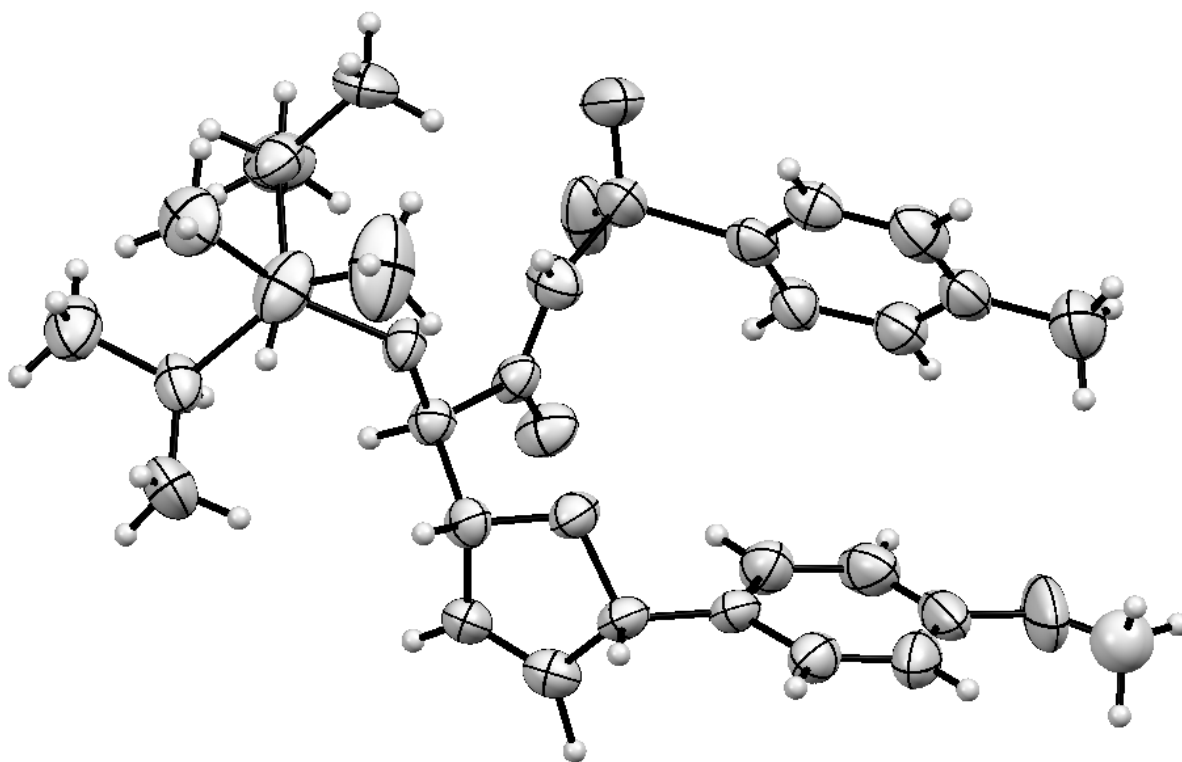
Empirical formula	C <sub>15</sub> H <sub>19</sub> NO <sub>3</sub> Si
Formula weight /g mol <sup>-1</sup>	289.40
Crystal color and habit	colorless prism
CCDC No.	1895501
Temperature /K	296(2)
Crystal system	triclinic
Space group	P 1
a /Å	6.4537(6)
b /Å	11.7057(10)
c /Å	12.3034(11)
α /°	108.846(5)
β /°	102.020(5)
γ /°	101.741(5)
Volume /Å <sup>3</sup>	822.72(13)
Z	2
ρ <sub>calc</sub> / g cm <sup>-3</sup>	1.168
μ/mm <sup>-1</sup>	1.317
F(000)	308
Crystal size /mm <sup>3</sup>	0.114 x 0.140 x 0.797
Θ range for data collection /°	3.97 to 68.37
Index ranges	-7<=h<=6, -13<=k<=14, -14<=l<=14
Reflections collected (all/independent)	24209/ 5454
Data/restraints/parameters	5454 / 3 / 388
Goodness-of-fit on F <sup>2</sup>	1.044
Final R indexes [I>2σ (I)]	R1 = 0.0467, wR2 = 0.1053
Final R indexes [all data]	R1 = 0.0702, wR2 = 0.1178
Largest diff. peak and hole /e Å <sup>-3</sup>	0.154 and -0.149



**Figure S2.** ORTEP diagram (10% probability) of **8b**

**Table S2.** Crystal data and structure refinement details for **8b**

Empirical formula	C <sub>26</sub> H <sub>43</sub> NO <sub>5</sub> SSi
Formula weight /g mol <sup>-1</sup>	509.76
Crystal color and habit	colorless prism
CCDC No.	1902129
Temperature /K	296(2)
Crystal system	monoclinic
Space group	P 1 21/c 1
a /Å	16.6337(9)
b /Å	15.0970(8)
c /Å	12.4084(6)
α /°	90
β /°	99.100(3)
γ /°	90
Volume /Å <sup>3</sup>	3076.8(3)
Z	4
ρ <sub>calc</sub> / g cm <sup>-3</sup>	1.100
μ/mm <sup>-1</sup>	1.560
F(000)	1104
Crystal size /mm <sup>3</sup>	0.112 x 0.187 x 0.216
Θ range for data collection /°	2.69 to 66.54
Index ranges	-18<=h<=19, -17<=k<=17, -14<=l<=12
Reflections collected (all/independent)	22461/ 5064
Data/restraints/parameters	5064 / 0 / 318
Goodness-of-fit on F <sup>2</sup>	0.912
Final R indexes [I>2σ (I)]	R1 = 0.0828, wR2 = 0.2376
Final R indexes [all data]	R1 = 0.1987, wR2 = 0.2823
Largest diff. peak and hole /e Å <sup>-3</sup>	0.365 and -0.217



**Figure S3.** ORTEP diagram (50% probability) of **20a**

**Table S3.** Crystal data and structure refinement details for **20a**

Empirical formula	C <sub>29</sub> H <sub>41</sub> NO <sub>6</sub> SSi
Formula weight /g mol <sup>-1</sup>	559.78
Crystal color and habit	colourless cube
CCDC No.	1895500
Temperature /K	296(2)
Crystal system	triclinic
Space group	P 1
a /Å	9.4418(3)
b /Å	12.2002(3)
c /Å	13.6897(4)
α /°	99.2360(10)
β /°	104.5580(10)
γ /°	97.6000 (10)
Volume /Å <sup>3</sup>	1481.73(7)
Z	2
ρ <sub>calc</sub> / g cm <sup>-3</sup>	1.255
μ/mm <sup>-1</sup>	1.697
F(000)	600
Crystal size /mm <sup>3</sup>	0.280 x 0.410 x 0.529
Θ range for data collection /°	3.41 to 66.58
Index ranges	-10<=h<=11, -14<=k<=14, -16<=l<=16
Reflections collected (all/independent)	50041/ 9885
Data/restraints/parameters	9885 / 3 / 747
Goodness-of-fit on F <sup>2</sup>	1.043
Final R indexes [I>2σ (I)]	R1 = 0.0413, wR2 = 0.1079
Final R indexes [all data]	R1 = 0.0466, wR2 = 0.1141
Largest diff. peak and hole /e Å <sup>-3</sup>	0.290 and -0.409

## 7. References and notes.

1. Occasionally, the reaction stops before full conversion of starting  $\beta$ -lactam most likely due to relatively quicker redox disproportionation of particular batches of InI powder under the developed conditions. In the cases when it can not be restarted with additional portion of InI, the use of InI in the form of small beads (~10 mesh) instead of fine powder is recommended in further applications of the procedure.
2. Hachiya, I.; Ogura, K.; Shimizu, M. Novel 2-Pyridone Synthesis via Nucleophilic Addition of Malonic Esters to Alkynyl Imines. *Org. Lett.* **2002**, *4*, 2755–2757.
3. Plata, P.; Klimczak, U.; Zambroń, B. K. Acyclic Remote 1,5- and 1,4,5-Stereocontrol in the Catalytic Stereoselective Reactions of  $\beta$ -Lactams with Aldehydes: The Effect of the *N*-Methylimidazole Ligand. *J. Org. Chem.* **2018**, *83*, 14527–14552.
4. Compounds (+)-**iv** and (-)-**v** were prepared according to the modified procedure reported previously: Kuznetsova, L.; Ungureanu, I. M.; Pepe, A.; Zanardi, I.; Wu, X.; Ojima, I. Trifluoromethyl- and difluoromethyl- $\beta$ -lactams as useful building blocks for the synthesis of fluorinated amino acids, dipeptides, and fluoro-taxoids. *J. Fluorine Chem.* **2004**, *125*, 487-500.
5. A total of 1000 mL of 0.2 M phosphate buffer solution (pH 7.5) was prepared by dissolution of  $\text{KH}_2\text{PO}_4$  (27.22 g) in water (930 mL), adjustment of pH to 7.5 with a 300 g/L aqueous solution of KOH, and dilution to 1000 mL of water.
6. Seitz, J. D.; Wang, T.; Vineberg, J. G.; Honda, T.; Ojima, I. Synthesis of a Next-Generation Taxoid by Rapid Methylation Amenable for  $^{13}\text{C}$ -Labeling. *Journal of Organic Chemistry* **2018**, *83*, 2847 – 2857.
7. Due to confirmed acute toxicity in mammals and proved carcinogenicity towards rats, HMPA should be considered dangerous. Thus, all necessary precautions must be taken to avoid exposure to this chemical and, when possible, the use of safer substitutes such as DMPU or DMI is recommended. For details see: Dykstra, R. R. Hexamethylphosphoric Triamide. In: Encyclopedia of Reagents for Organic Synthesis, 2011, doi:10.1002/047084289X.rh020 and references therein.
8. Containing ~ 8 % of two C5-epimers in 75:25 ratio according to  $^1\text{H}$  NMR.
9. In these cases, collected fractions were diluted with toluene (50% v/v) before removal of eluent under reduced pressure to avoid  $\text{HCO}_2\text{H}$  concentration.
10. Containing ~ 9% of two C5-epimers in 54:46 ratio according to  $^1\text{H}$  NMR.
11. 37% of starting  $\beta$ -lactam **10** was recovered.
12. 30% of starting  $\beta$ -lactam **10** was recovered.
13. 56% of starting  $\beta$ -lactam **15** was recovered.
14. 51% of starting  $\beta$ -lactam **15** was recovered.
15. Containing ~ 7 % of two C5-epimers in 75:25 ratio according to  $^1\text{H}$  NMR.
16. Klimczak, U. K.; Zambroń, B. K. Effective 1,5-stereocontrol in Pd(0)/InI promoted reactions of chiral *N*-Ts-4-vinylazetid-2-ones with aldehydes. An efficient entry to nonracemic semi-protected (3*Z*)-2,6-*anti*-enediols. *Chem. Commun.* **2015**, *51*, 6796– 6799.
17. Compound **19** was prepared according to the modified procedure reported previously: Winkler, J. D.; Quinn, K. J.; MacKinnon, C. H.; Hiscock, S. D.; McLaughlin, E. C. Tandem Diels–Alder/Fragmentation Approach to the Synthesis of Eleutherobin. *Org. Lett.* **2003**, *5*, 1805–1808.
18.  $\alpha$ -Allenyl ketone **19** appeared to be prone to epimerization on silica gel to give the mixture of both C5-epimers in 85:15 ratio after flash chromatography. However only single diastereomer of **19** can be detected in the crude reaction mixture – see page S58-S59.
19. Reduction of two double bonds and methylation of *N*-Ts-amido group prior to esterification is necessary since attempts of obtaining Mosher's esters directly from allenes **2** and **7** resulted in complex mixtures of products, while esterification of 1,5-diols bearing NH-Ts group led to corresponding caprolactams *via* subsequent intramolecular O(+)-MTPA group substitution under the reaction conditions.
20. For related structure to compound (-)-**v** see: Koo, B.; McDonald, F. E. Fischer Carbene Catalysis of Alkynol Cycloisomerization: Application to the Synthesis of the Altromycin B Disaccharide. *Org. Lett.* **2007**, *9*, 1737–1740.