Electronic Supplementary Information for

Au-catalyzed stereodivergent synthesis of 2,5-disubstituted pyrrolidines: Total synthesis of (+)-monomorine I and (+)-indolizidine 195B

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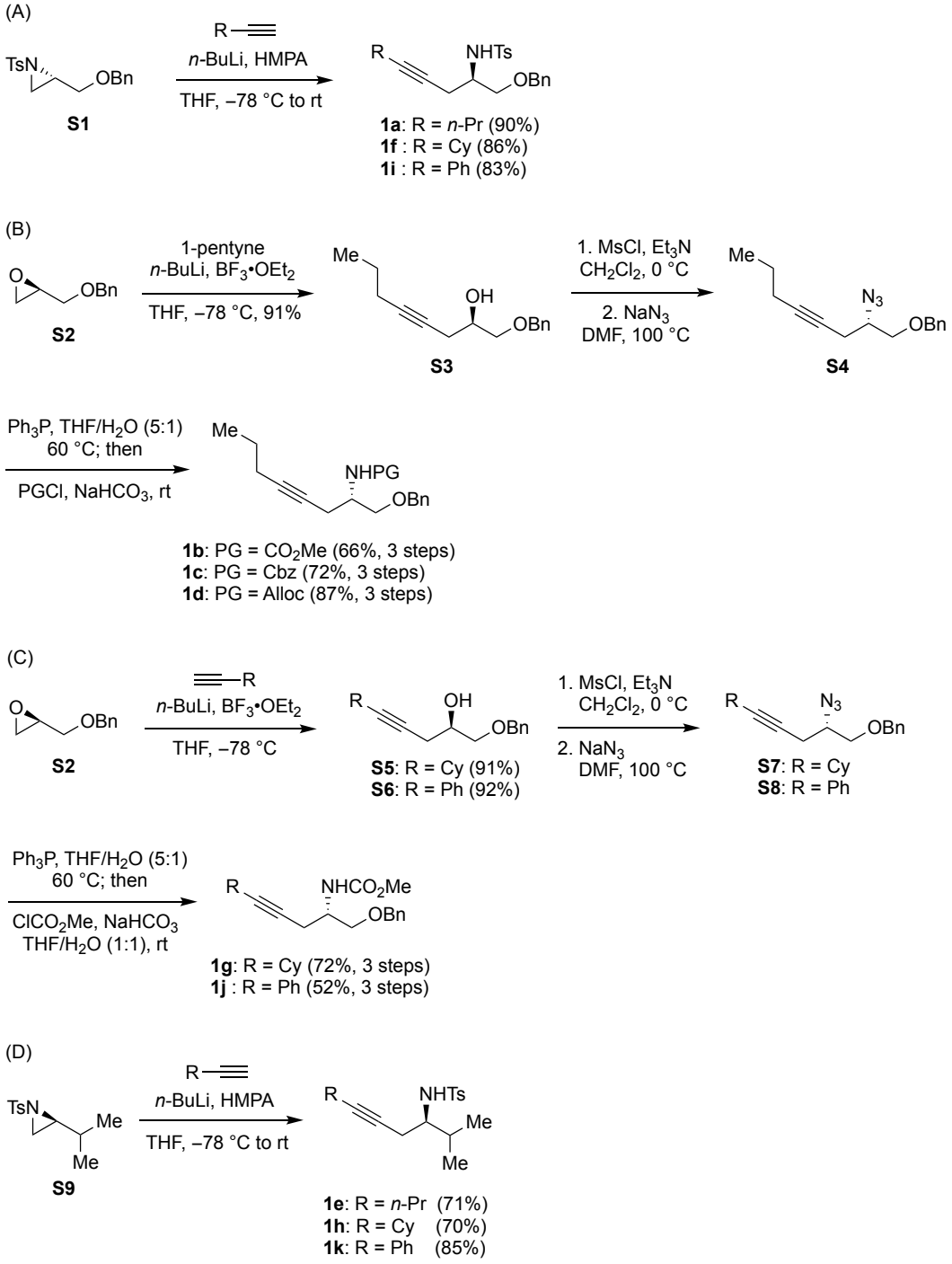
Preparation of starting materials

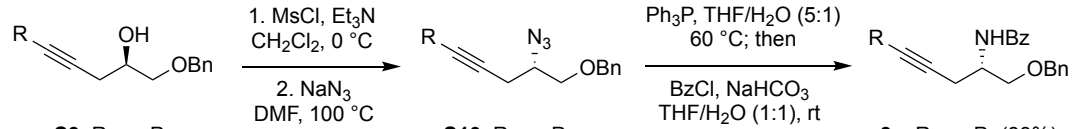
Compounds **1a**–**1d**, **1g**, **1i**, **1j**, **S1**, **S9**, and *rac*-**S13**[1,2] were synthesized as described previously.



[1] A. Yoshimura, R. Hanzawa and H. Fuwa, *Org. Lett.*, 2022, **24**, 6237.

[2] B. L. Elbert, D. S. W. Lim, H. G. Gudmundsson, J. A. O'Hanlon and E. A. Anderson, *Chem. Eur. J.*, 2014, **20**, 8594.

(E)

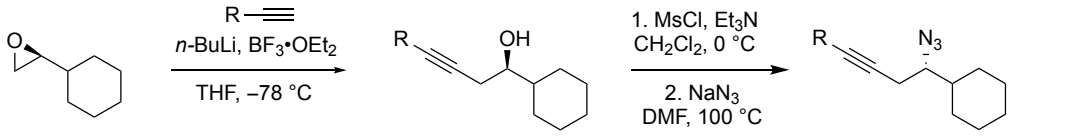


S3: R = *n*-Pr
S5: R = Cy
S6: R = Ph

S10: R = *n*-Pr
S11: R = Cy
S12: R = Ph

3a: R = *n*-Pr (83%)
3b: R = Cy (55%)
3c: R = Ph (47%)

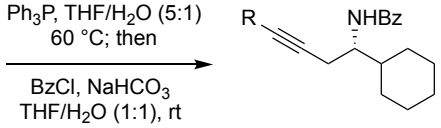
(F)



rac-**S13**

rac-**S14**: R = *n*-Pr (93%)
rac-**S15**: R = Ph (83%)

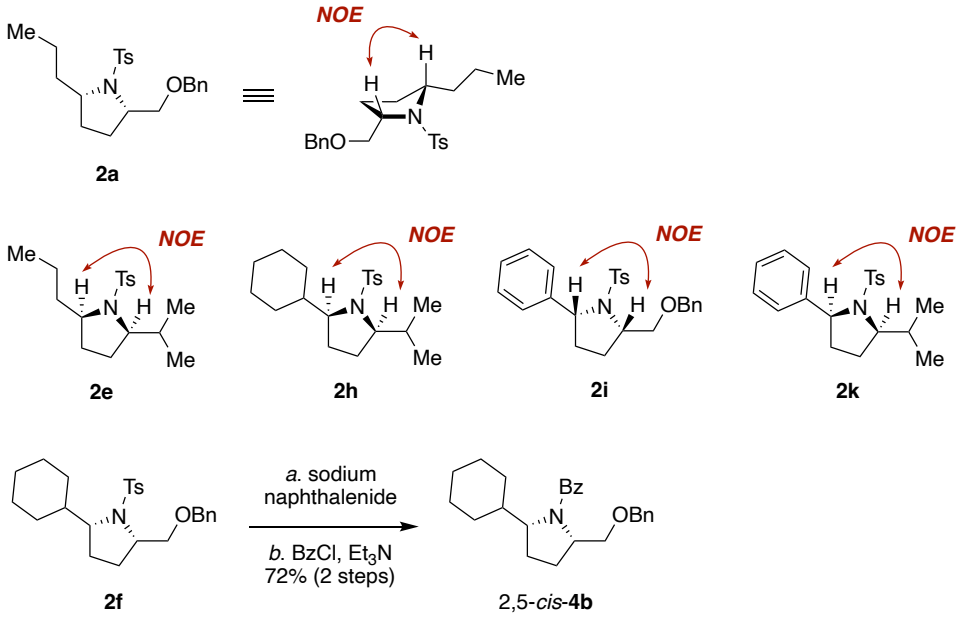
rac-**S16**: R = *n*-Pr (58%, 2 steps)
rac-**S17**: R = Ph (43%, 2 steps)



rac-**3d**: R = *n*-Pr (93%)
rac-**3e**: R = Ph (96%)

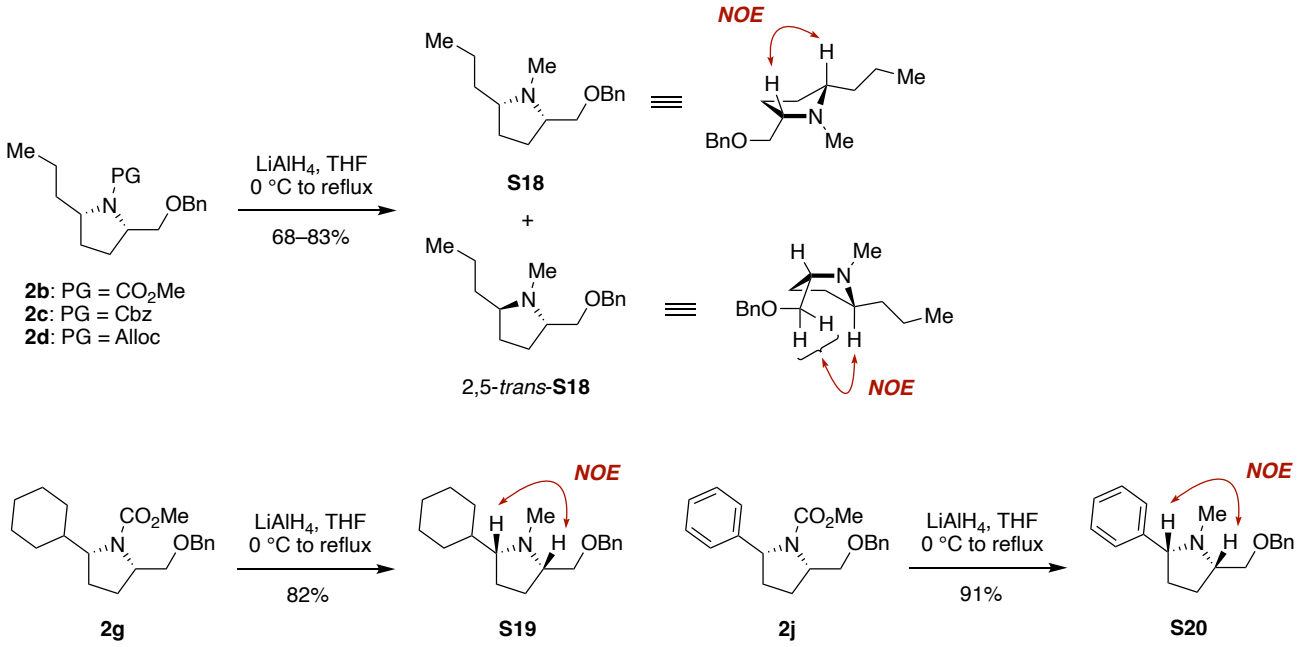
Stereochemical assignment of important compounds

1. *N*-Ts protected pyrrolidine derivatives **2a**, **2e**, **2f**, **2h**, **2i**, and **2k**.



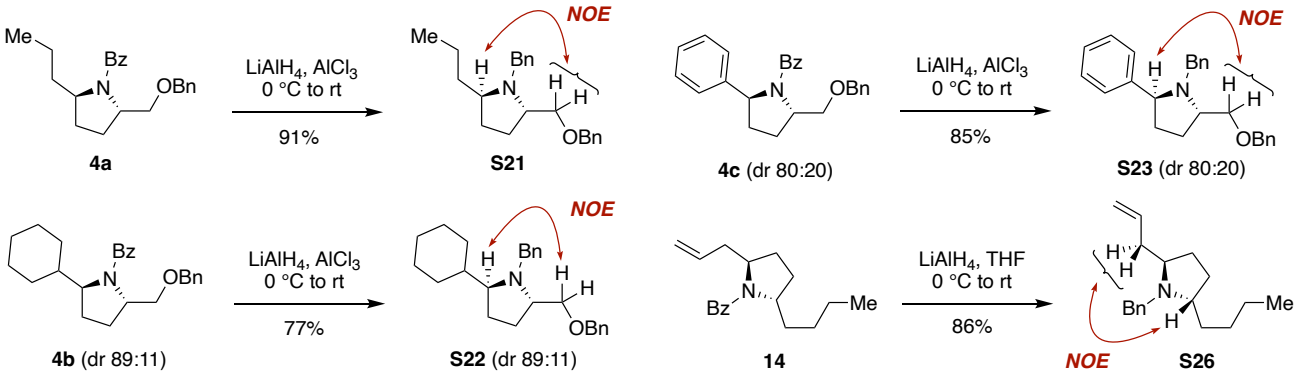
The configuration of compounds **2a**, **2e**, **2h**, **2i**, and **2k** was confirmed by NOE experiments as shown. The configuration of compound **2f** was assigned by its derivatization into 2,5-*cis*-**4b**, whose ^{1}H NMR spectrum showed significant signal broadening analogous to the ^{1}H NMR spectrum of 2,5-*cis*-**4a**.

2. *N*-CO_2R protected pyrrolidine derivatives **2b**–**2d**, **2g**, and **2j**.



The configuration of compounds **2b**, **2c**, **2d**, **2g**, and **2j** was confirmed by NOE experiments as shown.

3. *N*-Bz protected pyrrolidine derivatives **4a**–**4e** and **14**.



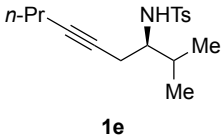
The configuration of compounds **4a**, **4b**, **4c**, and **14** was confirmed by NOE experiments as shown. Notably, significant signal broadening was observed for the ^{1}H NMR spectrum of 2,5-*cis*-**4a**, whereas two sets of sharp signals were recorded for the ^{1}H NMR spectrum of 2,5-*trans*-**4a**. These NMR characteristics were used for the configurational assignment of compounds **4d** and **4e**.

General remarks

All reactions sensitive to moisture and/or air were carried out under an atmosphere of argon in dry solvents under anhydrous conditions using oven-dried glassware unless otherwise noted. Where appropriate, solvents were degassed by the freeze–thaw technique immediately prior to use. Anhydrous dichloromethane, diethyl ether, tetrahydrofuran (THF), and toluene were purchased from Kanto Chemical Co. Inc. and used directly. 1,2-Dichloroethane (DCE) was distilled from calcium hydride under an atmosphere of argon. All other chemicals were purchased at highest commercial grade and used directly. Analytical thin-layer chromatography was performed using FUJIFILM Wako silica gel 70 F_{254} plates (0.25-mm thickness) or Fuji Silysia NH TLC plates (0.25-mm thickness). Flash column chromatography was carried out using CHROMATOREX PSQ100B, CHROMATOREX BW-300 or CHROMATOREX NH-DM2035 (Fuji Silysia Chemicals). Optical rotations were recorded on a JASCO P-1020 digital polarimeter. IR spectra were recorded on a JASCO FT/IR-4100 spectrometer. ^{1}H and ^{13}C NMR spectra were recorded on a JEOL ECZ-500R spectrometer or a Varian Mercury 400 spectrometer, and chemical shift values are reported in ppm (δ) downfield from tetramethylsilane with reference to internal residual solvent [^{1}H NMR, C*H*Cl_3 (7.24); ^{13}C NMR, $CDCl_3$ (77.0)] unless otherwise noted. Coupling constants (*J*) are reported in Hertz (Hz). The following abbreviations were used to designate the multiplicities: s = singlet; d = doublet; t = triplet; q = quartet; m = multiplet; br = broad. High-resolution mass spectra were measured on a JEOL JMS-T100LC AccuTOF spectrometer.

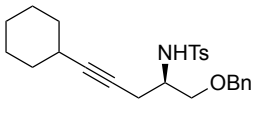
Experimental procedure and compound characterization data

1) Synthesis of starting materials



1e

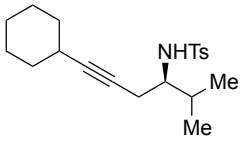
Amino alkyne 1e. To a solution of 1-pentyne (65 μL, 0.67 mmol) and HMPA (105 μL, 0.604 mmol) in THF (3.00 mL) at −78 °C was added *n*-BuLi (2.64 M solution in *n*-hexane, 230 μL, 0.607 mmol), and the resultant mixture was stirred at −78 °C for 20 min. To the reaction mixture at −78 °C was added a solution of azidirine **S9**[1] (102.5 mg, 0.4283 mmol) in THF (700 μL + 500 μL rinse), and the resultant mixture was allowed to warm to room temperature over a period of 9 h. The reaction was quenched with saturated aqueous NH_4Cl solution. The resultant mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% acetone/hexanes) gave amino alkyne **1e** (93.8 mg, 71%) as a colorless oil: $[\alpha]_D^{24}$ −106.8 (*c* 0.76, $CHCl_3$); **IR** (film): 3282, 2963, 2872, 1329, 1161, 666 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.74 – 7.73 (m, 2H), 7.27 – 7.25 (m, 2H), 4,75 (d, *J* = 9.5 Hz, 1H), 3.02 – 2.96 (m, 1H), 2.39 (s, 3H), 2.27 – 2.21 (m, 1H), 2.09 – 2.01 (m, 3H), 1.92 – 1.82 (m, 1H), 1.44 (qt, *J* = 7.5, 7.5 Hz, 2H), 0.91 (t, *J* = 7.5 Hz, 3H), 0.84 (d, *J* = 7.0 Hz, 3H), 0.81 (d, *J* = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.2, 138.0, 129.6 (2C), 127.0 (2C), 83.4, 74.8, 57.6, 30.8, 22.5, 22.2, 21.5, 20.6, 19.1, 18.3, 13.4; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{17}H_{25}NO_2NaS^+$ 330.1498; found: 330.1499.



1f

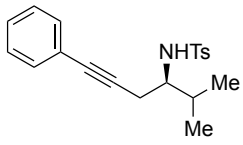
Amino alkyne 1f. According to the procedure described for amino alkyne **1e**, the reaction of aziridine **S1**[1] (250.0 mg, 0.7884 mmol) with cyclohexylacetylene (160 μL, 1.22 mmol) using HMPA (200 μL, 1.15 mmol) and *n*-BuLi (2.64 M solution in *n*-hexane, 420 μL, 1.11 mmol), followed by purification by flash column chromatography (silica gel, 5% EtOAc/toluene), gave amino alkyne **1f** (287.6 mg, 86%) as colorless crystals: **m.p.**: 91 – 92 °C; $[\alpha]_D^{24}$ +21.0 (*c* 0.20, $CHCl_3$); **IR** (KBr): 3426, 3309, 2926, 2853, 1450, 1329, 1156, 670 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.72 – 7.71 (m, 2H), 7.34 – 7.22 (m, 7H), 4.92 (d, *J* = 8.0 Hz, 1H), 4.41 (d, *J* = 12.5 Hz, 1H), 4.40 (d, *J* = 12.5 Hz, 1H), 3.55 (dd, *J* = 9.5, 4.0 Hz, 1H), 3.48 – 3.41 (m, 1H), 3.35 (dd, *J* = 9.5, 6.0 Hz, 1H), 2.43 (ddd, *J* = 17.0, 4.5, 2.0 Hz, 1H), 2.39 (s, 3H), 2.30 (ddd, *J* = 17.0, 7.0, 2.0 Hz, 1H), 2.25 – 2.18 (m, 1H), 1.71 – 1.58 (m, 4H), 1.52 – 1.45

(m, 1H), 1.33 – 1.18 (m, 5H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.3, 137.7, 129.6 (2C), 128.4 (2C), 127.7 (2C), 127.6 (2C), 127.0 (2C), 87.8, 74.6, 73.2, 69.9, 51.9, 32.8 (2C), 29.0, 25.8 (2C), 24.8, 22.3, 21.5; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{31}NO_3NaS^+$ 448.1917; found: 448.1891.



1h

Amino alkyne 1h. According to the procedure described for amino alkyne **1e**, the reaction of aziridine **S9** (74.1 mg, 0.310 mmol) with cyclohexylacetylene (60 μL, 0.46 mmol) using HMPA (80 μL, 0.46 mmol) and *n*-BuLi (2.70 M solution in *n*-hexane, 130 μL, 0.351 mmol), followed by purification by flash column chromatography (silica gel, 2 to 10% acetone/hexanes), gave amino alkyne **1h** (75.1 mg, 70%) as a colorless oil: **[α]**$_D^{24}$ −89.6 (*c* 0.98, $CHCl_3$); **IR** (film): 3283, 2959, 2929, 2853, 1448, 1329, 1161 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$) δ 7.51 (d, *J* = 8.5 Hz, 2H), 7.27 (d, *J* = 8.5 Hz, 2H), 4.63 (d, *J* = 10.0 Hz, 1H), 2.99 (dddd, *J* = 11.0, 9.5, 7.0, 4.0 Hz, 1H), 2.40 (s, 3H), 2.27 – 2.22 (m, 2H), 2.05 (ddd, *J* = 17.0, 6.0, 2.5 Hz, 1H), 1.91 – 1.81 (m, 1H), 1.72 – 1.70 (m, 2H), 1.66 – 1.61 (m, 2H), 1.49 – 1.48 (m, 1H), 1.36–1.23 (m, 5H), 0.85 (t, *J* = 7.0 Hz, 3H), 0.82 (t, *J* = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 Mz, $CDCl_3$): δ 143.2, 138.2, 129.6 (2C), 127.0 (2C), 88.0, 74.5, 57.5, 32.9 (2C), 31.0, 29.0, 25.8 (2C), 24.8, 22.4, 21.5, 19.1, 18.4; **HRMS** (DART) *m*/*z*: calcd for $C_{20}H_{30}NO_2^+$ [(M + H)$^+$] 348.1992; found: 348.1991.



1k

Amino alkyne 1k. According to the procedure described for amino alkyne **1e**, the reaction of aziridine **S9** (74.8 mg, 0.276 mmol) with phenyl acetylene (45 μL, 0.41 mmol) using HMPA (75 μL, 0.43 mmol) and *n*-BuLi (2.70 M solution in *n*-hexane, 140 μL, 0.378 mmol), followed by purification by flash column chromatography (silica gel, 10 to 15 % acetone/hexanes), gave amino alkyne **1k** (90.8 mg, 85%) as colorless crystals: **m.p.**: 100 – 102 °C; **[α]**$_D^{22}$ −155.1 (*c* 0.75, $CHCl_3$); **IR** (KBr): 3277, 3027, 2920, 2861, 1496 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.78 – 7.72 (m, 2H), 7.32 – 7.23 (m, 7H), 4.70 (d, *J* = 5.0 Hz, 1H), 3.12 (ddddd, *J* = 16.0, 13.0, 10.5, 6.0, 4.5 Hz, 1H), 2.53 (d, *J* = 16.0, 4.5 Hz, 1H), 2.41 – 2.37 (m, 4H), 2.03 – 1.93 (m, 1H), 0.88 – 0.86 (m, 6H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.3, 137.9, 131.6 (2C), 129.6 (2C), 128.2 (2C), 128.0, 127.0 (2C), 123.0, 84.9, 83.3, 57.6, 31.1, 23.4, 21.5, 19.1, 18.2; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{20}H_{24}NO_3S^+$ 342.1552; found 342.1523.

Amino alkyne 3a. To a solution of alcohol **S3**[1] (2.37 g, 10.2 mmol) in CH_2Cl_2 (50.0 mL) at 0 °C were added Et_3N (2.85 mL, 20.4 mmol) and MsCl (1.20 mL, 15.4 mmol), and the resultant mixture was stirred at 0 °C for 15 min. The reaction was quenched with H_2O at 0 °C. The resultant mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure to give crude mesylate as a pale yellow oil, which was used in the next reaction without further purification.

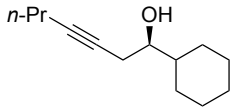
To a solution of the above mesylate in DMF (34.0 mL) was added NaN_3 (3.35 g, 51.5 mmol), and the resultant mixture was stirred at 100 °C for 14 h. The reaction was quenched with H_2O at 0 °C. The resultant mixture was extracted with EtOAc/hexanes (1:1, v/v), and the organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave azide **S10** (1.89 g) as a pale yellow oil, which was used in the next reaction without further purification.

To a solution of the above azide **S10** (1.89 g) in THF/H_2O (5:1, v/v, 54.0 mL) was added Ph_3P (5.35 g, 20.4 mmol), and the resultant mixture was stirred at 60 °C for 12 h. To the reaction mixture at 0 °C were added H_2O (35.0 mL), $NaHCO_3$ (2.57 g, 30.6 mmol), and benzoyl chloride (1.30 mL, 11.2 mmol), and the resultant mixture was stirred vigorously at room temperature for 4 h. The reaction mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (5 to 10% EtOAc/hexanes) gave amino alkyne **3a** (2.14 g, 83% for the three steps) as colorless crystals: **m.p.**: 48 – 49 °C; $[\alpha]_D^{24}$ +11.6 (*c* 0.95, $CHCl_3$); **IR** (KB r): 3324, 2962, 2863, 1639, 1535, 696 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.73 – 7.72 (m, 2H), 7.50 – 7.47 (m, 1H), 7.42 – 7.39 (m, 2H), 7.33 – 7.32 (m, 4H), 7.30 – 7.26 (m, 1H), 6.49 (d, *J* = 8.5 Hz, 1H), 4.56 (s, 2H), 4.42 – 4.36 (m, 1H), 3.77 (dd, *J* = 9.5 Hz, 4.5 Hz, 1H), 3.59 (dd, *J* = 9.5, 4.5 Hz, 1H), 2.64 (dddd, *J* = 16.5, 4.5, 2.5, 2.5 Hz, 1H), 2.55 (dddd, *J* = 16.5, 7.5, 2.5, 2.5 Hz, 1H), 2.10 (dddd, *J* = 7.5, 7.5, 2.5, 2.5 Hz, 2H), 1.46 (qdd, *J* = 7.5, 7.5, 7.5 Hz, 2H), 0.93 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 166.9, 138.0, 134.5, 131.5, 128.5 (2C), 128.4 (2C), 127.7 (2C), 126.9 (3C), 82.8, 75.7, 73.2, 69.8, 48.1, 22.3, 21.5, 20.7, 13.5; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{25}NO_2Na^+$ 358.1778; found: 358.1797.

Amino alkyne 3b. According to the procedure described for amino alkyne **3a**, the reaction of alcohol **S5**[1] (749.1 mg, 2.750 mmol) using Et_3N (770 μL, 5.52 mmol), MsCl (320 μL, 4.12 mmol), NaN_3 (896.8 g, 13.78 mmol), Ph_3P (1.46 g, 5.57 mmol), $NaHCO_3$ (693.5 mg, 8.255 mmol), and benzoyl chloride (350 μL, 3.01 mmol), followed by purification by flash column chromatography (silica gel, 5 to 20% EtOAc/hexanes), gave amino alkyne **3b** (568.0 mg, 55% for the three steps) as a colorless oil: $[\alpha]_D^{24}$ +12.5 (*c* 0.96, $CHCl_3$); **IR** (film): 3316, 2928, 2852, 1638, 1537, 1488, 696 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.74 – 7.72 (m, 2H), 7.50 – 7.46 (m, 1H), 7.44 – 7.40 (m, 2H), 7.33 – 7.26 (m, 5H), 6.49 (d, *J* = 8.5 Hz, 1H), 4.56 (s, 2H), 4.43 – 4.37 (m, 1H), 3.77 (dd, *J* = 9.5, 4.0 Hz, 1H), 3.59 (dd, *J* = 9.5, 5.5 Hz, 1H), 2.63 (ddd, *J* = 16.0, 9.5, 2.5 Hz, 1H), 2.55 (ddd, *J* = 16.0, 7.5, 2.5 Hz, 1H), 2.35 – 2.27 (m, 1H), 1.75 – 1.60 (m, 4H), 1.49 – 1.24 (m, 6H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 166.8, 138.0, 134.5, 131.5, 128.5 (2C), 128.4 (2C), 127.73, 127.69 (2C), 126.9 (2C), 87.3, 75.5, 73.2, 69.8, 48.1, 32.9 (2C), 29.0, 25.8 (2C), 24.8, 21.5; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{29}NO_2Na^+$ 398.2091; found: 398.2109.

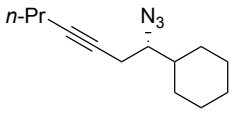
Amino alkyne 3c. According to the procedure described for amino alkyne **3a**, the reaction of alcohol **S6** (732.7 mg, 2.751 mmol) using Et_3N (770 μL, 5.52 mmol), MsCl (320 μL, 4.12 mmol), NaN_3 (896.5 mg, 13.77 mmol), Ph_3P (1.42 g, 5.41 mmol), $NaHCO_3$ (697.0 mg, 8.297 mmol), and benzoyl chloride (350 μL, 3.01 mmol), followed by purification by flash column chromatography (silica gel, 5% EtOAc/hexanes), gave amino alkyne **3c** (477.7 mg, 47% for the three steps) as colorless crystals: **m.p.**: 69 – 72 °C; $[\alpha]_D^{24}$ +23.8 (*c* 0.48, $CHCl_3$); **IR** (KBr): 3307, 2907, 1632, 1530, 1490, 692 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.76 – 7.74 (m, 2H), 7.51 – 7.25 (m, 13H), 6.59 (d, *J* = 8.5 Hz, 1H), 4.60 (s, 2H), 4.56 – 4.49 (m, 1H), 3.87 (dd, *J* = 9.0, 4.0 Hz, 1H), 3.67 (dd, *J* = 9.0, 5.0 Hz, 1H), 2.90 (dd, *J* = 16.5, 5.0 Hz, 1H), 2.82 (dd, *J* = 16.5, 3.0 Hz, 1H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 167.1, 138.0, 134.5, 131.75 (2C), 131.68, 128.7 (2C), 128.6 (2C), 128.4 (2C), 128.0, 127.95, 127.85 (2C), 127.1 (2C), 123.4, 85.9, 82.9, 73.5, 69.9, 48.3, 22.4; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{23}NO_2Na^+$ 392.1621; found: 392.1636.

Synthesis of amino alkyne *rac*-3d.



rac-**S14**

Alcohol *rac*-S14. To a solution of 1-pentyne (1.00 mL, 10.3 mmol) in THF (30.0 mL) at −78 °C was added *n*-BuLi (2.69 M solution in *n*-hexane, 3.60 mL, 9.68 mmol), and the resultant mixture was stirred at −78 °C for 15 min. To the reaction mixture at −78 °C was added BF_3•OEt_2 (1.20 mL, 9.55 mmol), and the resultant mixture was stirred at −78 °C for 15 min. To the reaction mixture was added epoxide **S13**[2] (862.0 mg, containing CH_2Cl_2 and hexanes, 4.892 mmol as calculated by ^{1}H NMR analysis) in THF (1.00 mL), and the resultant mixture was stirred at −78 °C for 3 h. The reaction was quenched with saturated aqueous NH_4Cl solution at −78 °C. The resultant mixture was warmed to room temperature and extracted with EtOAc. The organic layer was washed with H_2O and brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave alcohol *rac*-**S14** (887.4 mg, 93%) as a colorless oil: **IR** (film): 3414, 2926, 2852, 1449, 1038 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 3.41 – 3.37 (m, 1H), 2.39 (dddd, *J* = 16.5, 4.0, 2.0, 2.0 Hz, 1H), 2.27 (dddd, *J* = 16.5, 6.0, 2.0, 2.0 Hz, 1H), 2.12 (dddd, *J* = 7.5, 7.5, 2.0, 2.0 Hz, 2H), 1.92 – 1.85 (m, 2H), 1.75 – 1.68 (m, 2H), 1.65 – 1.61 (m, 2H), 1.49 (qt, *J* = 7.5, 7.5 Hz, 2H), 1.43 – 1.36 (m, 1H), 1.26 – 1.05 (m, 3H), 1.02 – 0.94 (m, 2H), 0.94 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 83.0, 76.5, 74.2, 42.5, 28.9, 28.3, 26.4, 26.1, 26.0, 25.0, 22.4, 20.7, 13.5; **HRMS** (DART) *m*/*z*: [(M + NH_4)$^+$] calcd for $C_{13}H_{26}NO^+$ 212.2009; found: 212.1993.



rac-**S16**

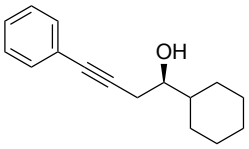
Azide *rac*-S16. To a solution of alcohol *rac*-**S14** (864.2 mg, 4.447 mmol) in CH_2Cl_2 (20.0 mL) at 0 °C were added Et_3N (1.25 mL, 8.97 mmol) and MsCl (520 μL, 6.69 mmol), and the resultant mixture was stirred at 0 °C for 15 min. The reaction was quenched with H_2O at 0 °C. The resultant mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure to give crude mesylate as a pale yellow oil, which was used in the next reaction without further purification.

To a solution of the above mesylate in DMF (15.0 mL) was added NaN_3 (1.44 g, 22.1 mmol), and the resultant mixture was stirred at 100 °C for 14 h. The reaction was quenched with H_2O at 0 °C. The resultant mixture was

extracted with 1:1 (v/v) EtOAc/hexanes, and the organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave azide *rac*-**S16** (568.6 mg, 58% for the two steps) as a pale yellow oil: **IR** (film): 2929, 2854, 2099, 1450, 1338 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 3.22 – 3.18 (m, 1H), 2.45 (dddd, *J* = 17.0, 5.0, 2.5, 2.5 Hz, 1H), 2.39 (dddd, *J* = 17.0, 10.0, 2.5, 2.5 Hz, 1H), 2.12 (dddd, *J* = 7.5, 7.5, 2.5, 2.5 Hz, 2H), 1.81 – 1.70 (m, 3H), 1.68 – 1.61 (m, 2H), 1.56 – 1.46 (m, 3H), 1.27 – 0.95 (m, 5H), 0.95 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 82.9, 75.9, 67.1, 41.1, 29.8, 28.3, 26.2, 26.1, 25.9, 22.6, 22.2, 20.7, 13.5; **HRMS** (DART) *m*/*z*: [$(M + NH_4)^+$] calcd for $C_{13}H_{25}N_4^+$ 237.2074; found: 237.2072.

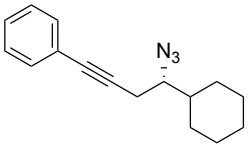
Amino alkyne *rac*-3d. To a solution of azide *rac*-**S16** (552.3 mg, 2.518 mmol) in THF/H_2O (5:1, v/v, 12.0 mL) was added Ph_3P (799.0 mg, 3.046 mmol), and the resultant mixture was stirred at 60 °C for 17 h. To the reaction mixture at 0 °C were added H_2O (8.0 mL), $NaHCO_3$ (640.0 mg, 7.618 mmol), and benzoyl chloride (320 μL, 2.75 mmol), and the resultant mixture was stirred vigorously at room temperature for 2 h. The resultant mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5 to 15% EtOAc/hexanes) gave amino alkyne *rac*-**3d** (694.9 mg, 93%) as colorless crystals: **m.p.**: 91 – 93 °C; **IR** (KBr): 3291, 2916, 2848, 1635, 1543, 693 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.76 – 7.75 (m, 2H), 7.49 – 7.45 (m, 1H), 7.43 – 7.40 (m, 2H), 6.26 (d, *J* = 9.5 Hz, 1H), 4.04 – 3.98 (m, 1H), 2.54 – 2.44 (m, 2H), 2.12 (dddd, *J* = 7.5, 7.5, 2.5, 2.5 Hz, 2H), 1.85 – 1.70 (m, 4H), 1.66 – 1.56 (m, 2H), 1.49 (qdd, *J* = 7.5, 7.5, 7.5 Hz, 2H), 1.28 – 0.98 (m, 5H), 0.94 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 167.0, 134.9, 131.3, 128.5 (2C), 126.8 (2C), 82.8, 75.8, 52.2, 40.5, 29.7, 29.3, 26.2, 26.05, 26.01, 22.4, 22.1, 20.7, 13.5; **HRMS** (ESI) *m*/*z*: [$(M + Na)^+$] calcd for $C_{20}H_{27}NONa^+$ 320.1985; found: 320.1987.

Synthesis of amino alkyne *rac*-3e.



rac-**S15**

Alcohol *rac*-S15. According to the procedure described for alcohol *rac*-**S14**, the reaction of epoxide **S13**[2] (890.6 mg, containing CH_2Cl_2 and hexanes, 5.073 mmol as calculated by ^{1}H NMR analysis) with phenyl acetylene (1.15 mL, 10.5 mmol) using *n*-BuLi (2.69 M solution in *n*-hexane, 3.75 mL, 10.1 mmol) and BF_3•OEt_2 (1.25 mL, 9.95 mmol), followed by purification by flash column chromatography (silica gel, 1st round: 5% EtOAc/hexanes, 2nd round: 2 to 10% acetone/hexanes), gave alcohol *rac*-**S15** (960.2 mg, 83%) as a pale yellow oil: **IR** (film): 3402, 2925, 2851, 1490, 755 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.41 – 7.38 (m, 2H), 7.28 – 7.26 (m, 3H), 3.58 – 3.54 (m, 1H), 2.66 (dd, *J* = 17.0, 4.5 Hz, 1H), 2.56 (dd, *J* = 17.0, 7.5 Hz, 1H), 1.96 – 1.92 (m, 2H), 1.80 – 1.63 (m, 4H), 1.54 – 1.46 (m, 1H), 1.31 – 0.99 (m, 5H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 131.6 (2C), 128.2 (2C), 127.9, 123.4, 86.5, 82.9, 74.2, 42.6, 29.0, 28.2, 26.4, 26.1, 26.0, 25.6; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{16}H_{21}O^+$ 229.1587; found: 229.1605.



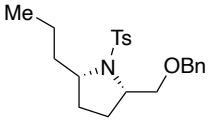
rac-**S17**

Azide *rac*-S17. According to the procedure described for azide *rac*-**S16**, the reaction of alcohol *rac*-**S15** (935.1 mg, 4.095 mmol) using Et_3N (1.15 mL, 8.25 mmol), MsCl (480 μL, 6.17 mmol), and NaN_3 (1.34 g, 20.6 mmol), followed by purification by flash column chromatography (silica gel, 5% EtOAc/hexanes), gave azide *rac*-**S17** (444.3 mg, 43% for the two steps) as a colorless oil: **IR** (film): 2928, 2853, 2116, 2099, 1490, 1261 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.43 – 7.39 (m, 2H), 7.29 – 7.26 (m, 3H), 3.37 – 3.34 (m, 1H), 2.72 (dd, *J* = 17.0, 5.0 Hz, 1H), 2.65 (dd, *J* = 17.0, 3.0 Hz, 1H), 1.85 – 1.56 (m, 6H), 1.30 – 1.01 (m, 5H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 131.5 (2C), 128.2 (2C), 127.9, 123.3, 85.8, 82.8, 66.7, 41.2, 29.8, 28.4, 26.2, 26.0, 25.9, 23.4; **HRMS** (DART) *m*/*z*: [(M + NH_4)$^+$] calcd for $C_{16}H_{23}N_4^+$ 271.1917; found: 271.1908.

Amino alkyne *rac*-3e. According to the procedure described for amino alkyne *rac*-**3d**, the reaction of azide *rac*-**17** (428.8 mg, 1.690 mmol) using Ph_3P (544.5 mg, 2.076 mmol), $NaHCO_3$ (426.3 mg, 5.074 mmol), and benzoyl chloride (220 μL, 1.89 mmol), followed by purification by flash column chromatography (silica gel, 5 to 15% EtOAc/hexanes), gave amino alkyne *rac*-**3e** (538.3 mg, 96%) as colorless crystals: **m.p.**: 161 – 162 °C; **IR**

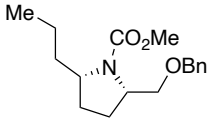
(KBr): 3330, 2915, 2849, 1637, 1530, 695 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.78 – 7.77 (m, 2H), 7.50 – 7.36 (m, 5H), 7.28 – 7.27 (m, 3H), 6.29 (d, *J* = 9.0 Hz, 1H), 4.17 – 4.21 (m, 1H), 2.77 (d, *J* = 5.0 Hz, 2H), 1.89 – 1.65 (m, 6H), 1.31 – 1.04 (m, 5H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 167.1, 134.8, 131.6 (2C), 131.4, 128.6 (2C), 128.3 (2C), 127.9, 126.9 (2C), 123.4, 85.9, 82.9, 52.3, 40.6, 29.8, 29.3, 26.2, 26.1, 26.0, 22.9; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{23}H_{26}NO^+$ 332.2009; found: 332.2012.

2) Synthesis of 2,5-*cis*-substituted pyrrolidine derivatives



2a

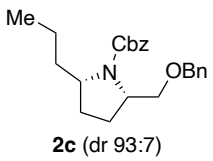
2,5-*cis*-Substituted pyrrolidine 2a. To a solution of amino alkyne **2a** (31.6 mg, 82.0 μmol) in moist DCE (820 μL) were added $AgSbF_6$ (1.6 mg, 4.7 μmol) and $(Ph_3P)AuCl$ (2.5 mg, 5.1 μmol), and the resultant mixture was stirred at room temperature for 40 min. To the reaction mixture were added Et_3SiH (55 μL, 0.35 mmol) and benzoic acid (10.6 mg, 86.8 μmol), and the resultant mixture was stirred at room temperature for 1 h. The reaction was quenched with saturated aqueous $NaHCO_3$ solution, and the resultant mixture was filtered through a pad of Celite. The filtrate was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave 2,5-*cis*-substituted pyrrolidine **2a** (28.3 mg, 89%, dr >95:5) as a colorless oil: **[α]**$_D^{22}$ −37.9 (*c* 0.51, $CHCl_3$); **IR** (film): 2957, 2870, 1455, 1343, 1160, 1092 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.70 – 7.68 (m, 2H), 7.35 – 7.25 (m, 7H), 4.55 (d, *J* = 7.0 Hz, 1H), 4.52 (d, *J* = 7.0 Hz, 1H), 3.77 – 3.72 (m, 2H), 3.55 – 3.49 (m, 1H), 3.44 – 3.40 (m, 1H), 2.40 (s, 3H), 1.87 – 1.78 (m, 2H), 1.52 – 1.26 (m, 6H), 0.89 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.3, 138.2, 134.7, 129.6 (2C), 128.3 (2C), 127.6 (2C), 127.6, 127.5 (2C), 73.45, 73.42, 61.8, 60.3, 38.8, 29.6, 27.5, 21.5, 19.4, 14.0; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{29}NO_3NaS^+$ 410.1760; found: 410.1741.



2b (dr 88:12)

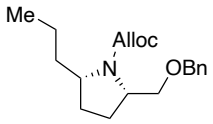
2,5-*cis*-Substituted pyrrolidine 2b. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2b** (24.7 mg, 85.4 μmol) using $AgSbF_6$ (1.6 mg, 4.7 μmol), $(Ph_3P)AuCl$ (2.6 mg, 5.3 μmol), Et_3SiH (55 μL, 0.35 mmol),

and benzoic acid (11.5 mg, 94.2 μmol), followed by purification by flash column chromatography (silica gel, 5% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2b** (23.5 mg, 94%, dr 88:12) as a colorless oil: $[\alpha]_D^{22}$ −44.3 (*c* 0.29, $CHCl_3$); **IR** (film): 2956, 2871, 1699, 1446, 1379, 1108 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.36 – 7.24 (m, 5H), 4.53 (d, *J* = 12.0 Hz, 1H), 4.50 (d, *J* = 12.0 Hz, 1H), 4.01 – 3.23 (m, 7H), 1.96 – 1.91 (m, 3H), 1.65 – 1.59 (m, 2H), 1.30 – 1.16 (m, 3H), 0.87 (t, *J* = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 128.3 (2C), 127.5 (2C), 73.2, 52.1, 19.4, 14.1, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{17}H_{26}NO_3^+$ 292.1907; found: 292.1924. The diastereomer ratio of this compound was determined by its derivatization into the corresponding *N*-methyl derivative by $LiAlH_4$ reduction (*vide infra*).



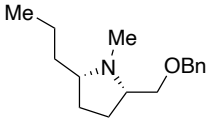
2c (dr 93:7)

2,5-*cis*-Substituted pyrrolidine 2c. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2c** (35.9 mg, 97.7 μmol) using $AgSbF_6$ (3.3 mg, 9.6 μmol), $(Ph_3P)AuCl$ (4.8 mg, 9.7 μmol), Et_3SiH (65 μL, 0.41 mmol), and benzoic acid (12.3 mg, 0.101 mmol), followed by purification by flash column chromatography (silica gel, 1st round: 5 to 10% EtOAc/hexanes, 2nd round: 10% acetone/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2c** (28.7 mg, 80%, dr 93:7) as a colorless oil: $[\alpha]_D^{24}$ −34.3 (*c* 0.76, $CHCl_3$); **IR** (film): 2957, 2871, 1698, 1406, 1098, 697 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.35 – 7.24 (m, 10H), 5.19 – 5.02 (m, 2H), 4.56 – 4.37 (m, 2H), 4.12 – 3.96 (m, 1H), 3.86 – 3.25 (m, 3H), 2.12 – 1.82 (m, 5H), 1.33 – 1.15 (m, 3H), 0.93 – 0.81 (m, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 136.9, 128.4 (2C), 128.3 (2C), 127.8, 127.7, 127.4 (2C), 73.1, 66.6, 19.4, 14.1, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{23}H_{29}NO_3Na^+$ 390.2040; found: 390.2019. The diastereomer ratio of this compound was determined by its derivatization into the corresponding *N*-methyl derivative by $LiAlH_4$ reduction (*vide infra*).

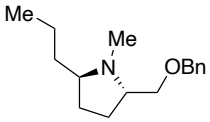


2d (dr 90:10)

2,5-*cis*-Substituted pyrrolidine 2d. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2d** (30.5 mg, 96.8 μmol) using $AgSbF_6$ (3.0 mg, 8.7 μmol), $(Ph_3P)AuCl$ (4.6 mg, 9.3 μmol), Et_3SiH (65 μL, 0.41 mmol), and benzoic acid (12.1 mg, 99.1 μmol), followed by purification by flash column chromatography (silica gel, 1st round: 5 to 10% EtOAc/hexanes, 2nd round: 8% acetone/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2d** (24.4 mg, 79%, dr 90:10) as a colorless oil: $[\alpha]_D^{24}$ −40.9 (*c* 0.65, $CHCl_3$); **IR** (film): 2957, 2871, 1699, 1399, 1099 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.34 – 7.24 (m, 5H), 5.96 – 5.80 (m, 1H), 5.30 – 5.14 (m, 2H), 4.65 – 4.45 (m, 4H), 4.08 – 4.00 (m, 1H), 3.84 – 3.25 (m, 3H), 2.03 – 1.62 (m, 5H), 1.32 – 1.17 (m, 3H), 0.91 – 0.86 (m, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 133.2, 128.3 (2C), 127.5 (2C), 116.9, 73.1, 65.4, 19.4, 14.1, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{19}H_{27}NO_3Na^+$ 340.1883; found: 340.1887. The diastereomer ratio of this compound was determined by its derivatization into the corresponding *N*-methyl derivative by $LiAlH_4$ reduction (*vide infra*).



S18



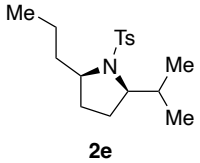
2,5-*trans*-**S18**

***N*-Methyl pyrrolidine S18 (from 2b).** To a suspension of $LiAlH_4$ (10.0 mg, 0.242 mmol) in THF (500 μL) at 0 °C was added a solution of 2,5-*cis*-substituted pyrrolidine **2b** (14.0 mg, 48.4 μmol) in THF (1.00 mL + 500 μL rinse), and the resultant mixture was heated at reflux for 13 h. The reaction was quenched with H_2O at 0 °C. To the resultant mixture was added 3 M aqueous NaOH solution, and the reaction mixture was stirred at 0 °C for 20 min before it was dried ($MgSO_4$), filtered, and concentrated under reduced pressure to give crude *N*-methyl pyrrolidine **S18** (12.7 mg, ~quant.) as a colorless oil. The ^{1}H NMR analysis of this crude material was used to estimate the diastereomer ratio of 2,5-*cis*-substituted pyrrolidine **2b**. Purification of the crude material (silica gel NH-DM2035, 5% *t*-BuOMe/hexanes) gave *N*-methyl pyrrolidine **S18** (9.2 mg, 77%) as a colorless oil, along with its diastereomer, 2,5-*trans*-**S18** (0.7 mg, 6%), as a colorless oil. Data for **S18**: $[\alpha]_D^{23}$ +10.8 (*c* 0.79, $CHCl_3$); **IR** (film): 2955, 2852, 1455, 1203, 1113, 696 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.32 – 7.23 (m, 5H), 4.53 (d, *J* = 12.0 Hz, 1H), 4.49 (d, *J* = 12.0 Hz, 1H), 3.53 (dd, *J* = 9.0, 5.0 Hz, 1H), 3.35 (dd, *J*

= 9.0, 6.0 Hz, 1H), 2.53 – 2.48 (m, 1H), 2.33 (s, 3H), 2.17 – 2.11 (m, 1H), 1.88 – 1.80 (m, 2H), 1.66 – 1.59 (m, 1H), 1.53 – 1.47 (m, 1H), 1.38 – 1.10 (m, 4H), 0.90 (t, *J* = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 138.5, 128.3 (2C), 127.6 (2C), 127.5, 74.2, 73.3, 67.9, 66.2, 40.2, 36.5, 29.5, 27.0, 20.0, 14.5; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{16}H_{26}NO^+$ 248.2009; found: 248.2017. Data for 2,5-*trans*-**S18**: (HN-III-103b) **[α]**$_D^{23}$ −75.2 (*c* 0.07, $CHCl_3$); **IR** (film): 2955, 2854, 1456, 1111, 697 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.34 – 7.25 (m, 5H), 4.49 (s, 2H), 3.49 (dd, *J* = 9.5, 5.0 Hz, 1H), 3.36 (dd, *J* = 9.5, 5.0 Hz, 1H), 3.09 – 3.04 (m, 1H), 2.82 – 2.77 (m, 1H), 2.41 (s, 3H), 1.99 – 1.85 (m, 2H), 1.63 – 1.54 (m, 1H), 1.48 – 1.42 (m, 1H), 1.34 – 1.13 (m, 3H), 1.09 – 1.02 (m, 1H), 0.89 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 138.5, 128.3 (2C), 127.6 (2C), 127.5, 73.3, 71.7, 63.6, 62.2, 35.6, 32.8, 29.0, 26.9, 20.1, 14.5; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{16}H_{26}NO^+$ 248.2009; found: 248.2019.

***N*-Methyl pyrrolidine S18 (from 2c).** According to the procedure described for the transformation of **2b**, the reaction of 2,5-*cis*-substituted pyrrolidine **2c** (7.0 mg, 19 μmol) using $LiAlH_4$ (4.8 mg, 0.12 mmol), followed by purification by flash column chromatography (silica gel NH-DM2035, 20% *t*-BuOMe/hexanes), gave a purified mixture of *N*-methyl pyrrolidine **S18** and its diastereomer (3.2 mg, 68%) as a colorless oil. The ^{1}H NMR analysis of this material showed the diastereomer ratio of **2c** to be 93:7.

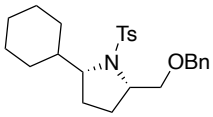
***N*-Methyl pyrrolidine S18 (from 2d).** According to the procedure described for the transformation of 2b, the reaction of 2,5-*cis*-substituted pyrrolidine **2d** (3.4 mg, 11 μmol) using $LiAlH_4$ (2.2 mg, 53 μmol), followed by purification by flash column chromatography (silica gel NH-DM2035, 20% *t*-BuOMe/hexanes), gave a purified mixture of *N*-methyl pyrrolidine **S18** and its diastereomer (2.1 mg, 79%) as a colorless oil. The ^{1}H NMR analysis of this material showed the diastereomer ratio of **2d** to be 90:10.



2e

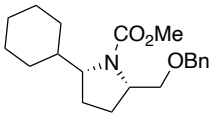
2,5-*cis*-Substituted pyrrolidine 2e. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2e** (23.7 mg, 77.1 μmol) using $AgSbF_6$ (1.2 mg, 3.5 μmol), $(Ph_3P)AuCl$ (2.0 mg, 4.0 μmol), Et_3SiH (50 μL, 0.31 mmol),

and benzoic acid (10.5 mg, 86.0 μmol), followed by purification by flash column chromatography (silica gel, 5 to 10% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2e** (19.7 mg, 83%, dr >95:5) as colorless crystals: **m.p.**: 98 – 100 °C; **[α]**$_D^{23}$ −17.0 (*c* 0.45, $CHCl_3$); **IR** (KBr): 2963, 2872, 1335, 1162, 666 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.69 – 7.68 (m, 2H), 7.28 – 7.27 (m, 2H), 3.57 – 3.52 (m, 1H), 3.39 – 3.35 (m, 1H), 2.40 (s, 3H), 2.00 (ttd, *J* = 7.0,.7.0, 7.0 Hz, 1H), 1.81 – 1.73 (m, 1H), 1.62 – 1.56 (m, 1H), 1.44 – 1.25 (m, 6H), 0.95 (t, *J* = 7.0 Hz, 3H), 0.90 (t, *J* =7.5 Hz, 3H), 0.87 (d, *J* = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.2, 135.3, 129.6 (2C), 127.7 (2C), 67.3, 61.7, 39.3, 31.7, 29.6, 25.6, 21.6, 20.3, 19.8, 17.5, 14.1; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{17}H_{27}NO_2NaS^+$ 332.1655; found: 332.1667.



2f

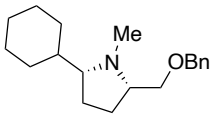
2,5-*cis*-Substituted pyrrolidine 2f. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2f** (34.3 mg, 80.6 μmol) using $AgSbF_6$ (1.3 mg, 3.8 μmol), $(Ph_3P)AuCl$ (2.2 mg, 4.4 μmol), Et_3SiH (50 μL, 0.31 mmol), benzoic acid (11.2 mg, 91.7 μmol), followed by purification by flash column chromatography (silica gel, 5 to 10% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2f** (31.0 mg, 90%, dr >95:5) as a colorless oil: **[α]**$_D^{23}$ −14.5 (*c* 0.79, $CHCl_3$); **IR** (film): 2925, 2851, 1343, 1160, 1092, 666 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 2H), 7.35 – 7.26 (m, 7H), 4.54 (d, *J* = 7.0 Hz, 1H), 4.51 (d, *J* = 7.0 Hz, 1H), 3.78 (dd, *J* = 8.5, 4.0 Hz, 1H), 3.75 – 3.69 (m, 1H), 3.41 – 3.36 (m, 2H), 2.40 (s, 3H), 1.82 – 1.58 (m, 8H), 1.52 – 1.45 (m, 1H), 1.27 – 1.04 (m, 4H), 1.00 – 0.91 (m, 1H), 0.88 – 0.80 (m, 1H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.3, 138.2, 134.7, 129.6 (2C), 128.3 (2C), 127.6 (5C), 73.4 (2C), 66.8, 60.0, 41.0, 30.6, 28.1, 27.6, 26.5, 26.3, 26.1, 25.8, 21.5; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{33}NO_3NaS^+$ 450.2073; found: 450.2074.



2g

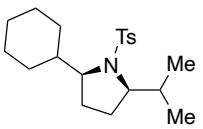
2,5-*cis*-Substituted pyrrolidine 2g. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2g** (29.7 mg, 90.2 μmol) using $AgSbF_6$ (2.2 mg, 6.4 μmol), $(Ph_3P)AuCl$ (3.4 mg, 6.9 μmol), Et_3SiH (60 μL, 0.38 mmol), and benzoic acid (11.3 mg, 92.5 μmol), followed by purification by flash column chromatography (silica gel, 5 to 10% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2g** (27.9 mg, 93%, dr >95:5) as a colorless oil:

$[\alpha]_D^{22}$ −19.2 (*c* 1.14, $CHCl_3$); **IR** (film): 2925, 2851, 1698, 1446, 1372, 1105 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.34 – 7.26 (m, 5H), 4.53 (d, *J* = 12.0 Hz, 1H), 4.49 (d, *J* = 12.0 Hz, 1H), 4.10 – 3.95 (m, 1H), 3.77 – 3.57 (m, 5H), 3.50 – 3.25 (m, 1H), 1.98 – 1.85 (m, 2H), 1.79 – 1.38 (m, 8H), 1.23 – 0.79 (m, 5H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 128.3 (2C), 127.5 (2C), 73.1, 52.1, 30.1, 26.5, 26.3, 26.1, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{20}H_{29}NO_3Na^+$ 354.2040; found: 354.2014. The diastereomer ratio of this compound was determined by its derivatization into the corresponding *N*-methyl derivative by $LiAlH_4$ reduction (*vide infra*).



S19

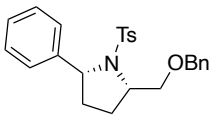
***N*-Methyl pyrrolidine S19 (from 2g).** According to the procedure described for the transformation of **2b**, the reaction of 2,5-*cis*-substituted pyrrolidine **2g** (16.4 mg, 49.5 μmol) using $LiAlH_4$ (11.2 mg, 0.272 mmol) gave crude *N*-methyl pyrrolidine **S19** (15.6 mg, ~quant.) as a colorless oil. The ^{1}H NMR analysis of this crude material showed the diastereomer ratio of **2g** to be >95:5. Purification of the crude material by flash column chromatography (silica gel NH-DM2035, 2% *t*-BuOMe/hexanes) gave *N*-methyl pyrrolidine **S19** (11.6 mg, 82%) as a colorless oil: $[\alpha]_D^{23}$ +4.9 (*c* 0.92, $CHCl_3$); **IR** (film): 2922, 2850, 1450, 1112, 697 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.32 – 7.23 (m, 5H), 4.52 (s, 2H), 3.53 – 3.51 (m, 1H), 3.32 – 3.29 (m, 1H), 2.58 – 2.52 (m, 1H), 2.30 (s, 3H), 2.21 – 2.17 (m, 1H), 1.85 – 1.79 (m, 1H), 1.73 – 1.38 (m, 8H), 1.26 – 1.05 (m, 4H), 0.99 – 0.84 (m, 2H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 138.7, 128.3 (2C), 127.5 (2C), 127.4, 74.4, 73.2, 72.3, 66.4, 41.1, 39.9, 31.2, 27.9, 27.0, 26.9, 26.44, 26.40, 24.6; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{19}H_{30}NO^+$ 288.2322; found: 288.2330.



2h

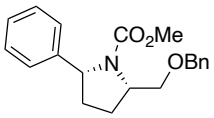
2,5-*cis*-Substituted pyrrolidine 2h. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2h** (27.7 mg, 79.7 μmol) using $AgSbF_6$ (1.2 mg, 3.5 μmol), $(Ph_3P)AuCl$ (2.1 mg, 4.2 μmol), Et_3SiH (50 μL, 0.31 mmol), and benzoic acid (10.3 mg, 84.3 μmol), followed by purification by flash column chromatography (silica gel, 5 to 30% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2f** (20.2 mg, 73%, dr >95:5) as colorless crystals:

m.p.: 144 – 145 °C; $[\alpha]_D^{23}$ −35.0 (*c* 0.48, $CHCl_3$); **IR** (KBr): 3420, 2854, 1342, 1156, 666 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.69 – 7.67 (m, 2H), 7.28 – 7.26 (m, 2H), 3.37 – 3.28 (m, 2H), 2.40 (s, 3H), 1.97 – 1.95 (m, 1H), 1.92 – 1.84 (m, 1H), 1.78 – 1.40 (m, 7H), 1.24 – 0.96 (m, 9H), 0.91 – 0.82 (m, 4H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.0, 135.2, 129.5 (2C), 127.8 (2C), 67.4, 66.9, 41.6, 31.7, 30.8, 28.9, 26.5, 26.30, 26.26, 26.19, 25.9, 21.5, 20.4, 17.9; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{20}H_{31}NO_2NaS^+$ 372.1968; found: 372.1977.



2i (dr 88:12)

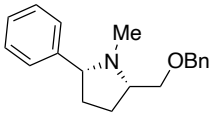
2,5-*cis*-Substituted pyrrolidine 2i. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2i** (37.0 mg, 88.2 μmol) using $AgSbF_6$ (1.2 mg, 3.5 μmol), $(Ph_3P)AuCl$ (2.3 mg, 4.6 μmol), Et_3SiH (60 μL, 0.37 mmol), and benzoic acid (11.3 mg, 92.5 μmol), followed by purification by flash column chromatography (silica gel, 5 to 20% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2i** (35.6 mg, 96%, dr 88:12) as a colorless oil: $[\alpha]_D^{23}$ +37.1 (*c* 0.68, $CHCl_3$); IR (film): 3030, 2868, 1495, 1453, 1347, 1161, 1092 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, signals for the major diastereomer): δ 7.67 – 7.64 (m, 2H), 7.38 – 7.19 (m, 12H), 4.60 – 4.54 (m, 3H), 4.05 – 4.00 (m, 1H), 3.90 (dd, *J* = 9.0, 4.0 Hz, 1H), 3.65 (dd, *J* = 9.0, 9.0 Hz, 1H), 2.41 (s, 3H), 1.98 – 1.84 (m, 3H), 1.71 – 1.60 (m, 1H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, signals for the major diastereomer): δ 143.4, 142.4, 138.1, 134.5, 129.5 (2C), 128.3 (2C), 128.2 (2C), 127.68 (2C), 127.67 (2C), 127.6, 127.0, 126.3 (2C), 73.4, 73.2, 65.0, 60.7, 34.7, 27.9, 21.5; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{27}NO_3NaS^+$ 444.1604; found: 444.1608.



2j (dr 93:7)

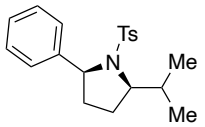
2,5-*cis*-Substituted pyrrolidine 2j. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2j** (26.6 mg, 82.3 μmol) using $AgSbF_6$ (1.1 mg, 3.2 μmol), $(Ph_3P)AuCl$ (2.5 mg, 5.1 μmol), Et_3SiH (55 μL, 0.35 mmol), and benzoic acid (11.2 mg, 91.7 μmol), followed by purification by flash column chromatography (silica gel, 5 to 30% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2j** (22.2 mg, 83%, dr 93:7) as a colorless oil: $[\alpha]_D^{23}$ −15.3 (*c* 0.28, $CHCl_3$); **IR** (film): 2952, 2869, 1698, 1446, 1376, 1113 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a

mixture of amide rotamers): δ 7.34 – 7.15 (m, 10H), 4.81 (dd, *J* = 7.5, 7.5 Hz, 1H), 4.58 (s, 2H), 4.27 – 4.13 (m, 1H), 3.90 – 3.46 (m, 5H), 2.30 – 2.23 (m, 1H), 2.03 – 1.89 (m, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 138.3, 128.3 (2C), 128.2 (2C), 127.6 (2C), 126.6, 125.6 (2C), 73.2, 52.3, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{20}H_{23}NO_3Na^+$ 348.1570; found: 348.1542. The diastereomer ratio of this compound was determined by its derivatization into the corresponding *N*-methyl derivative by $LiAlH_4$ reduction (*vide infra*).



S20

***N*-Methyl pyrrolidine S20 (from 2j).** According to the procedure described for the transformation of **2b**, the reaction of 2,5-*cis*-substituted pyrrolidine **2j** (12.6 mg, 38.7 μmol) using $LiAlH_4$ (8.6 mg, 0.21 mmol) gave crude *N*-methyl pyrrolidine **S20** (12.1 mg, ~quant.) as a colorless oil. The ^{1}H NMR analysis of this crude material showed the diastereomer ratio of **2j** to be 93:7. Purification of the residue by flash column chromatography (silica gel NH-DM2035, 10% *t*-BuOMe/hexanes) gave *N*-methyl pyrrolidine **S20** (9.9 mg, 91%) as a colorless oil: **[α]**$_D^{24}$ +53.0 (*c* 0.88, $CHCl_3$); **IR** (film): 2947, 2847, 1494, 1453, 1097, 699 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.37 – 7.26 (m, 9H), 7.23 – 7.20 (m, 1H), 4.58 (s, 2H), 3.64 (dd, *J* = 9.5, 5.0 Hz, 1H), 3.46 (dd, *J* = 9.5, 6.5 Hz, 1H), 3.29 (dd, *J* = 9.5, 6.5 Hz, 1H), 2.75 – 2.70 (m, 1H), 2.21 (s, 3H), 2.09 – 1.95 (m, 2H), 1.76 – 1.64 (m, 2H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 143.6, 138.6, 128.3 (2C), 128.3 (2C), 127.6 (2C), 127.5, 127.4 (2C), 126.9, 74.3, 73.3, 72.6, 65.5, 40.1, 34.1, 27.7; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{19}H_{24}NO^+$ 282.1852; found: 282.1866.

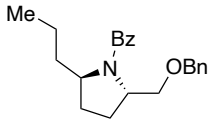


2k (dr 88:12)

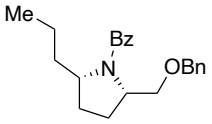
2,5-*cis*-Substituted pyrrolidine 2k. According to the procedure described for 2,5-*cis*-substituted pyrrolidine **2a**, the reaction of amino alkyne **2k** (28.8 mg, 84.3 μmol) using $AgSbF_6$ (1.4 mg, 4.1 μmol), $(Ph_3P)AuCl$ (2.4 mg, 4.9 μmol), Et_3SiH (55 μL, 0.34 mmol), and benzoic acid (10.3 mg, 84.3 μmol), followed by purification by flash column chromatography (silica gel, 5 to 30% EtOAc/hexanes), gave 2,5-*cis*-substituted pyrrolidine **2k** (22.1 mg, 76%, dr 88:12) as colorless crystals: **m.p.**: 95 – 97 °C; **[α]**$_D^{25}$ −90.3 (*c* 0.57, $CHCl_3$); **IR** (KBr): 2977, 2927, 1454, 1342, 1165, 667 cm^{-1}; **^{1}H NMR**

(500 MHz, $CDCl_3$, signals for the major diastereomer): δ 7.69 – 7.67 (m, 2H), 7.38 – 7.19 (m, 7H), 4.61 (dd, *J* = 7.0, 7.0 Hz, 1H), 3.60 (ddd, *J* = 7.5, 7.5, 2.0 Hz, 1H), 2.41 (s, 3H), 2.10 – 1.81 (m, 3H), 1.73 – 1.63 (m, 1H), 1.39 – 1.31 (m, 1H), 1.10 (d, *J* = 7.0 Hz, 3H), 0.88 (d, *J* = Hz, 3H); **$^{13}C\{^1H\}$ NMR** (125 MHz, $CDCl_3$, signals for the major diastereomer): δ 143.3, 142.6, 134.8, 129.5 (2C), 128.2 (2C), 127.9 (2C), 126.9, 126.3 (2C), 68.1, 64.7, 33.8, 31.9, 26.6, 21.5, 20.6, 18.4; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{20}H_{25}NO_2NaS^+$ 366.1498; found: 366.1504.

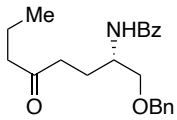
3) Synthesis of 2,5-*trans*-substituted pyrrolidine derivatives



4a



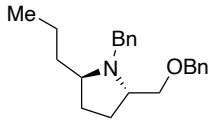
2,5-*cis*-**4a**



5a

2,5-*trans*-Substituted pyrrolidine 4a. To a solution of amino alkyne **3a** (30.3 mg, 90.3 μmol) in moist DCE (900 μL) were added $AgSbF_6$ (1.7 mg, 4.9 μmol) and $(p\text{-}CF_3C_6H_4)_3PAuCl$ (3.8 mg, 5.4 μmol), and the resultant mixture was stirred at room temperature for 40 min. To the reaction mixture were added Et_3SiH (60 μL, 0.37 mmol) and benzoic acid (11.0 mg, 90.0 μmol), and the resultant mixture was stirred at 70 °C for 18 h. The reaction was quenched with saturated aqueous $NaHCO_3$ solution at 0 °C. The resultant mixture was filtered through a pad of Celite, and the filtrate was extracted with EtOAc. The organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 20 to 50% *t*-BuOMe/hexanes) gave 2,5-*trans*-substituted pyrrolidine **4a** (24.3 mg, 80%) as a colorless oil, its diastereomer, 2,5-*cis*-**4a** (2.1 mg, 7%), as a colorless oil, and ketone **5a** (3.0 mg, 9%) as colorless crystals. Data for **4a**: $[\alpha]_D^{23}$ −149.6 (*c* 0.58, $CHCl_3$); **IR** (film): 2957, 2871, 1626, 1399, 1101, 699 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.51 – 7.21 (m, 9H), 7.07 – 7.05 (m, 1H), 4.58 (d, *J* = 12.0 Hz, 0.6H), 4.53 (d, *J* = 12.0 Hz, 0.6H), 4.51 – 4.48 (m, 0.6H), 4.29 – 4.22 (m, 0.4H), 4.17 – 4.11 (m, 1.2H), 3.96 – 3.93 (m, 0.6H), 3.71 (dd, *J* = 9.0, 3.0 Hz, 0.6H), 3.64 (dd, *J* = 9.0, 6.5 Hz, 0.6H), 3.03 – 2.94 (m, 0.8H), 2.21 – 1.64 (m, 4.4H), 1.42 – 1.13 (m, 1.8H), 1.09 – 0.98 (m, 1.2H), 0.94 (t, *J* = 7.0 Hz, 1.2H), 0.87 – 0.76 (m, 0.6H), 0.48 (t, *J* = 7.0 Hz, 1.8H); **$^{13}C\{^1H\}$ NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 170.6, 170.1, 138.6, 138.0, 137.9, 137.8, 129.6, 129.5 (2C), 129.2, 128.32 (2C), 128.26 (2C), 128.20 (2C), 127.6, 127.50, 127.47,

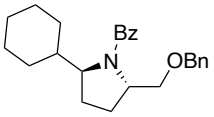
127.3 (2C), 126.9 (2C), 126.8 (2C), 126.3, 73.1, 72.7, 70.4, 69.8, 59.5, 58.3, 57.8, 56.7, 36.7, 35.3, 28.4, 27.2, 26.2, 25.4, 19.7, 19.2, 14.1, 13.2; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{27}NO_2Na^+$ 360.1934; found: 360.1927. Data for 2,5-*cis*-**4a**: **[α]**$_D^{23}$ −49.7 (*c* 0.12, $CHCl_3$); **IR** (film): 2957, 2870, 1628, 1403, 700 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.50 – 7.14 (m, 10H), 4.65 – 3.10 (m, 6H), 2.23 – 0.47 (m, 11H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 170.8, 137.8, 129.2, 128.33 (2C), 128.28 (2C), 127.5 (2C), 126.3 (2C), 73.1, 71.1, 19.5, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{27}NO_2Na^+$ 360.1934; found: 360.1952. Data for **5a**: **m.p.**: 97 – 98 °C; **[α]**$_D^{23}$ −36.5 (*c* 0.42, $CHCl_3$); **IR** (KBr): 3415, 3317, 2957, 1703, 1633, 1547, 708 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.73 – 7.72 (m, 2H), 7.49 – 7.46 (m, 1H), 7.42 – 7.39 (m, 2H), 7.33 – 7.25 (m, 5H), 6.59 (d, *J* = 9.5 Hz, 1H), 4.52 (d, *J* = 12.0 Hz, 1H), 4.50 (d, *J* = 12.0 Hz, 1H), 4.28 – 4.21 (m, 1H), 3.58 (dd, *J* = 9.5, 3.5 Hz, 1H), 3.52 (d, *J* = 9.5, 4.5 Hz, 1H), 2.56 (td, *J* = 18.0, 7.0 Hz, 1H), 2.46 (td, *J* = 18.0, 7.0 Hz, 1H), 2.38 – 2.27 (m, 2H), 2.05 – 1.98 (m, 1H), 1.95 – 1.88 (m, 1H), 1.57 – 1.46 (m, 2H), 0.83 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 211.6, 167.1, 138.1, 134.4, 131.6, 128.6 (2C), 127.9 (2C), 127.0 (4C), 73.4, 71.9, 49.41, 49.38, 45.0, 39.6, 25.7, 17.4, 13.8; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{27}NO_3Na^+$ 376.1883; found: 376.1861. The relative configuration of **4a** was confirmed by its derivatization into the corresponding *N*-benzyl derivative by $LiAlH_4$ reduction (*vide infra*).



S21

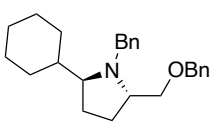
***N*-Benzyl pyrrolidine S21.** To a suspension of $LiAlH_4$ (21.7 mg, 0.526 mmol) in Et_2O (1.00 mL) was added $AlCl_3$ (46.7 mg, 0.350 mmol), and the resultant mixture was stirred at room temperature for 10 min. To the reaction mixture at 0 °C was added a solution of 2,5-*trans*-substituted pyrrolidine **4a** (19.5 mg, 57.8 μmol) in Et_2O (0.500 mL + 0.500 mL rinse), and the resultant mixture was allowed to warm to room temperature over a period of 4 h. The reaction was quenched with H_2O at 0 °C. To the reaction mixture was added 3 M aqueous NaOH solution, and the resultant mixture was stirred at 0 °C for 10 min. The reaction mixture was dried ($MgSO_4$) and filtered through a pad of Celite. The filtrate was concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica

gel, 1% *i*-$PrNH_2$/$CHCl_3$) gave *N*-benzyl pyrrolidine **S21**(15.4 mg, 91%) as a colorless oil: $[\alpha]_D^{24}$ −80.8 (*c* 0.81, $CHCl_3$); **IR** (film): 2955, 2870, 1495, 1454, 1101 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.34 – 7.18 (m, 10H), 4.44 (s, 2H), 3.90 (d, *J* = 14.0 Hz, 1H), 3.73 (d, *J* = 14.0 Hz, 1H), 3.41 (dd, *J* = 10.0, 4.5 Hz, 1H), 3.34 (dd, *J* = 10.0, 7.0 Hz, 1H), 3.15 – 3.09 (m, 1H), 2.98 – 2.91 (m, 1H), 2.00 – 1.86 (m, 2H), 1.72 – 1.67 (m, 1H), 1.68 – 1.48 (m, 2H), 1.34 – 1.25 (m, 1H), 1.17 – 1.07 (m, 2H), 0.85 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 141.0, 138.7, 128.4 (4C), 128.2 (2C), 127.7 (2C), 127.5, 126.5, 73.3, 72.3, 61.1, 59.7, 52.1, 33.0, 28.6, 27.1, 19.7, 14.6; **HRMS** (ESI) *m*/*z*: [(M + H)$^+$] calcd for $C_{22}H_{30}NO^+$ 324.2322; found: 324.2337.



4b (dr 89:11)

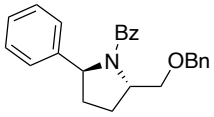
2,5-*trans*-Substituted pyrrolidine 4b. According to the procedure described for 2,5-*trans*-substituted pyrrolidine **4a**, the reaction of amino alkyne **3b** (32.6 mg, 86.8 μmol) using $AgSbF_6$ (3.0 mg, 8.7 μmol), (p-$CF_3C_6H_4$)$_3$PAuCl (6.2 mg, 8.9 μmol), Et_3SiH (60 μL, 0.37 mmol), and benzoic acid (11.3 mg, 92.5 μmol), followed by purification by flash column chromatography (silica gel, 10 to 30% acetone/hexanes), gave 2,5-*trans*-substituted pyrrolidine **4b** (28.9 mg, 88%, dr 89:11) as a colorless oil: $[\alpha]_D^{24}$ −479.9 (*c* 0.27, $CHCl_3$); **IR** (film): 2924, 2850, 1628, 1395, 1102, 699 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of *cis*/*trans* isomers and amide rotamers): δ 7.43 – 7.21 (m, 9H), 7.07 – 7.06 (m, 1H), 4.58 – 3.26 (m, 5H), 3.03 – 2.98 (m, 1H), 2.15 – 1.50 (m, 9H), 1.31 – 0.67 (m, 6H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of *cis*/*trans* isomers and amide rotamers): δ 170.8, 170.7, 138.6, 138.4, 138.1, 138.0, 137.8, 129.8, 129.6, 128.3, 128.2, 127.6, 127.5, 127.4, 127.2, 126.7, 73.2, 72.7, 70.8, 70.1, 64.5, 62.2, 59.1, 57.8, 42.2, 39.2, 30.4, 30.3, 28.4, 27.6, 26.9, 26.7, 26.42, 26.37, 26.31, 25.9, 23.4 (Note: Due to the complicated spectrum, only clearly observable signals are listed); **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{31}NO_2Na^+$ 400.2247; found: 400.2261. The relative configuration of **4b** was confirmed by its derivatization into the corresponding *N*-benzyl derivative by $LiAlH_4$ reduction (*vide infra*).



S22 (dr 89:11)

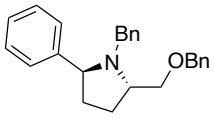
***N*-Benzyl pyrrolidine S22.** According to the procedure described for *N*-benzyl pyrrolidine **S21**, the reaction of 2,5-*trans*-substituted pyrrolidine **4b** (21.5 mg, 56.9 μmol, dr 89:11) using $LiAlH_4$ (22.0 mg, 0.533 mmol) and $AlCl_3$ (46.5 mg, 0.349 mmol), followed by

purification by flash column chromatography (silica gel, 1% *i*-$PrNH_2$/$CHCl_3$), gave *N*-benzyl pyrrolidine **S22** (16.0 mg, 77%, dr 89:11) as a colorless oil: $[\alpha]_D^{23}$ −63.9 (*c* 1.13, $CHCl_3$); **IR** (film): 2922, 2850, 1494, 1451, 697 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of *trans*/*cis* isomers): δ 7.37 – 7.17 (m, 10H), 4.43 (d, *J* = 12.5 Hz, 0.8H), 4.40 (d, *J* = 12.5 Hz, 0.8H), 4.33 (d, *J* = 12.5 Hz, 0.2H), 4.30 (d, *J* = 12.5 Hz, 0.2H), 3.88 – 3.81 (m, 1H), 3.75 – 3.61 (m, 1H), 3.40 (dd, *J* = 10.0, 4.0 Hz, 0.8H), 3.35 (dd, *J* = 10.0, 6.0 Hz, 0.8H), 3.24 – 3.16 (m, 1H), 3.13 – 3.06 (m, 0.4H), 2.97 – 2.92 (m, 0.2H), 2.87 – 2.83 (m, 0.8H), 1.89 – 0.81 (m, 15H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of *trans*/*cis* isomers, signals for the major diastereomer): δ 141.0, 138.7, 128.3 (2C), 128.1 (2C), 128.0 (2C), 127.45 (2C), 127.36, 126.3, 73.1, 70.2, 66.1, 59.0, 51.5, 39.7, 30.9, 27.4, 27.1, 26.9, 26.4, 26.1, 24.8; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{25}H_{34}NO^+$ 364.2635; found: 364.2642.



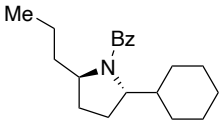
4c (dr 80:20)

2,5-*trans*-Substituted pyrrolidine 4c. According to the procedure described for 2,5-*trans*-substituted pyrrolidine **4a**, the reaction of amino alkyne **3c** (32.2 mg, 87.2 μmol) using $AgSbF_6$ (3.0 mg, 8.7 μmol) and [(*p*-$CF_3C_6H_4)_3P$]AuCl (6.3 mg, 8.9 μmol), Et_3SiH (60 μL, 0.37 mmol), and benzoic acid (10.8 mg, 88.4 μmol), followed by purification by flash column chromatography (silica gel, 30 to 40% *t*-BuOMe/hexanes), gave 2,5-*trans*-substituted pyrrolidine **4c** (22.6 mg, 70%, dr 80:20) as a colorless oil: $[\alpha]_D^{25}$ −146.7 (*c* 1.14, $CHCl_3$); **IR** (film): 2925, 2857, 1633, 1494, 1394, 698 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of *cis*/*trans* isomers and amide rotamers): δ 7.51 – 6.81 (m, 15H), 5.39 (app. d, *J* = 8.0 Hz, 0.2H), 4.95 (app. d, *J* = 8.0 Hz, 0.8H), 4.78 (dddd, *J* = 9.0, 4.5, 4.5, 1.5 Hz, 0.8H), 4.64 (d, *J* = 12.5 Hz, 0.8H), 4.59 (d, *J* = 12.5 Hz, 0.8H), 4.46 – 4.41 (m, 0.2H), 3.84 – 3.80 (m, 1.6H), 3.15 – 3.08 (m, 0.4H), 2.62 – 1.70 (m, 4H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of *cis*/*trans* isomers and amide rotamers): δ 171.8, 169.9, 144.2, 143.6, 138.5, 137.8, 137.7, 137.4, 129.8, 129.4, 128.9, 128.4, 128.2, 127.7, 127.6, 127.5, 127.4, 126.9, 126.7, 126.6, 126.3, 125.4, 73.2, 72.9, 71.2, 70.5, 70.0, 64.2, 61.1, 59.1, 57.9, 34.0, 31.5, 27.1, 25.1 (Note: Due to the complicated spectrum, only clearly observable signals are listed); **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{25}H_{25}NO_2Na^+$ 394.1778; found: 394.1805. The relative configuration of **4c** was confirmed by its derivatization into the corresponding *N*-benzyl derivative by $LiAlH_4$ reduction (*vide infra*).

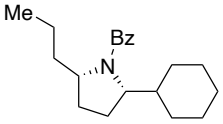


S23 (dr 80:20)

***N*-Benzyl pyrrolidine S23.** According to the procedure described for *N*-benzyl pyrrolidine **S21**, the reaction of 2,5-*trans*-substituted pyrrolidine **4c** (11.8 mg, 31.8 μmol, dr 80:20) using $LiAlH_4$ (11.2 mg, 0.272 mmol) and $AlCl_3$ (24.6 mg, 0.184 mmol), followed by purification by flash column chromatography (silica gel, 1% *i*-$PrNH_2$/$CHCl_3$), gave *N*-benzyl pyrrolidine **S23** (9.7 mg, 85%) as a colorless oil: $[\alpha]_D^{24}$ −54.9 (*c* 0.82, $CHCl_3$); **IR** (film): 3026, 2849, 1494, 1453, 698 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of *trans*/*cis* isomers): δ 7.44 – 7.15 (m, 15H), 4.50 (d, *J* = 17.0 Hz, 0.8H), 4.47 (d, *J* = 17.0 Hz, 0.8H), 4.35 (s, 0.4H), 4.05 (dd, *J* = 7.0, 7.0 Hz, 0.8H), 3.85 (d, *J* = 13.5 Hz, 0.2H), 3.75 – 3.69 (m, 1H), 3.56 (d, *J* = 15.0 Hz, 0.8H), 3.52 – 3.40 (m, 2.6H), 3.21 – 3.09 (m, 0.6H), 2.36 – 2.28 (m, 0.8H), 2.19 – 2.11 (m, 0.8H), 2.24 – 1.63 (m, 2.4H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of *trans*/*cis* isomers, signals for the major diastereomer): δ 145.1, 140.5, 138.6, 128.3 (2C), 128.2 (2C), 128.02 (2C), 128.00 (2C), 127.6 (2C), 127.5 (2C), 126.7, 126.3, 73.2, 71.1, 66.8, 58.4, 51.3, 34.1, 27.1 (one aromatic carbon obscured); **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{25}H_{28}NO^+$ 358.2165; found: 358.2188.



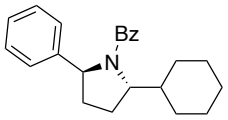
rac-**4d**



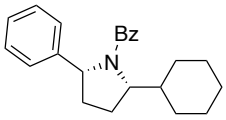
rac-2,5-*cis*-**4d**

2,5-*trans*-Substituted pyrrolidine *rac*-4d. According to the procedure described for 2,5-*trans*-substituted pyrrolidine **4a**, the reaction of amino alkyne **3d** (27.0 mg, 90.8 μmol) using $AgSbF_6$ (6.2 mg, 18 μmol), [(*p*-$CF_3C_6H_4)_3P$]AuCl (12.8 mg, 18.3 μmol), Et_3SiH (60 μL, 0.37 mmol), and benzoic acid (11.3 mg, 92.5 μmol), followed by purification by flash column chromatography (silica gel, 5 to 20% EtOAc/hexanes), gave 2,5-*trans*-substituted pyrrolidine *rac*-**4d** (18.2 mg, 67%) as a colorless oil, along with its diastereomer, *rac*-2,5-*cis*-**4d** (2.5 mg, 9%) as a colorless oil. Data for *rac*-**4d**: **IR** (film): 2925, 2851, 1627, 1396, 700 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.49 – 7.33 (m, 5H), 4.28 – 4.24 (m, 0.3H), 4.21 – 4.18 (m, 0.7H), 3.97 – 3.94 (m, 0.7H), 3.90 – 3.87 (m, 0.3H), 2.15 – 2.08 (m, 0.7H), 2.03 – 1.60 (m, 7.0H), 1.52 – 0.66 (m, 12.2H), 0.48 (t, *J* = 7.5 Hz, 2.1H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 171.1, 170.4*, 138.7*, 138.5, 129.6, 129.5*, 128.2 (2C), 127.2 (2C), 126.7 (2C)*, 64.0*, 61.8, 59.7, 58.3*, 42.0*, 39.2, 37.0, 35.3*, 30.4, 30.3*, 29.3, 27.9*, 27.7, 26.9*, 26.7, 26.4, 26.34, 26.30*, 25.6*, 23.5, 19.4*, 19.2, 14.1*, 13.2 (signals with asterisk are assigned to carbon atoms of the minor amide rotamer);

HRMS (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{20}H_{30}NO^+$ 300.2322; found: 300.2331. Data for *rac*-2,5-*cis*-**4d**: **IR** (film): 2926, 2851, 1630, 1404, 701 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.41 – 7.33 (m, 5H), 4.27 – 4.10 (m, 1H), 3.72 – 3.50 (m, 1H), 2.15 – 0.62 (m, 22H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 171.6, 138.2, 129.1, 128.2 (2C), 128.4 (2C), 62.1, 60.3, 41.8, 37.7, 30.4, 29.2, 28.4, 26.4 (2C), 26.2 (2C), 19.8, 13.7; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{20}H_{30}NO^+$ 300.2322; found: 300.2329. The relative configuration of *rac*-**4d** and *rac*-2,5-*cis*-**4d** was assigned in analogy to that of **4a** and 2,5-*cis*-**4a**.



rac-**4e**

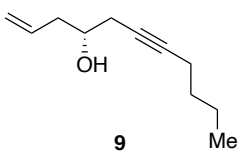


rac-2,5-*cis*-**4e**

2,5-*trans*-Substituted pyrrolidine *rac*-4e. According to the procedure described for 2,5-*trans*-substituted pyrrolidine **4a**, the reaction of amino alkyne **3e** (28.9 mg, 87.2 μmol) using $AgSbF_6$ (5.8 mg, 17 μmol), [(*p*-$CF_3C_6H_4)_3$P]AuCl (12.1 mg, 17.3 μmol), Et_3SiH (60 μL, 0.37 mmol), and benzoic acid (11.0 mg, 90.1 μmol), followed by purification by flash column chromatography (silica gel, 10 to 30% *t*-BuOMe/hexanes), gave 2,5-*trans*-substituted pyrrolidine *rac*-**4e** (9.2 mg, 32%) as colorless crystals, along with its diastereomer, *rac*-2,5-*cis*-**4e** (8.5 mg, 29%) as a colorless oil. Data for *rac*-**4e**: **m.p.**: 161 – 162 °C; **IR** (KBr): 2922, 2849, 1616, 1601, 1397, 695 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.55 – 7.53 (m, 0.4H), 7.40 – 7.03 (m, 8H), 6.78 – 6.76 (m, 1.6H), 5.32 (d, *J* = 9.0, 3.0 Hz, 0.2H), 4.95 – 4.94 (m, 0.8H), 4.54 – 4.51 (m, 0.8H), 4.23 – 4.19 (m, 0.2H), 2.44 – 2.29 (m, 1H), 2.26 – 2.10 (m, 1H), 2.07 – 1.98 (m, 1H), 1.88 – 0.73 (m, 12H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 172.3, 144.8, 138.4, 129.8*, 129.0, 128.4 (2C)*, 128.3 (2C)*, 128.2 (2C), 127.7 (2C), 126.8*, 126.6 (2C), 126.5, 125.4 (2C), 64.8*, 64.7, 63.1, 62.0*, 41.9*, 39.7, 34.8, 33.0*, 30.5, 30.3*, 27.9, 26.9*, 26.7, 26.5, 26.4, 26.31*, 26.26*, 25.6*, 23.3 (signals with asterisk are assigned to carbon atoms of the minor amide rotamer); **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{23}H_{28}NO^+$ 334.2165; found: 334.2165. Data for *rac*-2,5-*cis*-**4e**: **IR** (film): 2922, 2849, 1616, 1600, 1397, 695 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.28 – 7.10 (m, 10H), 4.97 – 4.73 (m, 1H), 4.43 – 4.22 (m, 1H), 2.18 – 1.01 (m, 15H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 173.6, 143.3, 137.4, 129.4, 128.3 (2C), 127.9 (2C), 126.7, 126.6 (2C), 126.2 (2C), 65.3, 63.2,

44.5, 34.8, 31.2, 30.5, 28.0, 26.4 (2C), 26.2; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{23}H_{28}NO^+$ 334.2165; found: 334.2174. The relative configuration of *rac*-**4e** and *rac*-2,5-*cis*-**4e** was assigned in analogy to that of **4a** and 2,5-*cis*-**4a**.

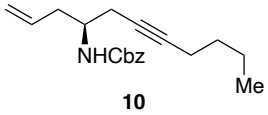
4) Total synthesis of (+)-monomorine I and (+)-indolizidine 195B



9

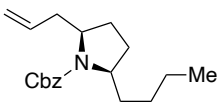
Homoallylic alcohol 9. To a solution of 3-octyn-1-ol (500 μL, 3.49 mmol) in CH_2Cl_2 (35.0 mL) at 0 ℃ was added Dess–Martin periodinane (2.10 g, 4.95 mmol), and the resultant mixture was stirred at 0 ℃ for 5 min and then at room temperature for 1 h. The reaction mixture was diluted with pentane (35.0 mL) and cooled to −15 ℃. The reaction mixture was directly purified by flash column chromatography (silica gel, 20% Et_2O/pentane at −40 ℃) to give crude aldehyde as a colorless oil, which was immediately used in the next reaction without characterization.

To a solution of (+)-Ipc_2BOMe (1.58 g, 4.99 mmol) in Et_2O (24.0 mL) at −78 ℃ was added allylmagnesium bromide (1 M solution in Et_2O, 3.80 mL, 3.80 mmol), and the resultant mixture was stirred at room temperature for 1 h. To the resultant mixture at −78 ℃ was added a solution of the above aldehyde in Et_2O (5.50 mL + 1.00 mL rinse), and the resultant mixture was stirred at −78 ℃ for 3 h. The reaction was quenched with 3 M aqueous NaOH solution (10.5 mL) and 34.5 % aqueous H_2O_2 solution (7.0 mL). The resultant mixture was stirred at room temperature for 17 h before it was diluted with EtOAc. The organic layer was separated, washed with H_2O and brine, dried ($MgSO_4$), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% *t*-BuOMe/hexanes) gave homoallylic alcohol **9** (398.9 mg, 69% for the two steps, 95% ee) as a colorless oil: $[\alpha]_D^{23}$ −0.34 (*c* 0.96, $CHCl_3$); **IR** (film): 3393, 2958, 2931, 2873 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 5.81 (dddd, *J* = 17.5, 10.5, 7.0, 7.0 Hz, 1H), 5.15 – 5.09 (m, 2H), 3.40 (dddd, *J* = 7.0, 7.0, 5.0, 5.0 Hz, 1H), 2.45 – 2.23 (m, 4H), 2.16 (tt, *J* = 7.0, 2.0 Hz, 2H), 1.49 – 1.34 (m, 4H), 0.89 (t, *J* = 7.0 Hz, 3H), one proton missing due to H/D exchange; **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 134.3, 118.1, 83.1, 75.7, 69.4, 40.6, 31.0, 27.0, 21.9, 18.4, 13.6; **HRMS** (DART) *m*/*z*: [(M + NH_4)$^+$] calcd for $C_{11}H_{22}NO^+$ 184.1696; found: 184.1679.



10

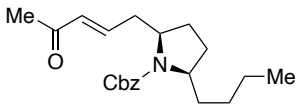
Amino alkyne 10. To a solution of homoallylic alcohol **9** (247.0 mg, 1.487 mmol) in THF (7.00 mL) was added Ph_3P (467.8 mg, 1.784 mmol), and the reaction mixture was cooled to 0 °C. To the reaction mixture at 0 °C were added DIAD (350 μL, 1.78 mmol) and DPPA (380 μL, 1.77 mmol), and the resultant mixture was stirred at room temperature for 3 h. To the reaction mixture were added Ph_3P (779.8 mg, 2.973 mmol) and H_2O (1.40 mL), and the resultant mixture was stirred at 50 °C for 3 h. To the reaction mixture at 0 °C were added H_2O (5.60 mL), $NaHCO_3$ (376.2 mg, 4.478 mmol), and CbzCl (250 μL, 1.77 mmol), and the resultant mixture was stirred at room temperature for 1 h. The reaction mixture was extracted with EtOAc, and the organic layer was washed with H_2O and brine. The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave amino alkyne **10** (319.5 mg, 72%) as a colorless oil: $[\alpha]_D^{24}$ −48.5 (*c* 0.17, $CHCl_3$); **IR** (film): 3326, 2956, 2931, 1716, 1698, 1540 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.38 – 7.27 (m, 5H), 5.79 – 5.71 (m, 1H), 5.12 – 5.06 (m, 4H), 4.90 – 4.88 (m, 1H), 3.84 – 3.77 (m, 1H), 2.39 – 2.32 (m, 4H), 2.13 (dddd, *J* = 7.0, 7.0, 2.5, 2.5 Hz, 2H), 1.48 – 1.35 (m, 4H), 0.88 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 155.8, 136.6, 134.2, 128.6 (3C), 128.2 (2C), 118.2, 83.4, 75.3, 66.8, 49.2, 38.2, 31.1, 24.1, 22.0, 18.5, 13.7; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{19}H_{25}NO_2Na^+$ 322.1778; found: 322.1776.



11

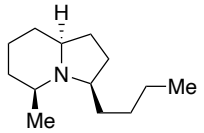
2,5-*cis*-Substituted pyrrolidine 11. To a solution of amino alkyne **10** (30.3 mg, 0.101 mmol) in moist DCE (1.00 mL) were added $AgSbF_6$ (1.5 mg, 4.4 μmol) and $(Ph_3P)AuCl$ (2.8 mg, 5.7 μmol), and the resultant mixture was stirred at room temperature for 40 min. To the reaction mixture were added Et_3SiH (70 μL, 0.44 mmol) and benzoic acid (13.4 mg, 0.110 mmol), and the resultant mixture was stirred at room temperature for 1 h. The reaction was quenched with saturated aqueous $NaHCO_3$ solution. The resultant mixture was filtered through a pad of Celite. The filtrate was extracted with EtOAc, and the organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave 2,5-*cis*-substituted pyrrolidine **11** (26.0 mg, 85%, dr >95:5) as a colorless oil: $[\alpha]_D^{23}$ +11.8 (*c* 0.99, $CHCl_3$); **IR** (film): 2956, 2930, 1699, 1405, 1353, 1101 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers):

δ 7.39 – 7.26 (m, 5H), 5.79 – 5.65 (m, 1H), 5.18 – 4.96 (m, 4H), 3.92 – 3.86 (m, 1H), 3.84 – 3.77 (m, 1H), 2.68 – 2.38 (m, 1H), 2.16 – 1.53 (m, 6H), 1.36 – 1.14 (m, 5H), 0.92 – 0.79 (m, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 155.3, 137.0, 135.1, 128.4 (2C), 127.75, 127.70 (2C), 117.0, 66.5, 28.5, 22.6, 14.1, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{19}H_{27}NO_2Na^+$ 324.1934; found: 324.1944. The ^{1}H and ^{13}C NMR spectra of this compound matched those of the enantiomer previously reported by Toyooka et al.[3]



12

α,β-Unsaturated ketone 12. To a solution of 2,5-*cis*-substituted pyrrolidine **11** (28.5 mg, 94.5 μmol) and methyl vinyl ketone (40 μL, 0.49 mmol) in degassed CH_2Cl_2 (2.30 mL) was added a solution of the second-generation Grubbs complex (**G-II**) (8.6 mg, 10 μmol) in degassed CH_2Cl_2 (1.00 mL), and the resultant mixture was heated at reflux for 13 h. After being cooled to room temperature, the reaction mixture was directly purified by flash column chromatography (silica gel, 1st round: 10 to 20% EtOAc/hexanes, 2nd round: 10% *t*-BuOMe/hexanes) to give α,β-unsaturated ketone **12** (30.6 mg, 94%, *E*/*Z* >95:5) as a colorless oil: **[α]**$_D^{24}$ +32. 8 (*c* 0.70, $CHCl_3$); **IR** (film): 2955, 2930, 1697, 1675, 1404 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.36 – 7.26 (m, 5H), 6.78 – 6.58 (m, 1H), 6.07 – 5.95 (m, 1H), 5.18 – 5.05 (m, 2H), 4.03 – 3.96 (m, 1H), 3.87 – 3.78 (m, 1H), 2.80 – 1.58 (m, 10H), 1.38 – 1.12 (m, 5H), 0.91 – 0.79 (m, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers, signals for the major rotamer): δ 198.6, 155.4, 144.7, 136.8, 133.2, 128.4 (2C), 127.9 (2C), 127.8, 66.7, 58.6, 57.7, 38.1, 35.5, 29.5, 28.9, 28.5, 26.7, 22.6, 14.0; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{21}H_{29}NO_3Na^+$ 366.2040; found: 366.2049.

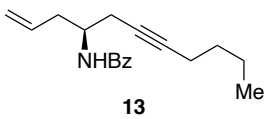


(+)-monomorine I (**6**)

(+)-Monomorine I (6). To a solution of α,β-unsaturated ketone **12** (16.7 mg, 48.6 μmol) in EtOH (1.40 mL) was added 20% $Pd(OH)_2$/C (7.0 mg, 42 wt%), and the resultant suspension was stirred vigorously at room temperature under an atmosphere of H_2 (balloon) for 17 h.

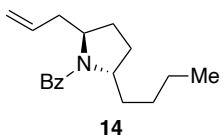
[3] N. Toyooka, D. Zhou and H. Nemoto, *J. Org. Chem.*, 2008, **73**, 4575.

The reaction mixture was filtered through a pad of Celite, and the filtrate was concentrated under reduced pressure to give (+)-monomorine I (**6**) (6.3 mg, 66%, dr >95:5) as a pale yellow oil: $[\alpha]_D^{24}$ +34.0 (*c* 0.65, *n*-hexane); **IR** (film): 2956, 2928, 2859, 2363, 1457, 1377 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 2.48 – 2.41 (m, 1H), 2.23 – 2.15 (m, 1H), 2.09 – 2.00 (m, 1H), 1.91 – 1.60 (m, 5H), 1.51 – 1.10 (m, 14H), 0.86 (t, *J* = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 67.2, 62.9, 60.3, 39.6, 35.7, 30.8, 32.5, 29.7, 29.5, 24.8, 22.9 (2C), 14.2; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{13}H_{26}N^+$ 196.2060; found: 196.2044.



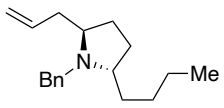
13

Amino alkyne 13. To a solution of homoallylic alcohol **9** (294.5 mg, 1.773 mmol) in THF (8.00 mL) was added Ph_3P (556.5 mg, 2.122 mmol), and the resultant mixture was cooled to 0 °C. To the reaction mixture at 0 °C were added DIAD (420 μL, 2.02 mmol) and DPPA (460 μL, 2.14 mmol), and the resultant mixture was stirred at room temperature for 1 h. To the reaction mixture were added Ph_3P (930.5 mg, 3.548 mmol) and H_2O (1.60 mL), and the resultant mixture was stirred at 50 °C for 2 h. To the reaction mixture at 0 °C were added H_2O (6.40 mL), $NaHCO_3$ (456.5 mg, 5.434 mmol), and benzoyl chloride (230 μL, 1.98 mmol), and the resultant mixture was stirred at room temperature for 1 h. The reaction mixture was extracted with EtOAc, and the organic layer was washed with H2O and brine. The organic layer was dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave amino alkyne **13** (354.2 mg, 74%) as a colorless oil: $[\alpha]_D^{24}$ −64.1 (*c* 0.16, $CHCl_3$); **IR** (film): 3305, 2957, 2931, 1635, 1539, 1490 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.74 – 7.72 (m, 2H), 7.49 – 7.46 (m, 1H), 7.43 – 7.40 (m, 2H), 6.28 (d, *J* = 8.5 Hz, 1H), 5.81 (dddd, *J* = 18.0, 10.5, 7.5, 7.5 Hz, 1H), 5.14 (dd, *J* = 17.0, 2.0 Hz, 1H), 5.11 – 5.08 (m, 1H), 4.30 – 4.23 (m, 1H), 2.53 – 2.39 (m, 4H), 2.17 (tt, *J* = 7.5, 2.5 Hz, 2H), 1.49 – 1.35 (m, 4H), 0.88 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 166.8, 134.7, 134.2, 131.4, 128.5 (2C), 126.8 (2C), 118.1, 83.4, 75.3, 47.3, 37.9, 31.0, 23.7, 21.9, 18.4, 13.6; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{18}H_{23}NONa^+$ 292.1672; found: 292.1678.



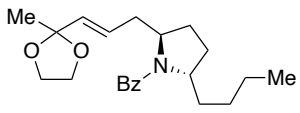
14

2,5-*trans*-Substituted pyrrolidine 14. To a solution of amino alkyne **13** (273.5 mg, 1.015 mmol) in moist DCE (10.0 mL) were added $AgSbF_6$ (34.5 mg, 0.100 mmol) and [(*p*-$CF_3C_6H_4)_3P$]AuCl (70.8 mg, 0.101 mmol), and the resultant mixture was stirred at room temperature for 40 min. To the reaction mixture were added Et_3SiH (650 μL, 4.06 mmol) and benzoic acid (127.3 mg, 1.042 mmol), and the resultant mixture was stirred at 70 ℃ for 16 h. The reaction was quenched with saturated aqueous $NaHCO_3$ solution at 0 ℃. The resultant mixture was filtered through a pad of Celite, and the filtrate was extracted with EtOAc. The organic layer was washed with H_2O and brine, dried (Na_2SO_4), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 15 to 30% *t*-BuOMe/hexanes) gave 2,5-*trans*-substituted pyrrolidine **14** (169.8 mg, 62%) as a colorless oil, along with its diastereomer, 2,5-*cis*-substituted pyrrolidine, 2,5-*cis*-**14** (25.6 mg, 9%). Data for 2,5-*trans*-**14**: $[\alpha]_D^{24}$ +138.0 (*c* 1.05, $CHCl_3$); **IR** (film): 2955, 2930, 1626, 1445, 1399 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.46 – 7.23 (m, 5H), 5.87 – 5.79 (m, 0.6H), 5.32 (dddd, *J* = 17.5, 10.0, 7.5, 7.5 Hz, 0.4H), 5.10 – 5.05 (m, 1.2H), 4.85 (d, *J* = 10.5 Hz, 0.4H), 4.70 (dd, *J* = 17.5, 1.5 Hz, 0.4H) 4.36 – 4.32 (m, 0.6H), 4.27 – 4.23 (m, 0.4H), 4.01 – 3.97 (m, 0.4H), 3.93 – 3.89 (m, 0.6H), 2.64 – 2.60 (m, 0.6H), 2.32 – 2.26 (m, 0.6H), 2.10 – 1.63 (m, 5.8H), 1.41 – 0.70 (m, 6.2H), 0.58 (t, *J* = 7.0 Hz, 1.8H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 170.3, 170.1, 138.2, 135.2, 134.2, 129.5, 129.4, 128.3 (2C), 128.2 (2C), 126.8 (4C), 117.5, 117.3, 59.7, 59.0, 57.9, 56.6, 39.0, 37.2, 34.2, 32.7, 28.6, 28.2, 28.01, 28.00, 27.8, 26.1, 26.0, 22.6, 21.7, 14.1, 13.6; **HRMS** (ESI) *m*/*z*: [$(M + Na)^+$] calcd for $C_{18}H_{25}NONa^+$ 294.1828; found: 294.1845. Data for 2,5-*cis*-**14**: $[\alpha]_D^{23}$ +6.3 (*c* 0.62, $CHCl_3$); **IR** (film): 2956, 2930, 1628, 1445, 1404 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.38 – 7.34 (m, 5H), 5.82 – 3.57 (m, 5H), 2.90 – 0.64 (m, 15H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 170.3, 138.0, 129.1, 128.2 (2C), 126.2 (2C), 35.3, 28.5, 13.9, other carbon signals were not clearly observable due to slow rotation of the amide bond, see the attached spectrum; HRMS (ESI) *m*/*z*: [$(M + Na)^+$] calcd for $C_{18}H_{25}NONa^+$ 294.1828; found: 294.1855.

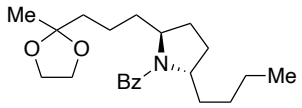


S26

Benzyl amine S26 (derivatization of 2,5-*trans*-substituted pyrrolidine **14**). To a suspension of $LiAlH_4$ (34.0 mg, 0.824 mmol) in THF (1.00 mL) at 0 °C was added a solution of 2,5-*trans*-substituted pyrrolidine **14** (52.1 mg, 0.192 mmol) in THF (500 μL + 500 μL rinse), and the resultant mixture was stirred at room temperature for 12 h. The reaction was quenched with H_2O at 0 °C. To the reaction mixture was added 3 M aqueous NaOH solution, and the resultant mixture was stirred at 0 °C for 30 min before it was dried ($MgSO_4$) and then filtered through a pad of Celite. The filtrate was concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5% EtOAc/hexanes) gave benzyl amine **S26** (42.7 mg, 86%) as a colorless oil: $[\alpha]_D^{23}$ +80.5 (*c* 0.21, $CHCl_3$); **IR** (film): 2955, 2926, 2856, 1456, 915, 699 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.36 – 7.34 (m, 2H), 7.29 – 7.26 (m, 2H), 7.21 – 7.18 (m, 1H), 5.72 – 5.64 (m, 1H), 4.98 – 4.94 (m, 2H), 3.85 (d, *J* = 14.0 Hz, 1H), 3.63 (d, *J* = 14.0 Hz, 1H), 2.96 – 2.91 (m, 1H), 2.84 – 2.79 (m, 1H), 2.33 – 2.29 (m, 1H), 1.95 – 1.76 (m, 3H), 1.59 – 1.44 (m, 3H), 1.29 – 1.04 (m, 5H), 0.84 (t, *J* = 7.5 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 140.7, 136.7, 128.4 (2C), 128.1 (2C), 126.4, 116.0, 60.4, 59.5, 51.3, 34.8, 30.7, 28.5, 28.2, 27.5, 23.0, 14.2; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{18}H_{28}N^+$ 258.2216; found: 258.2207.



S27

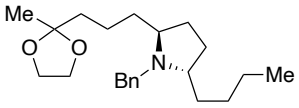


16

Benzamide 16. To a mixture of 2,5-*trans*-substituted pyrrolidine **14** (26.4 mg, 97.3 μmol) and 2-vinyl-1,3-dioxolane (**15**) (45 μL, 0.41 mmol) was added a solution of the second-generation Grubbs complex (**G-II**) (8.5 mg, 10 μmol) in degassed CH_2Cl_2 (1.00 mL), and the resultant mixture was heated at reflux for 11 h. After being cooled to room temperature, the reaction mixture was directly purified by flash column chromatography (silica gel, 10 to 40% EtOAc/hexanes) to give olefin **S27** (30.5 mg, 88%, *E*/*Z* >95:5) as a pale yellow oil: $[\alpha]_D^{24}$ +114.5 (*c* 0.26, $CHCl_3$); **IR** (film): 2955, 2931, 1624, 1398, 1039, 702 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.46 – 7.34 (m, 5H), 5.82 (ddd, *J* = 15.5, 10.0, 8.5 Hz, 0.6H), 5.50 (d, *J* = 15.5 Hz, 0.6H), 5.33 (ddd, *J* = 15.0, 8.5, 8.5 Hz, 0.4H), 5.10 (d, *J* = 15.0 Hz, 0.4H), 4.36 – 4.32 (m, 0.6H), 4.26 – 4.23 (m, 0.4H), 4.01 – 3.83 (m, 4.2H), 3.77 – 3.70 (m, 0.8H), 2.61 – 2.57 (m, 0.6H), 2.32 – 2.25 (m, 0.6H), 2.10 – 1.64 (m, 5.8H), 1.45 (s, 1.8H), 1.40 – 0.69 (m, 7.4H), 0.58 (t, *J* = 7.0 Hz, 1.8H);

$^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$, a mixture of amide romaters): δ 170.3, 170.1, 138.2 (2C), 133.5, 133.1, 129.6, 129.5, 128.3 (2C), 128.2 (2C), 127.5, 126.8 (4C), 126.4, 107.2, 106.9, 64.5, 64.4 (2C), 64.3, 59.7, 58.9, 57.9, 56.6, 37.0, 35.1, 34.2, 32.7, 28.6, 28.2, 28.1, 27.9, 26.09, 26.06, 24.9, 24.8, 22.7, 21.8, 14.1, 13.6; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{31}NO_3Na^+$ 380.2196; found: 380.2198.

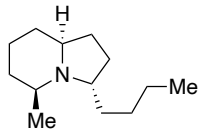
To a solution of olefin **S27** (27.3 mg, 75.9 μmol) in EtOAc (1.90 mL) were added Et_3N (45 μL, 0.32 mmol) and 10% Pd/C (14.5 mg, 53 wt%), and the resultant suspension was stirred vigorously at room temperature under an atmosphere of H_2 (balloon) for 2 h. The reaction mixture was filtered through a pad of Celite, and the filtrate was concentrated under reduced pressure to give benzamide **16** (26.1 mg, 96%) as a colorless oil: **[α]**$_D^{24}$ +85.0 (*c* 0.31, $CHCl_3$); **IR** (film): 2953, 1623, 1398, 1060 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$, a mixture of amide rotamers): δ 7.45 – 7.41 (m, 2H), 7.36 – 7.32 (m, 3H), 4.24 – 4.21 (m, 1H), 3.94 – 3.72 (m, 5H), 2.10 – 1.86 (m, 3H), 1.75 – 1.58 (m, 3.5H), 1.49 – 0.69 (m, 14H), 0.58 (t, *J* = 7.0 Hz, 1.5H); **$^{13}C\{^1H\}$ NMR** (125 MHz, $CDCl_3$, a mixture of amide rotamers): δ 170.2, 170.1, 138.4 (2C), 129.39, 129.36, 128.21 (2C), 128.18 (2C), 126.9 (2C), 126.8 (2C), 110.0, 109.6, 64.6 (2C), 64.5 (2C), 59.3, 59.2, 57.5 (2C), 38.9, 38.1, 34.8, 34.1, 33.0, 32.6, 28.7, 28.2, 28.1 (2C), 26.3, 26.2, 23.8, 23.7, 22.7, 21.8, 21.1, 20.4, 14.1, 13.6; **HRMS** (ESI) *m*/*z*: [(M + Na)$^+$] calcd for $C_{22}H_{33}NO_3Na^+$ 382.2353; found: 382.2360.



17

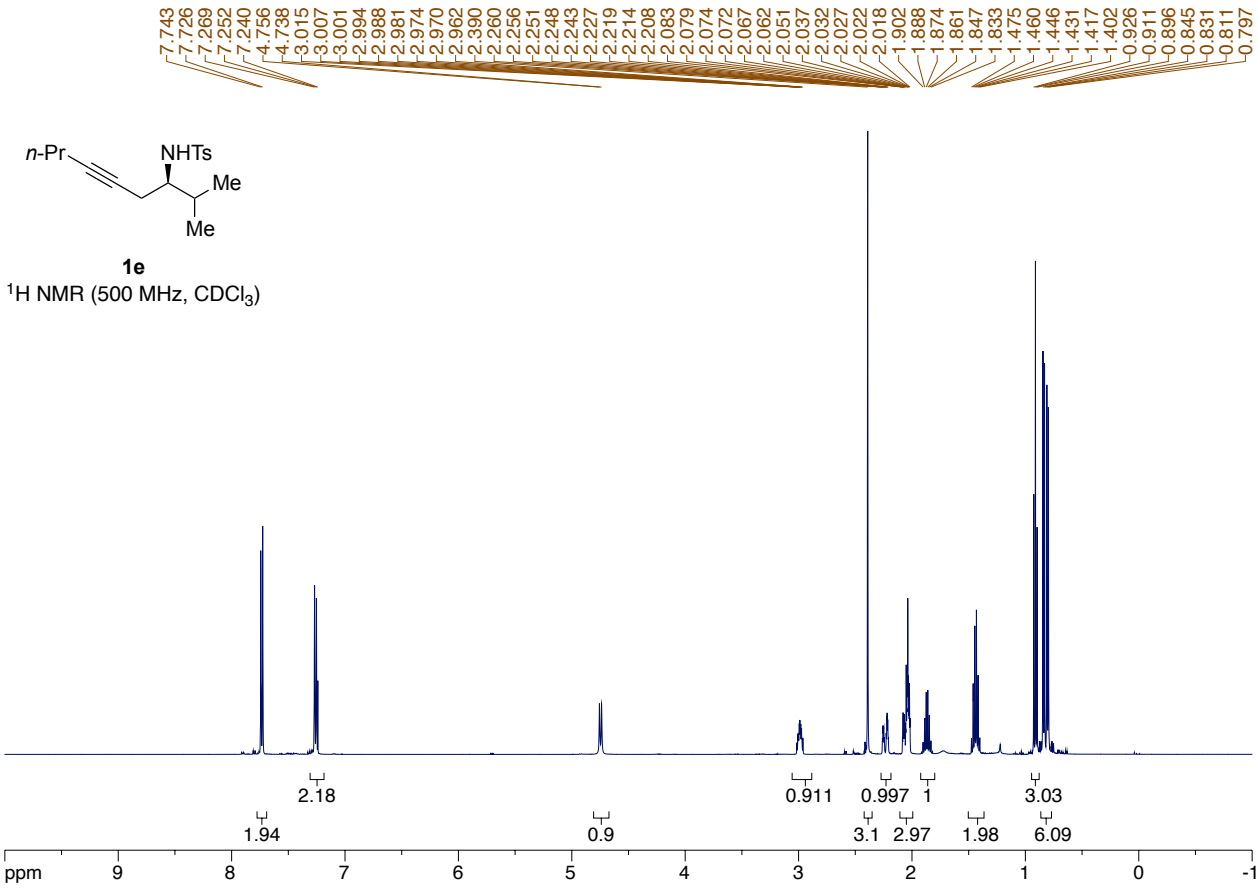
Benzyl amine 17. To a suspension of $LiAlH_4$ (10.8 mg, 0.262 mmol) in THF (500 μL) at 0 °C was added a solution of benzamide **16** (22.8 mg, 63.4 μmol) in THF (1.00 mL + 0.500 mL rinse), and the resultant mixture was stirred at room temperature for 6 h. The reaction was quenched with H_2O at 0 °C. To the reaction mixture was added 3 M aqueous NaOH solution, and the resultant mixture was stirred at 0 °C for 30 min before it was dried ($MgSO_4$) and then filtered through a pad of Celite. The filtrate was concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel, 5 to 40% EtOAc/hexanes) gave benzyl amine **17** (21.9 mg, quant.) as a colorless oil: **[α]**$_D^{24}$ +76.6 (*c* 0.28, $CHCl_3$); **IR** (film): 2952, 2871, 1455, 1211, 1374, 699 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 7.34 – 7.33 (m, 2H), 7.28 – 7.25 (m, 2H), 7.20 – 7.17 (m, 1H), 3.93 – 3.85 (m, 4H), 3.79 (d, *J* = 14.0 Hz, 1H), 3.61 (d, *J* = 14.0 Hz, 1H), 2.83 – 2.78 (m, 2H), 1.91 – 1.81 (m, 2H), 1.60 – 1.44

(m, 6H), 1.41 – 1.32 (m, 1H), 1.26 (s, 3H), 1.24 – 1.02 (m, 7H), 0.83 (t, J = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 140.9, 128.4 (2C), 128.0 (2C), 126.3, 110.0, 64.6 (2C), 60.25, 60.23, 51.3, 39.4, 30.9, 30.1, 28.6, 28.2 (2C), 23.7, 23.0, 20.9, 14.1; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{22}H_{36}NO_2^+$ 346.2741; found: 346.2762.



(+)-indolizidine 195B (**7**)

(+)-Indolizidine 195B (7). To a solution of benzyl amine **17** (19.2 mg, 55.6 μmol) in EtOH/aq. HCl (1.10 mL, v/v 10:1) was added 20% $Pd(OH)_2$/C (18.8 mg, 98 wt%), and the resultant suspension was stirred vigorously at room temperature under an atmosphere of H_2 (balloon) for 15 h. The reaction mixture was filtered through a pad of Celite, and the filtrate was concentrated under reduced pressure. The residue was partitioned between CH_2Cl_2 and saturated aqueous Na_2CO_3 solution. The organic layer was separated, and the aqueous layer was extracted twice with CH_2Cl_2. The organic layer was combined, dried (Na_2CO_3), filtered, and concentrated under reduced pressure. Purification of the residue by flash column chromatography (silica gel NH-DM2035, 15% $CHCl_3$/hexanes) gave indolizidine 195B (**7**) (6.5 mg, 60%) as a slightly pink-colored oil: **[α]**$_D^{24}$ +98.0 (*c* 0.067, MeOH); **IR** (film): 2924, 2854, 1733, 1540, 1458 cm^{-1}; **^{1}H NMR** (500 MHz, $CDCl_3$): δ 3.30 – 3.22 (m, 1H), 2.54 – 2.45 (m, 1H), 2.40 – 2.32 (m, 1H), 1.89 – 0.98 (m, 19H), 0.88 (t, J = 7.0 Hz, 3H); **^{13}C{^{1}H} NMR** (125 MHz, $CDCl_3$): δ 58.9, 58.7, 51.9, 34.5, 32.4, 30.0, 29.2, 26.3, 24.8, 24.7, 23.0, 20.5, 14.3; **HRMS** (DART) *m*/*z*: [(M + H)$^+$] calcd for $C_{13}H_{26}N^+$ 196.2060; found: 196.2048.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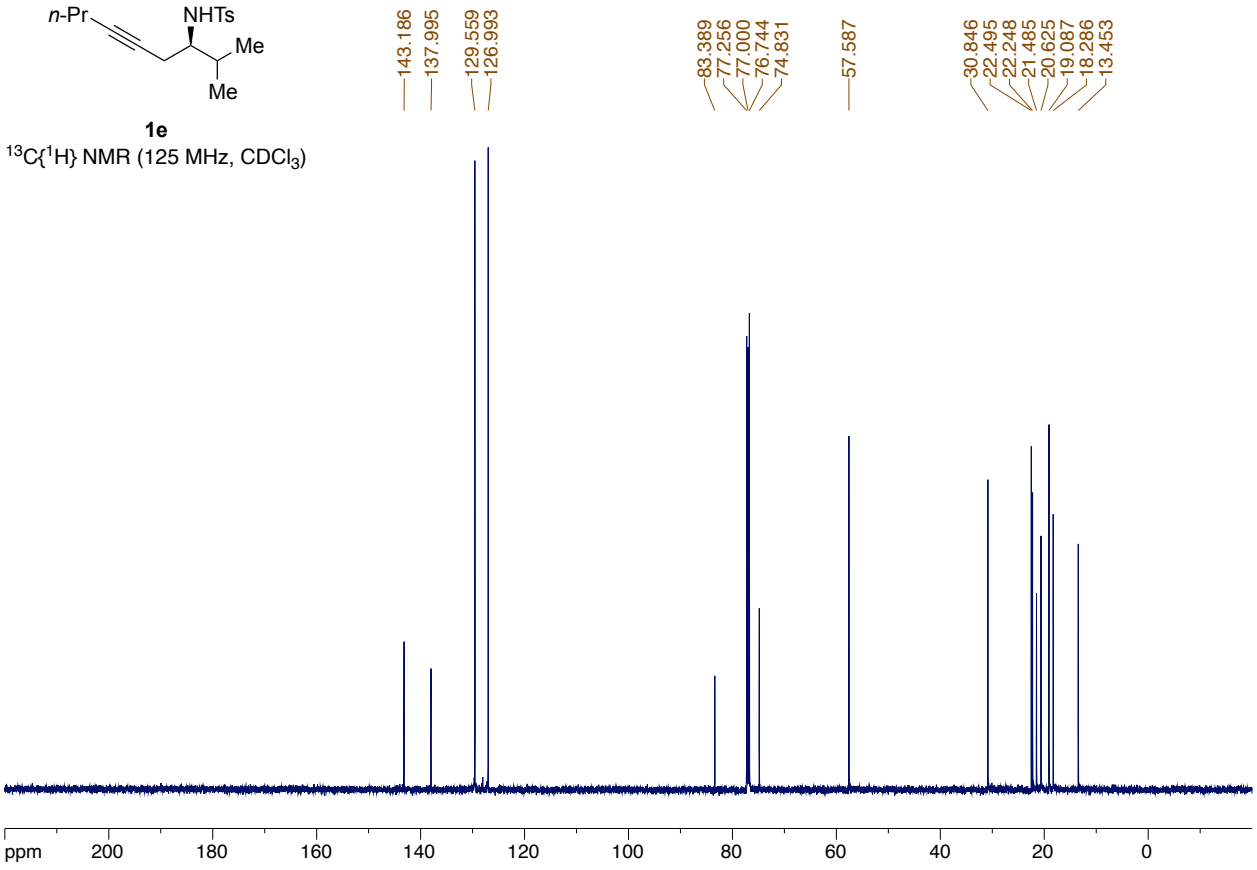
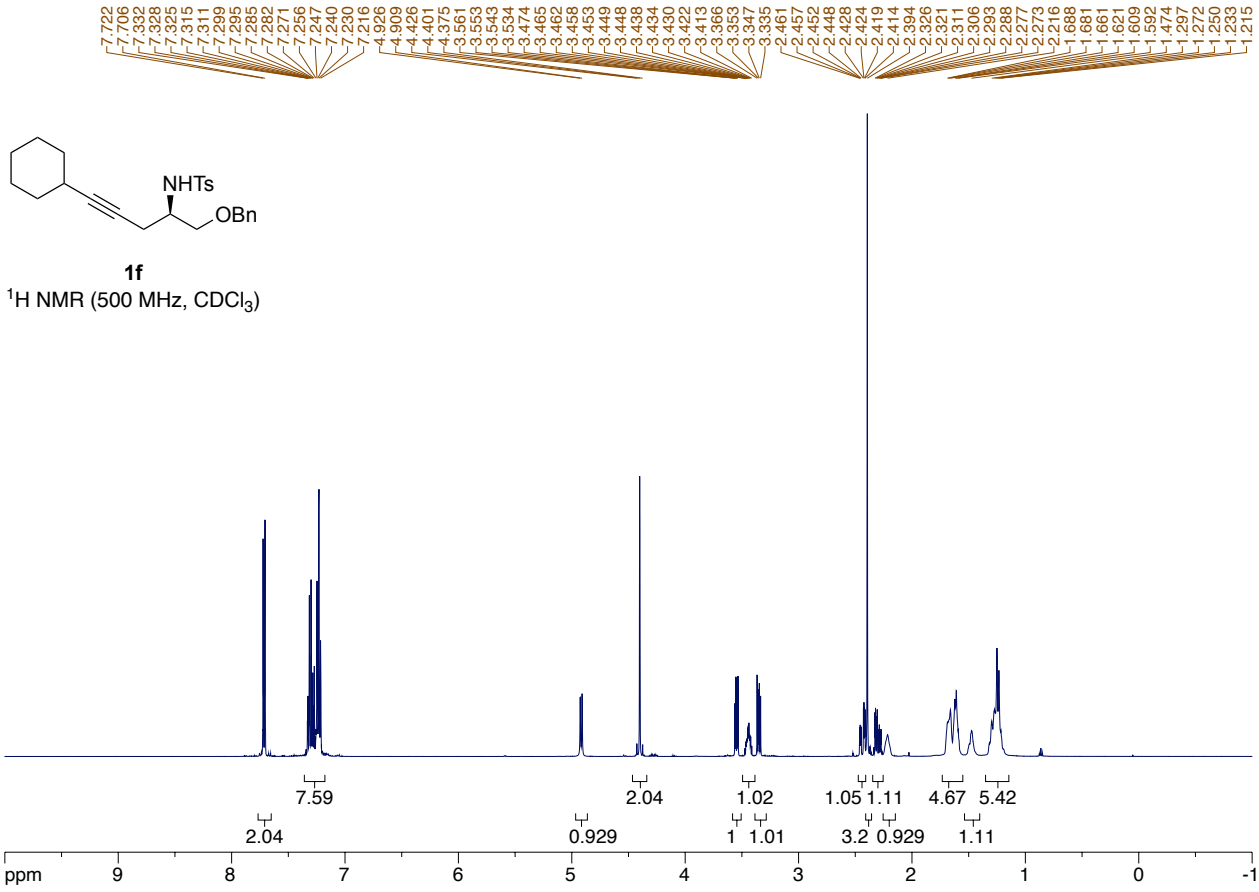
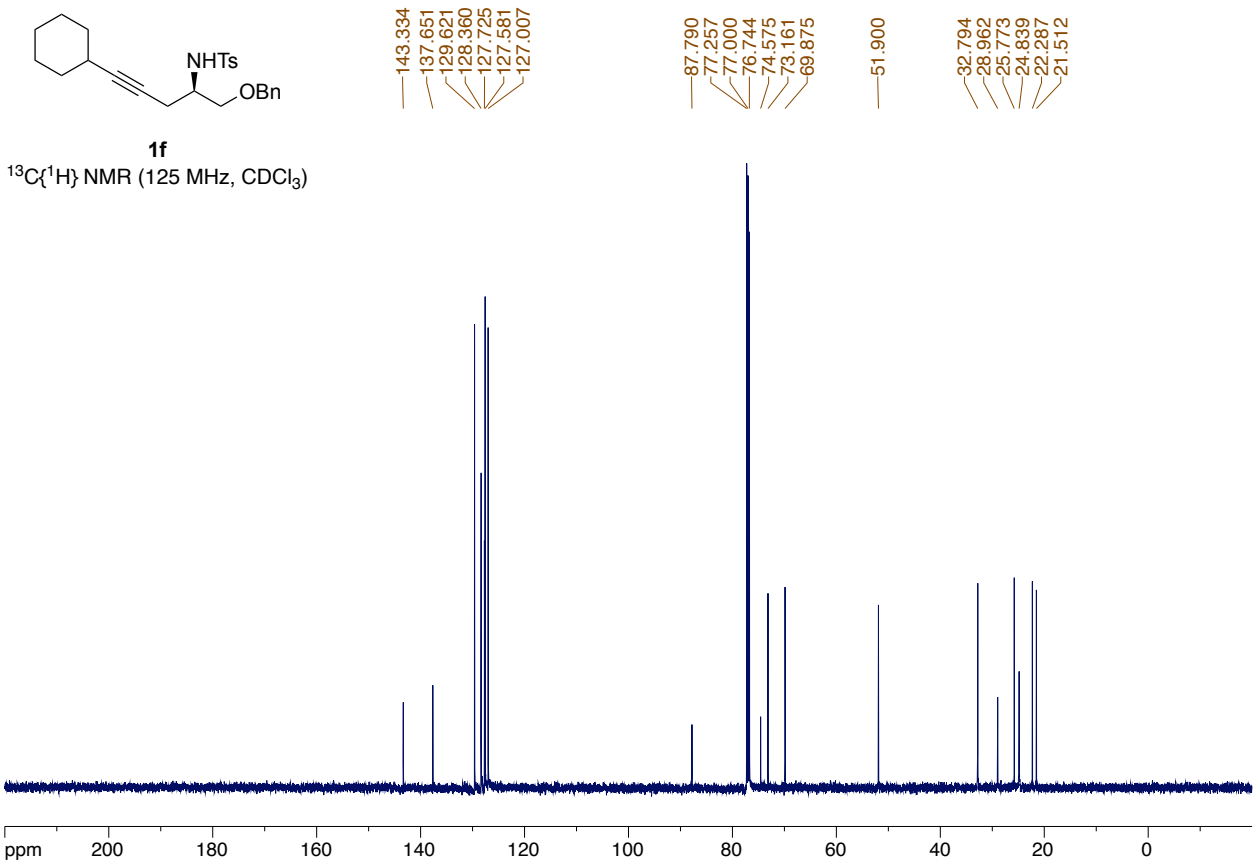
7.269
7.252
7.240
4.756
4.738
3.015
3.007
3.001
2.994
2.988
2.981
2.974
2.970
2.962
2.390
2.260
2.256
2.251
2.248
2.243
2.227
2.219
2.214
2.208
2.083
2.079
2.074
2.072
2.067
2.062
2.051
2.037
2.032
2.027
2.022
2.018
1.902
1.888
1.874
1.861
1.847
1.833
1.475
1.460
1.446
1.431
1.417
1.402
0.926
0.911
0.896
0.845
0.831
0.811
0.797
n-Pr
NHTs
Me
Me
1e
1H NMR (500 MHz, CDCl3)
2.18
0.911
0.997
1
3.03
1.94
0.9
3.1
2.97
1.98
6.09
ppm
9
8
7
6
5
4
3
2
1
0
-1


n-Pr
NHTs
Me
Me
1e
13C{1H} NMR (125 MHz, CDCl3)
143.186
137.995
129.559
126.993
83.389
77.256
77.000
76.744
74.831
57.587
30.846
22.495
22.248
21.485
20.625
19.087
18.286
13.453
ppm
200
180
160
140
120
100
80
60
40
20
0



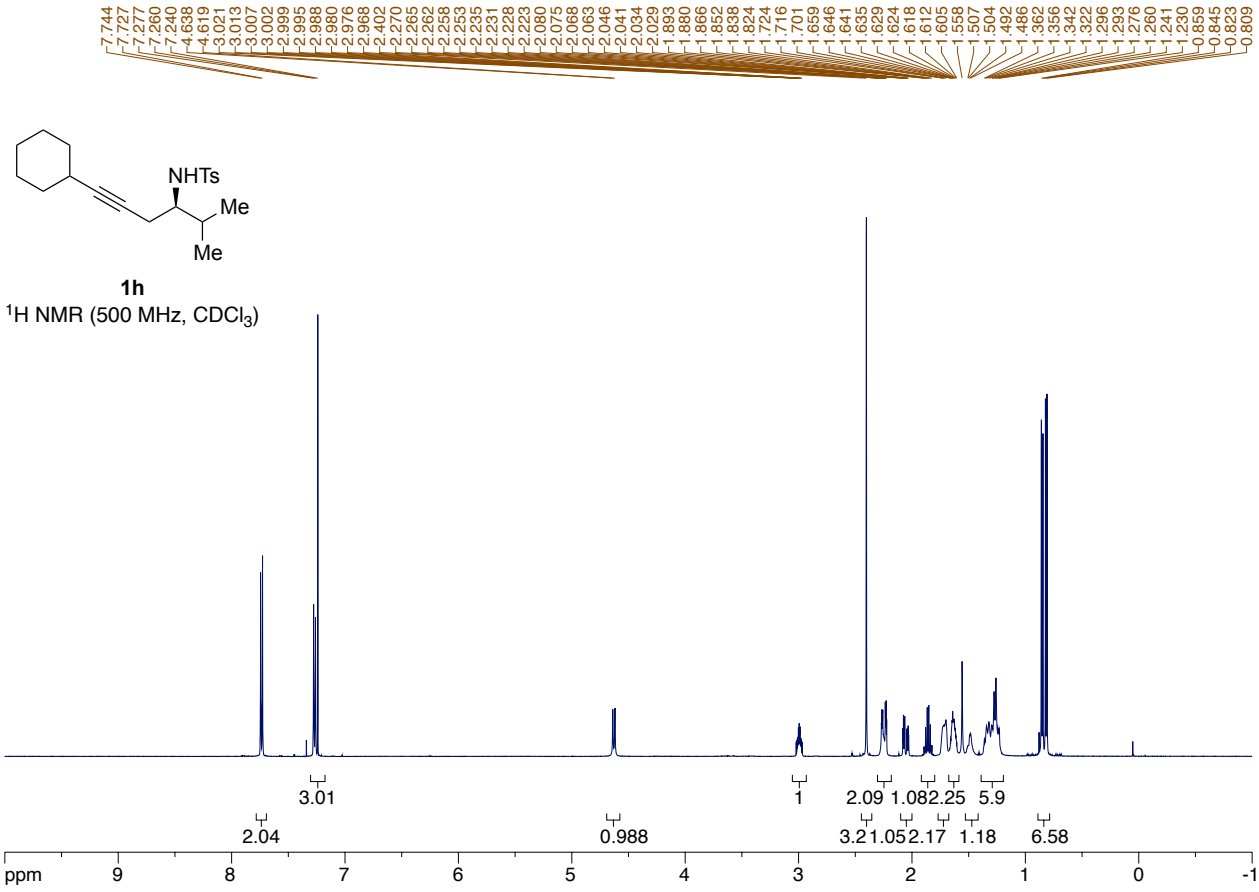
1f

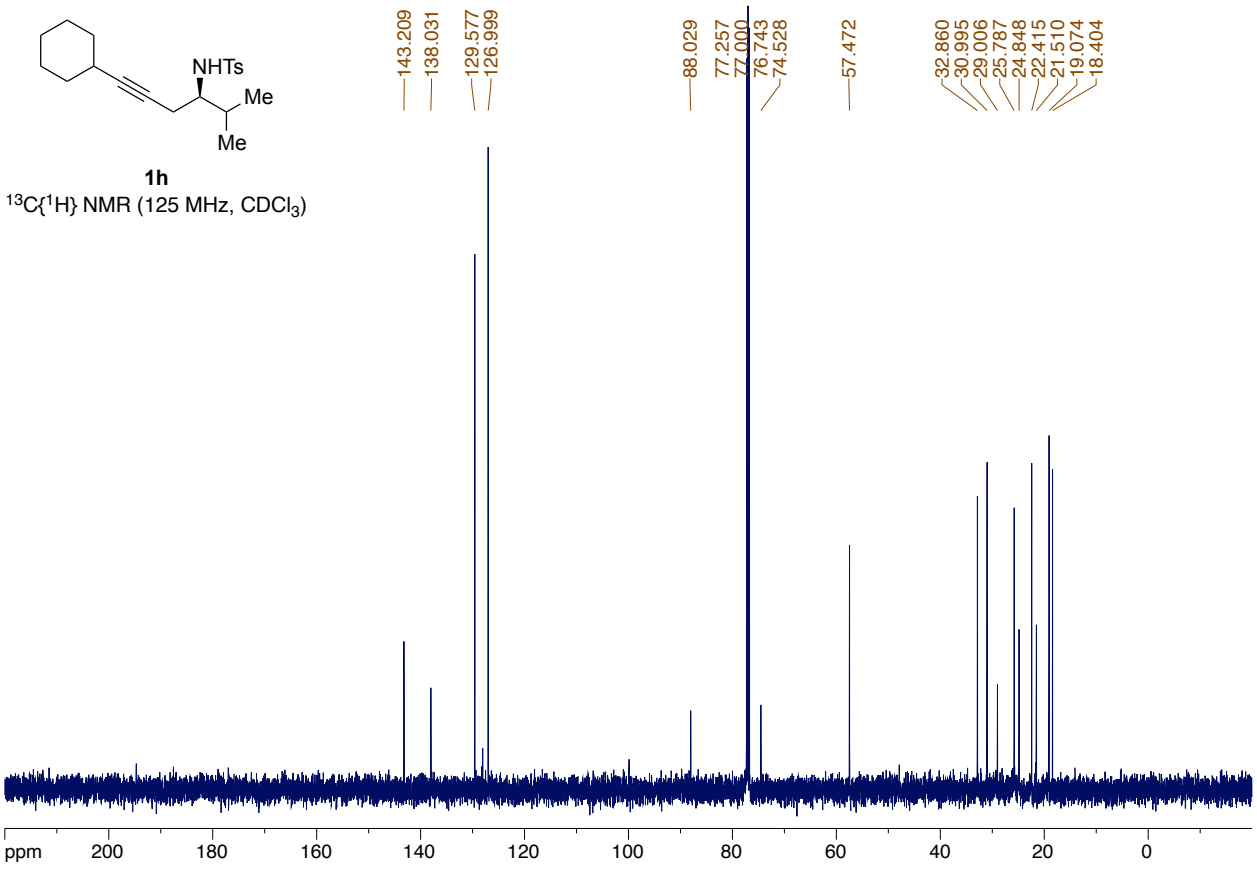
^{1}H NMR (500 MHz, $CDCl_3$)



1f

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)


7.744
7.727
7.277
7.260
7.240
4.638
4.619
3.021
3.013
3.007
3.002
2.999
2.995
2.988
2.980
2.976
2.968
2.402
2.270
2.265
2.262
2.258
2.253
2.235
2.231
2.228
2.223
2.080
2.075
2.068
2.063
2.046
2.041
2.034
2.029
1.893
1.880
1.866
1.852
1.838
1.824
1.724
1.716
1.701
1.659
1.646
1.641
1.635
1.629
1.624
1.618
1.612
1.605
1.558
1.507
1.504
1.492
1.486
1.362
1.356
1.342
1.322
1.296
1.293
1.276
1.260
1.241
1.230
0.859
0.845
0.823
0.809
NHTs
Me
Me
1h
1H NMR (500 MHz, CDCl3)
3.01
1
2.09
1.08
2.25
5.9
2.04
0.988
3.21
1.05
2.17
1.18
6.58
ppm
9
8
7
6
5
4
3
2
1
0
-1


NHTs
Me
Me
1h
13C{1H} NMR (125 MHz, CDCl3)
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138.031
129.577
126.999
88.029
77.257
77.000
76.743
74.528
57.472
32.860
30.995
29.006
25.787
24.848
22.415
21.510
19.074
18.404
ppm
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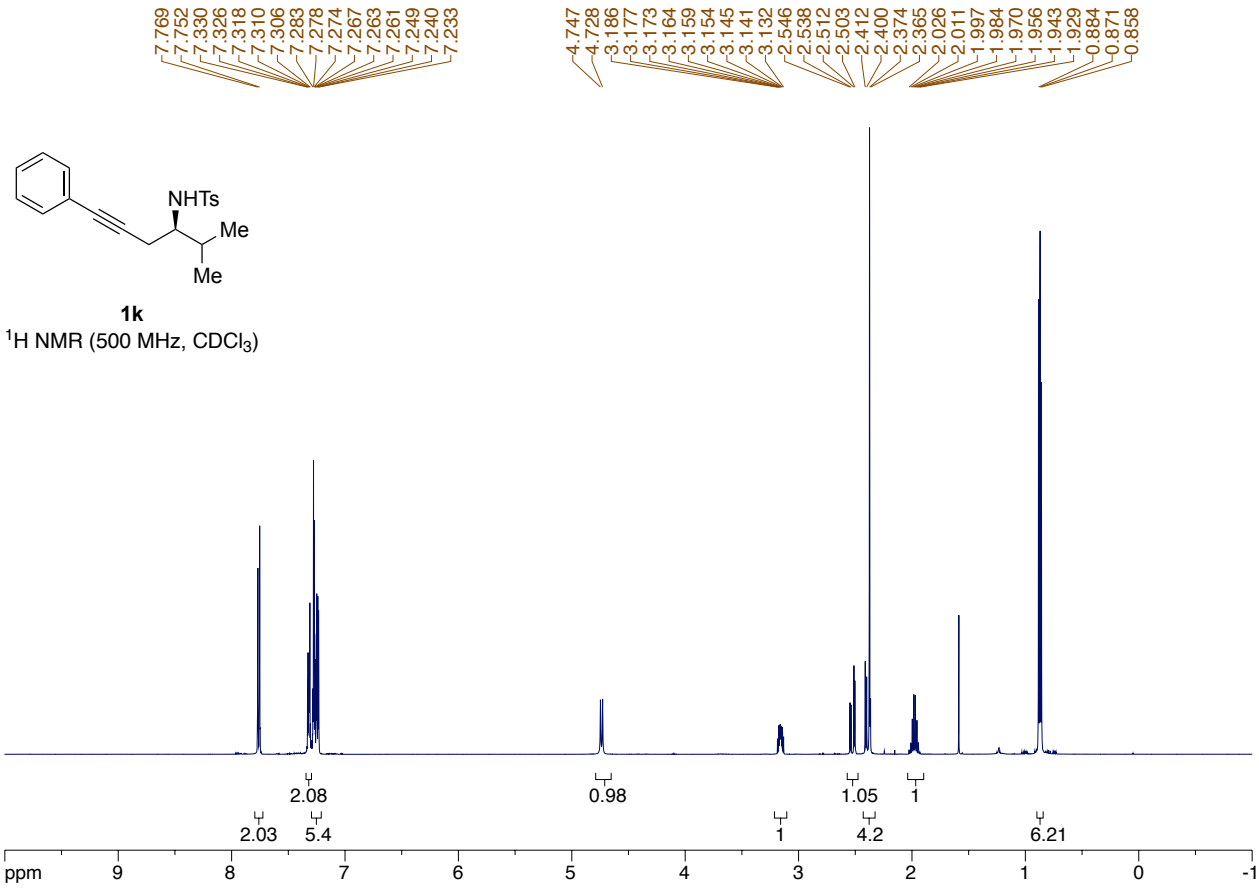
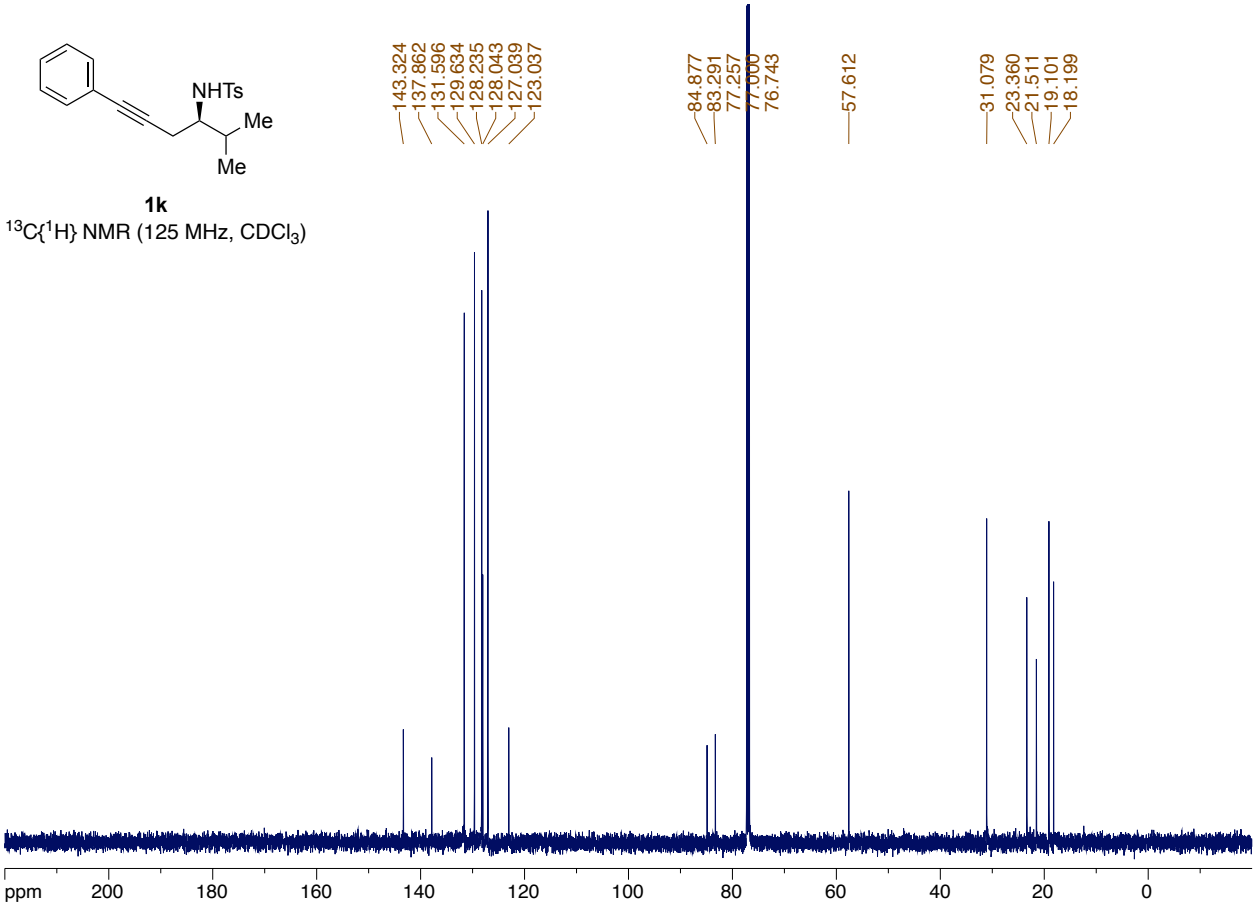
180
160
140
120
100
80
60
40
20
0



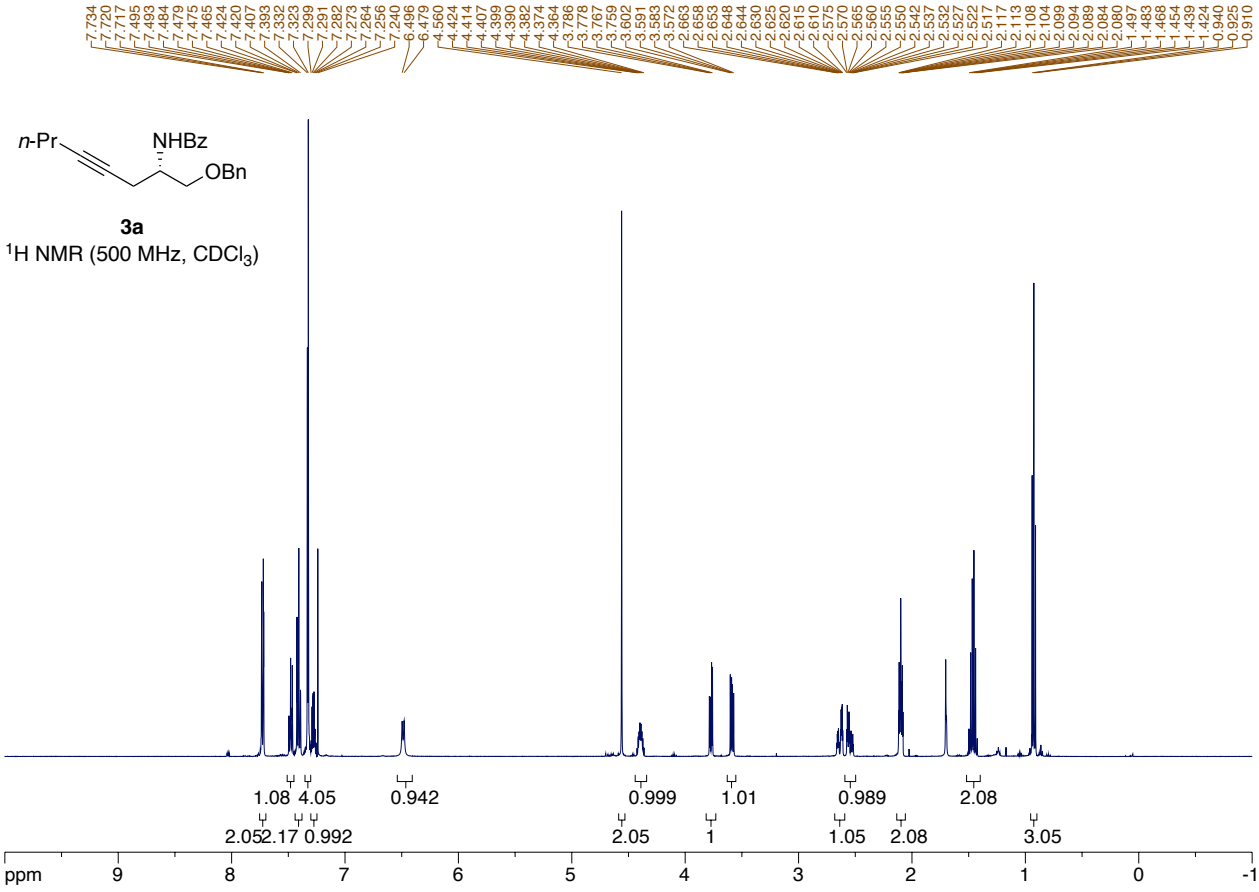
1k

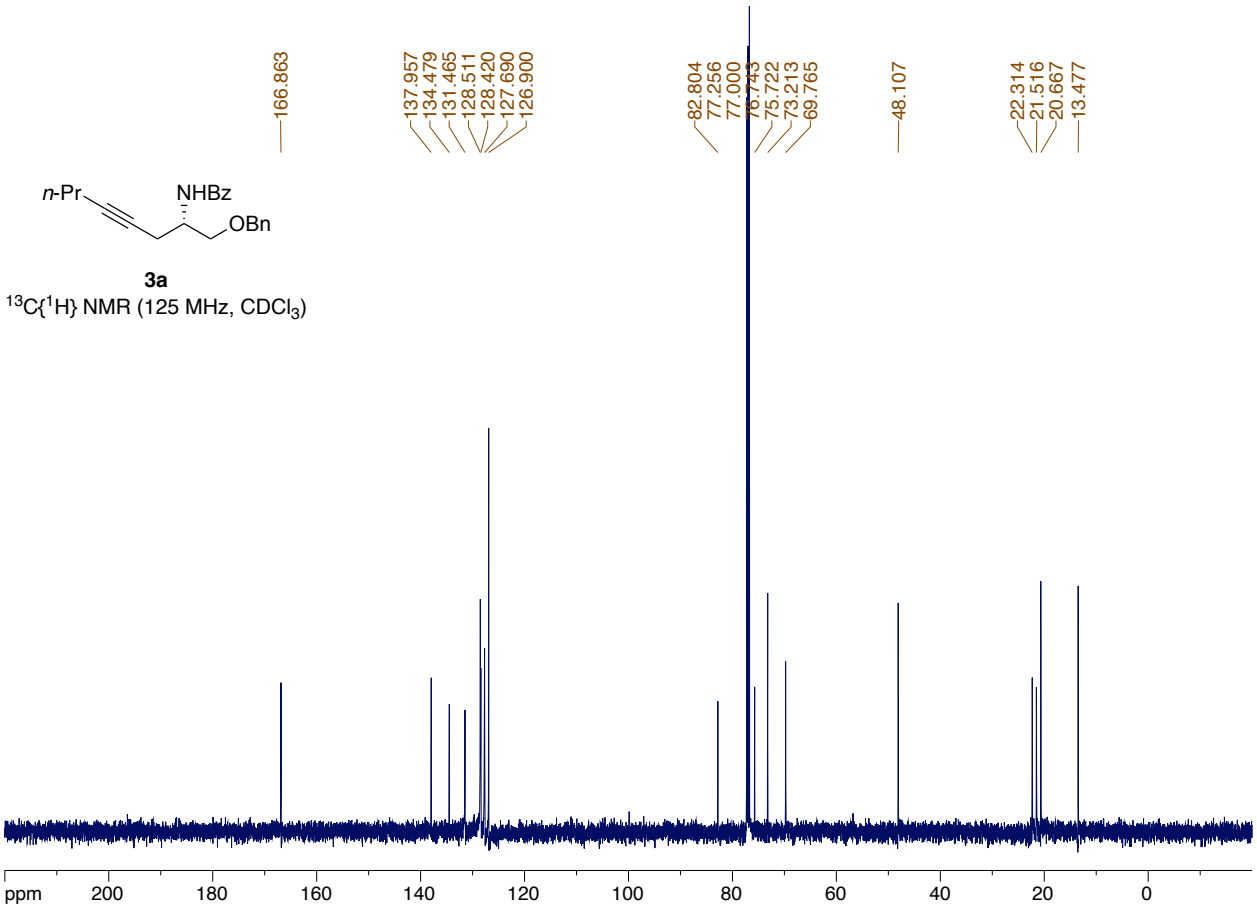
^{1}H NMR (500 MHz, $CDCl_3$)



1k

$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)


n-Pr
NHBz
OBn
3a
1H NMR (500 MHz, CDCl3)
7.734 7.720 7.717 7.495 7.493 7.484 7.479 7.475 7.465 7.424 7.420 7.407 7.393 7.332 7.323 7.299 7.291 7.282 7.273 7.264 7.256 7.240 6.496 6.479 4.560 4.424 4.414 4.407 4.399 4.390 4.382 4.374 4.364 3.786 3.778 3.767 3.759 3.602 3.591 3.583 3.572 2.663 2.658 2.653 2.648 2.644 2.630 2.625 2.620 2.615 2.610 2.575 2.570 2.565 2.560 2.555 2.550 2.542 2.537 2.532 2.527 2.522 2.517 2.117 2.113 2.108 2.104 2.099 2.094 2.089 2.084 2.080 1.497 1.483 1.468 1.454 1.439 1.424 0.940 0.925 0.910
1.08 4.05 0.942 0.999 1.01 0.989 2.08
2.05 2.17 0.992 2.05 1 1.05 2.08 3.05
ppm 9 8 7 6 5 4 3 2 1 0 -1


n-Pr
NHBz
OBn
3a
13C{1H} NMR (125 MHz, CDCl3)
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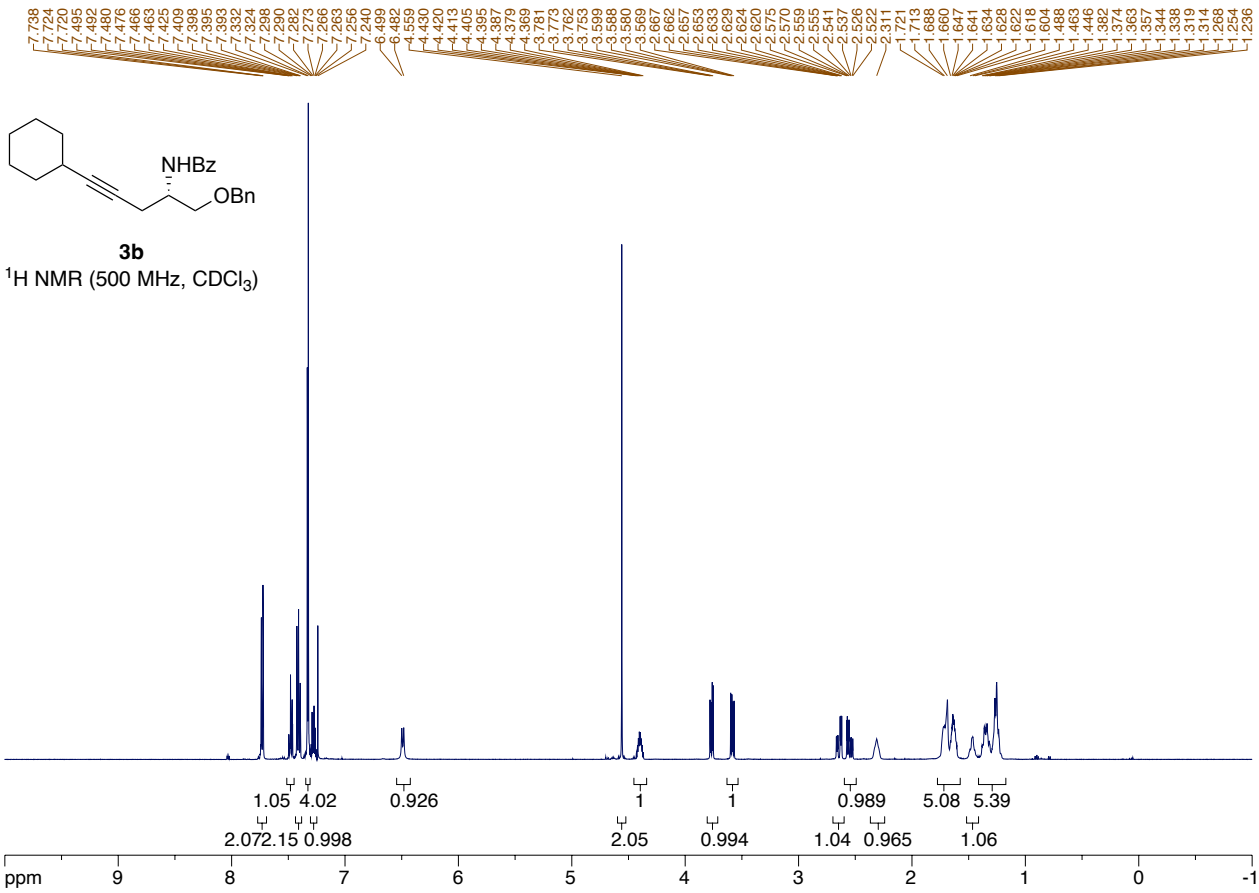
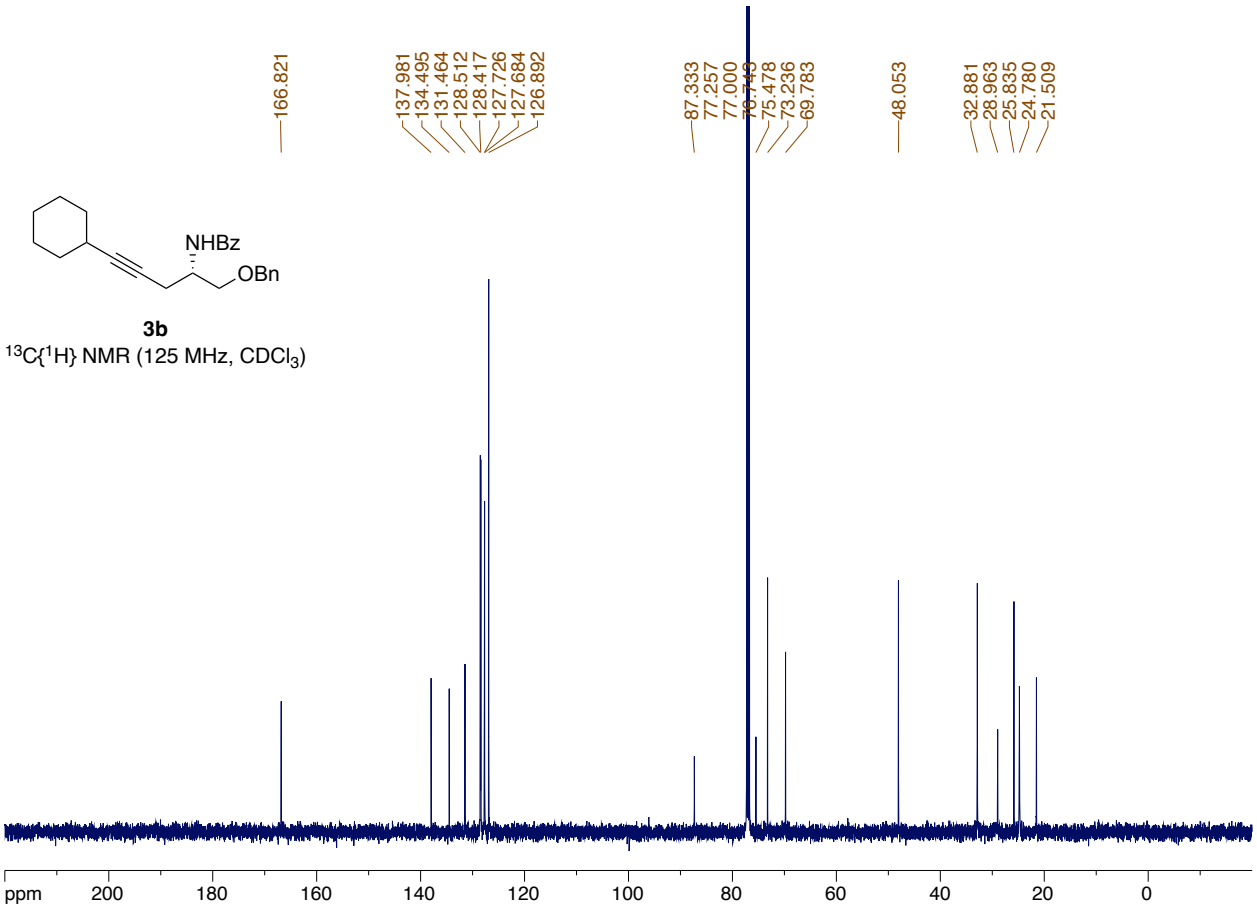
137.957 134.479 131.465 128.511 128.420 127.690 126.900
82.804 77.256 77.000 76.743 75.722 73.213 69.765
48.107
22.314 21.516 20.667 13.477
ppm 200 180 160 140 120 100 80 60 40 20 0


NHBz
OBn
3b
1H NMR (500 MHz, CDCl3)
7.738 7.724 7.720 7.495 7.492 7.480 7.476 7.466 7.463 7.425 7.409 7.398 7.395 7.393 7.332 7.324 7.298 7.290 7.282 7.273 7.266 7.263 7.256 7.240 6.499 6.482 4.559 4.430 4.420 4.413 4.405 4.395 4.387 4.379 4.369 3.781 3.773 3.762 3.753 3.598 3.588 3.580 3.569 2.667 2.662 2.657 2.653 2.633 2.629 2.624 2.620 2.575 2.570 2.559 2.555 2.541 2.537 2.526 2.522 2.311 1.721 1.713 1.688 1.660 1.647 1.641 1.634 1.628 1.622 1.618 1.604 1.488 1.463 1.446 1.382 1.374 1.363 1.357 1.344 1.338 1.319 1.314 1.268 1.254 1.236
1.05 4.02 0.926 1 1 0.989 5.08 5.39
2.07 2.15 0.998 2.05 0.994 1.04 0.965 1.06
ppm 9 8 7 6 5 4 3 2 1 0 -1


NHBz
OBn
3b
13C{1H} NMR (125 MHz, CDCl3)
166.821
137.981 134.495 131.464 128.512 128.417 127.726 127.684 126.892
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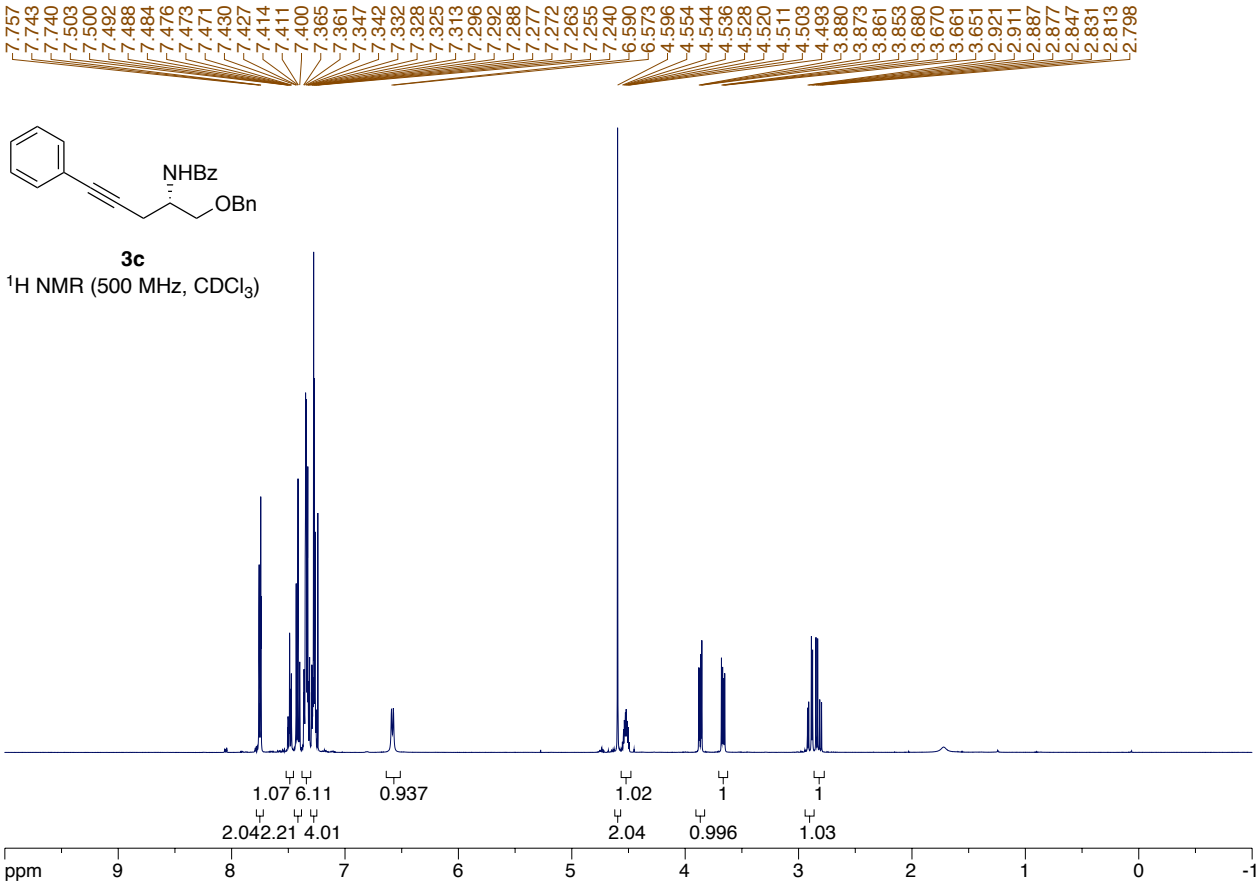
48.053
32.881 28.963 25.835 24.780 21.509
ppm 200 180 160 140 120 100 80 60 40 20 0


7.757
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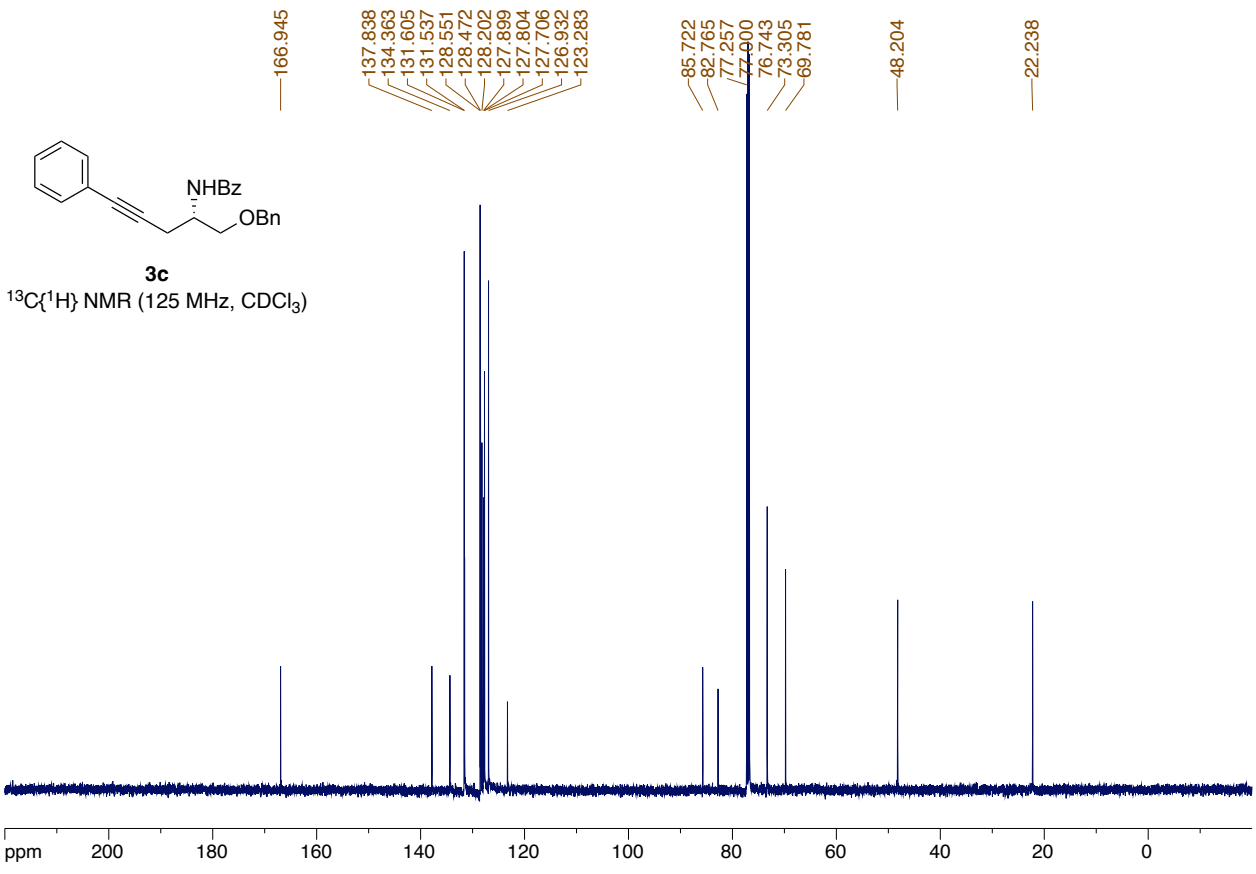
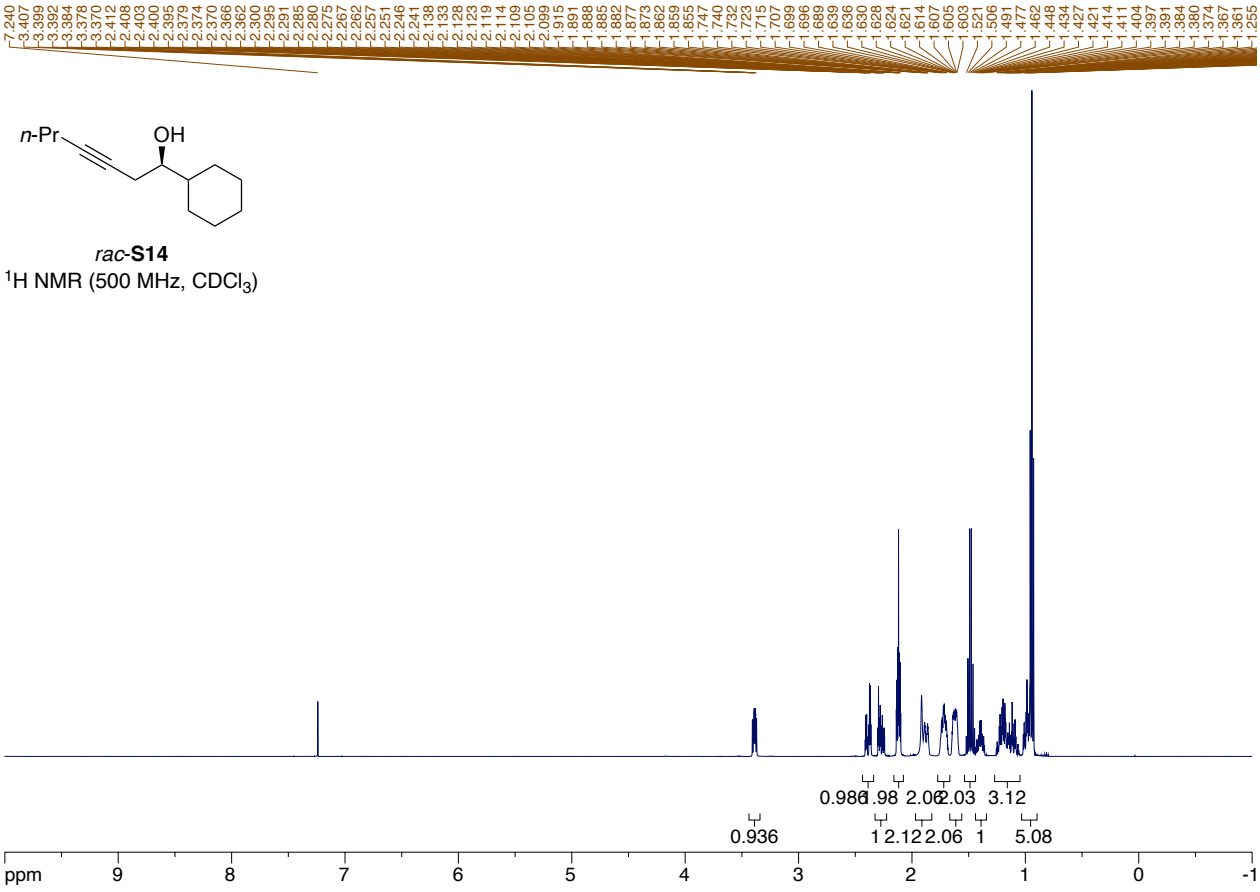
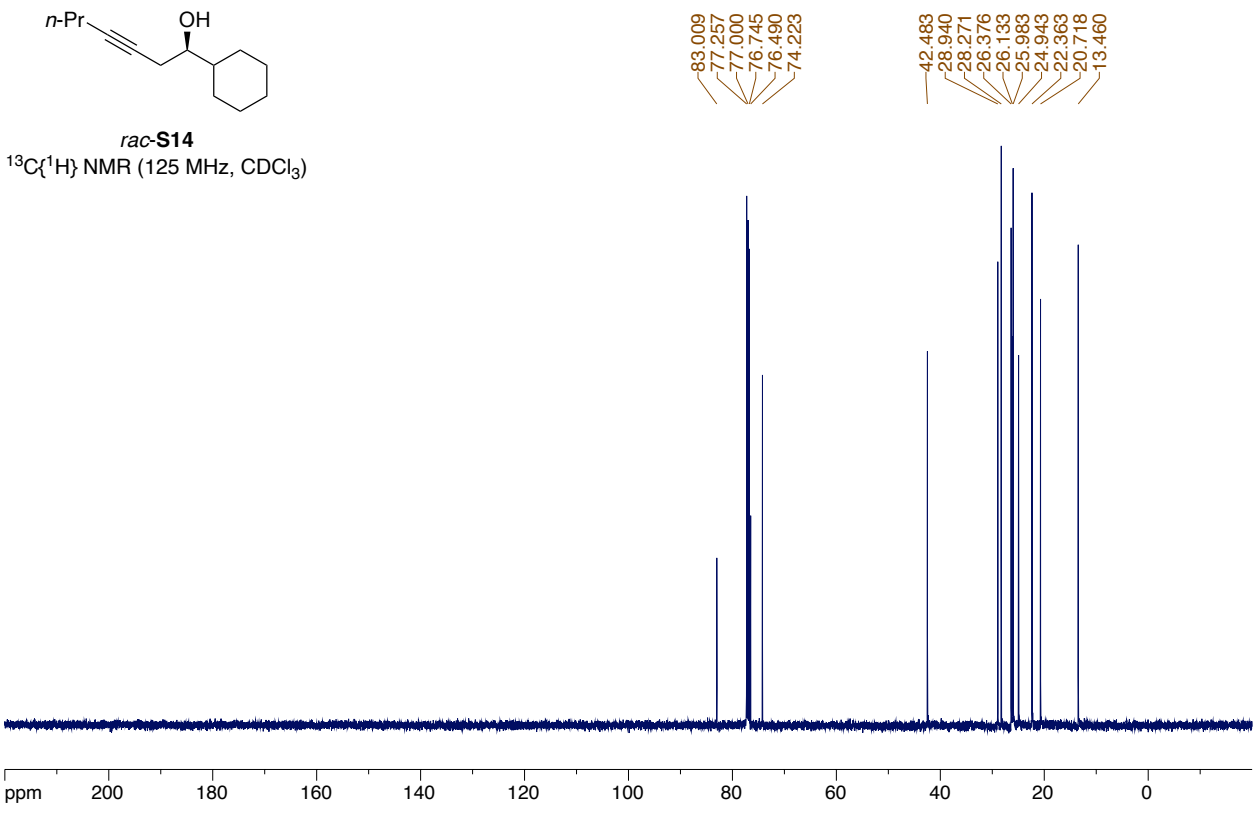
7.740
7.503
7.500
7.492
7.488
7.484
7.476
7.473
7.471
7.430
7.427
7.414
7.411
7.400
7.365
7.361
7.347
7.342
7.332
7.328
7.325
7.313
7.296
7.292
7.288
7.277
7.272
7.263
7.255
7.240
6.590
6.573
4.596
4.554
4.544
4.536
4.528
4.520
4.511
4.503
4.493
3.880
3.873
3.861
3.853
3.680
3.670
3.661
3.651
2.921
2.911
2.887
2.877
2.847
2.831
2.813
2.798
NHBz
OBn
3c
1H NMR (500 MHz, CDCl3)
1.07
6.11
0.937
1.02
1
1
2.04
2.21
4.01
2.04
0.996
1.03
ppm
9
8
7
6
5
4
3
2
1
0
-1


166.945
137.838
134.363
131.605
131.537
128.551
128.472
128.202
127.899
127.804
127.706
126.932
123.283
85.722
82.765
77.257
77.000
76.743
73.305
69.781
48.204
22.238
NHBz
OBn
3c
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0



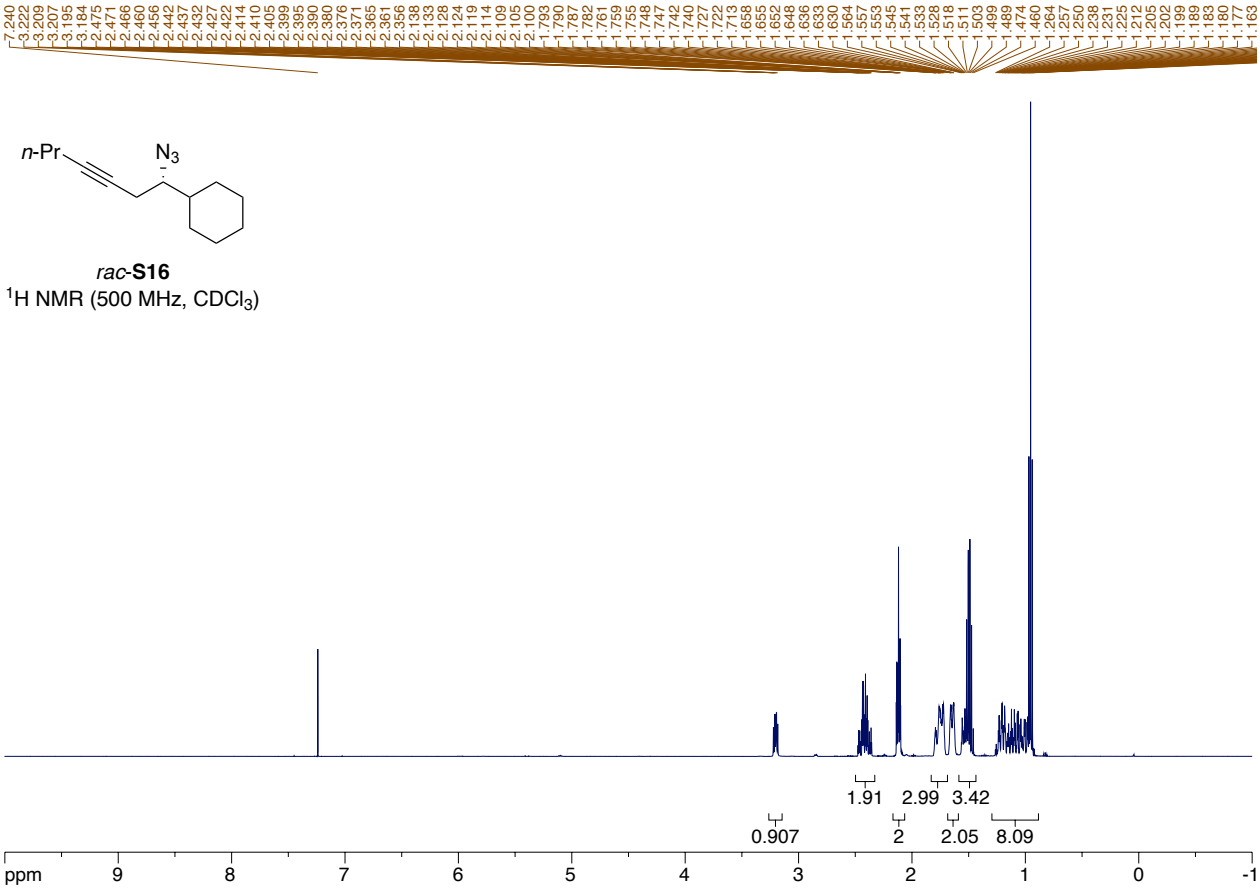
rac-**S14**

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



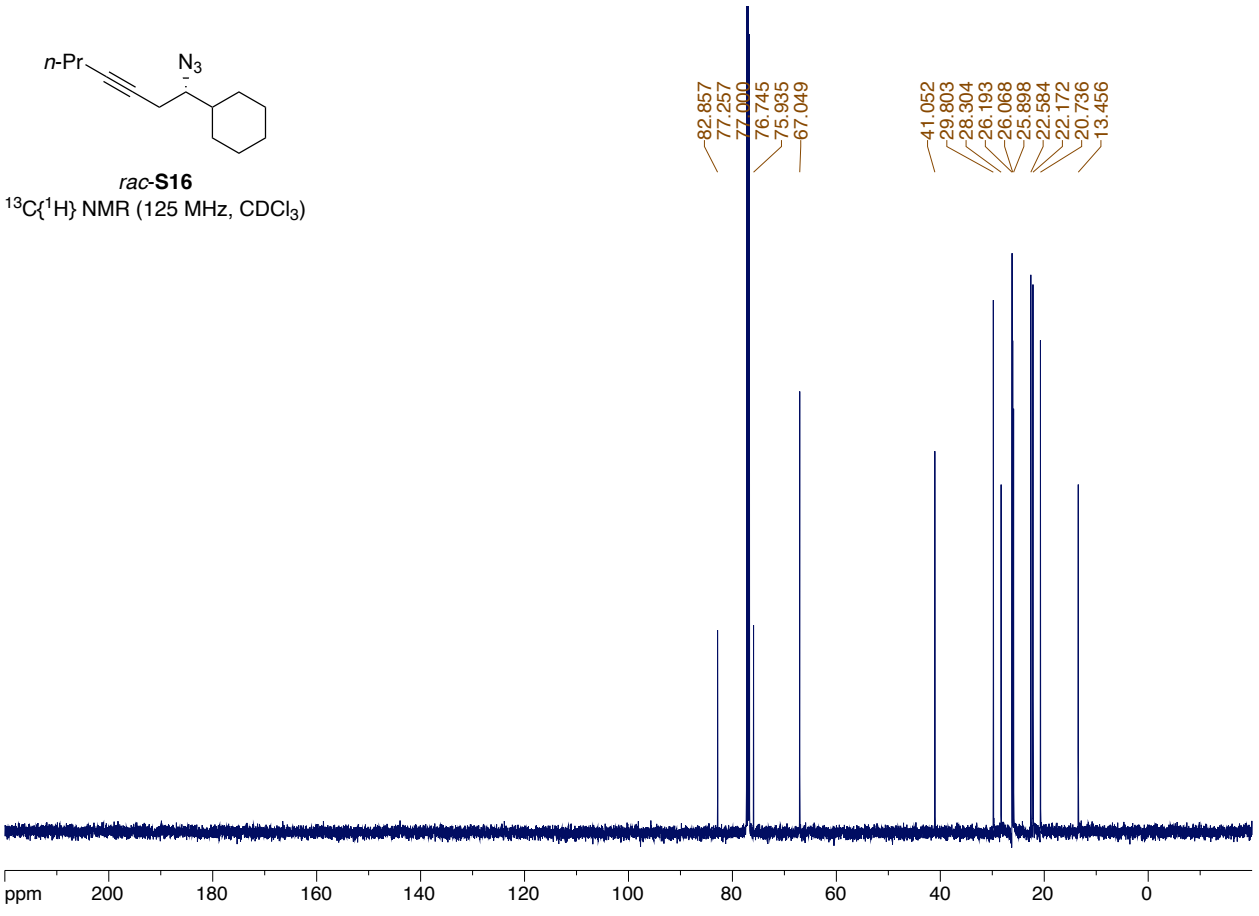
rac-**S14**

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



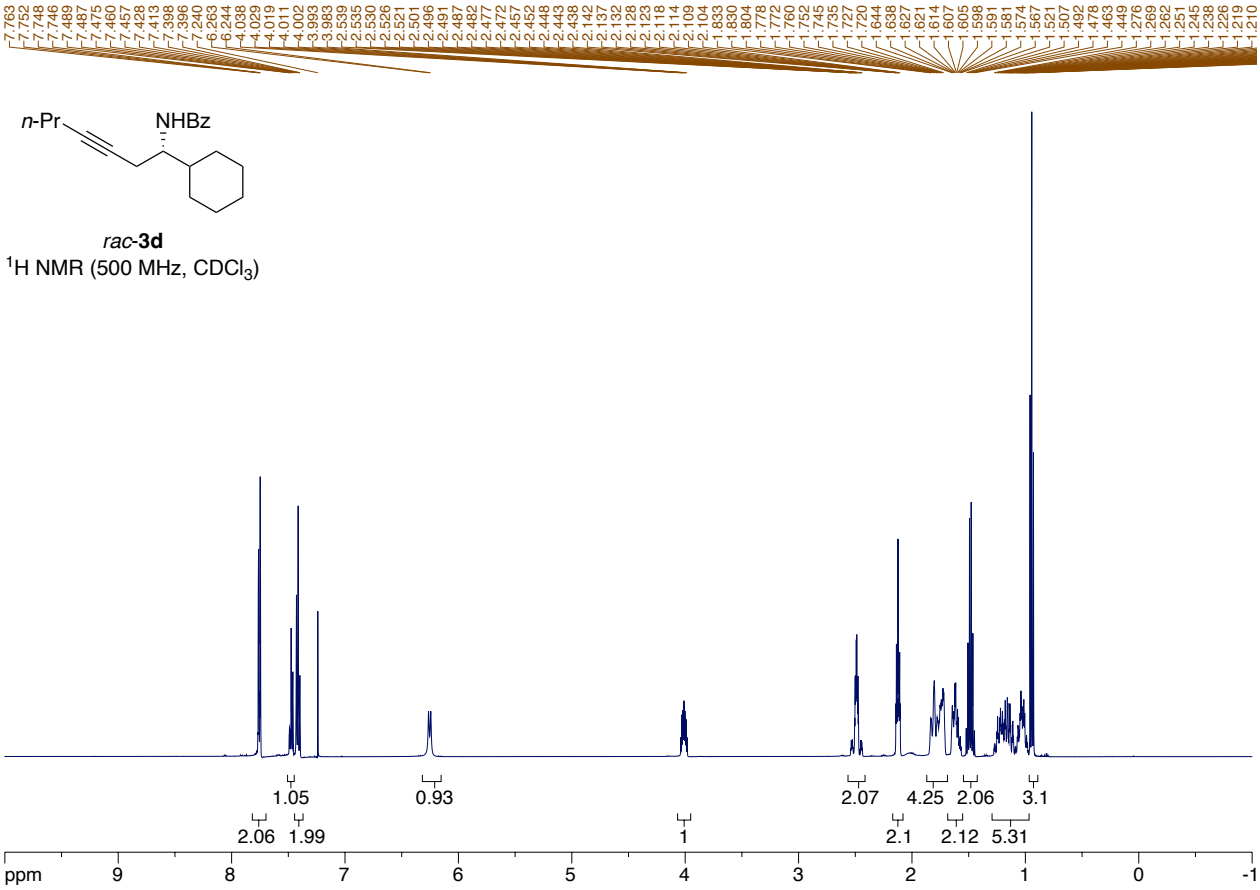
rac-**S16**

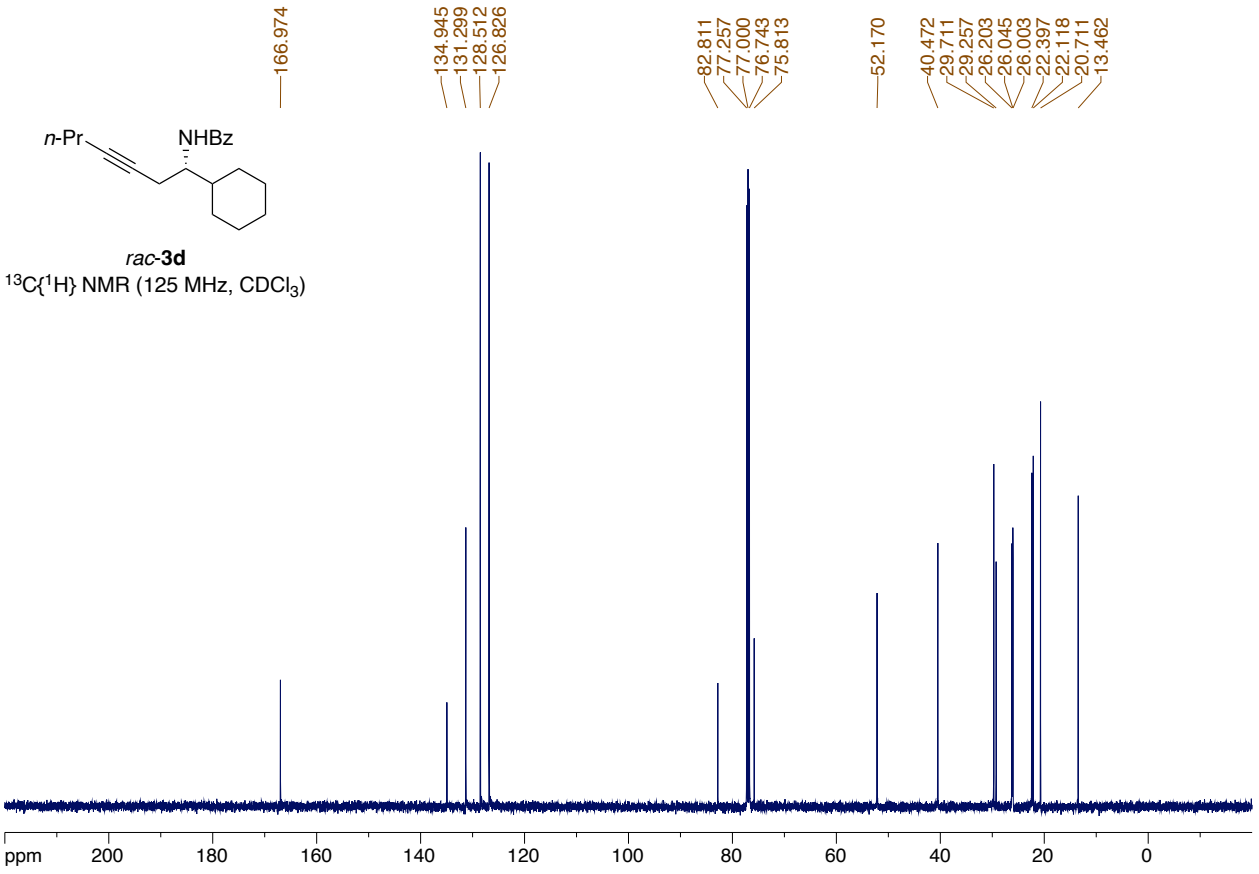
^{1}H NMR (500 MHz, $CDCl_3$)

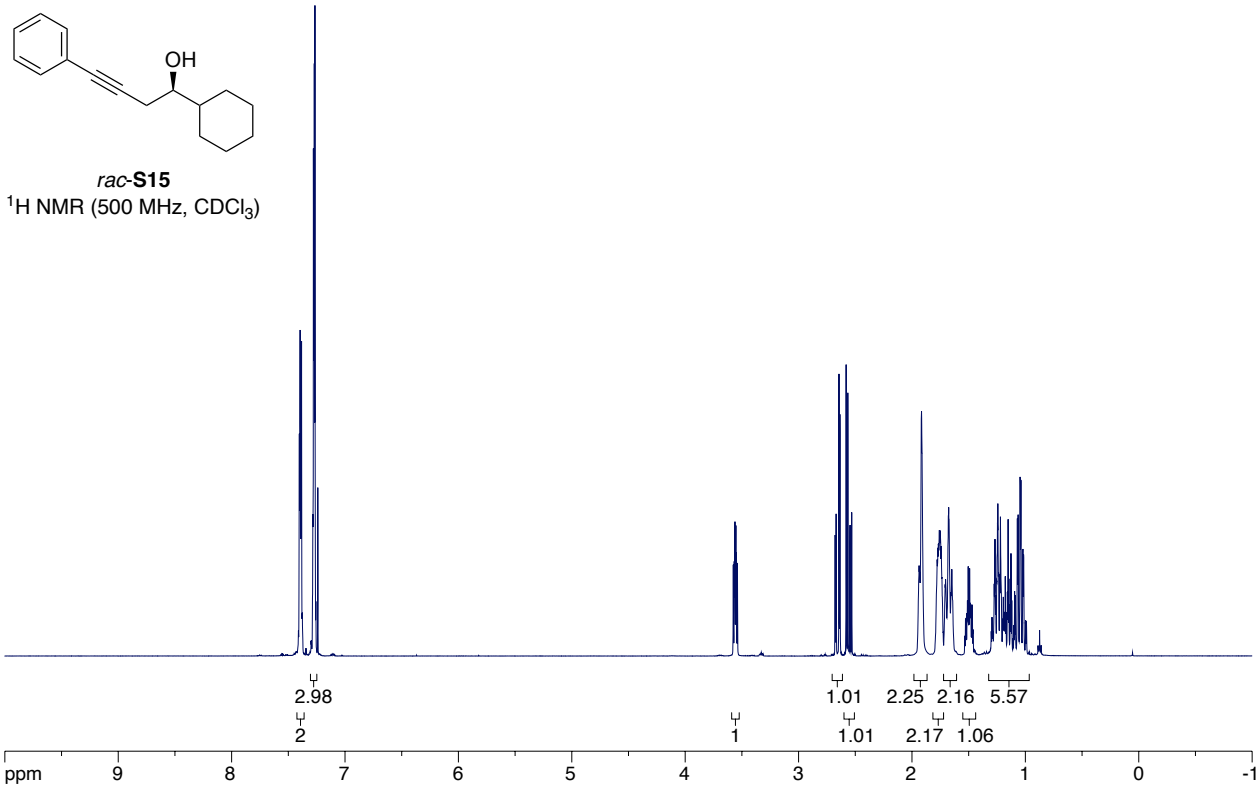


rac-**S16**

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

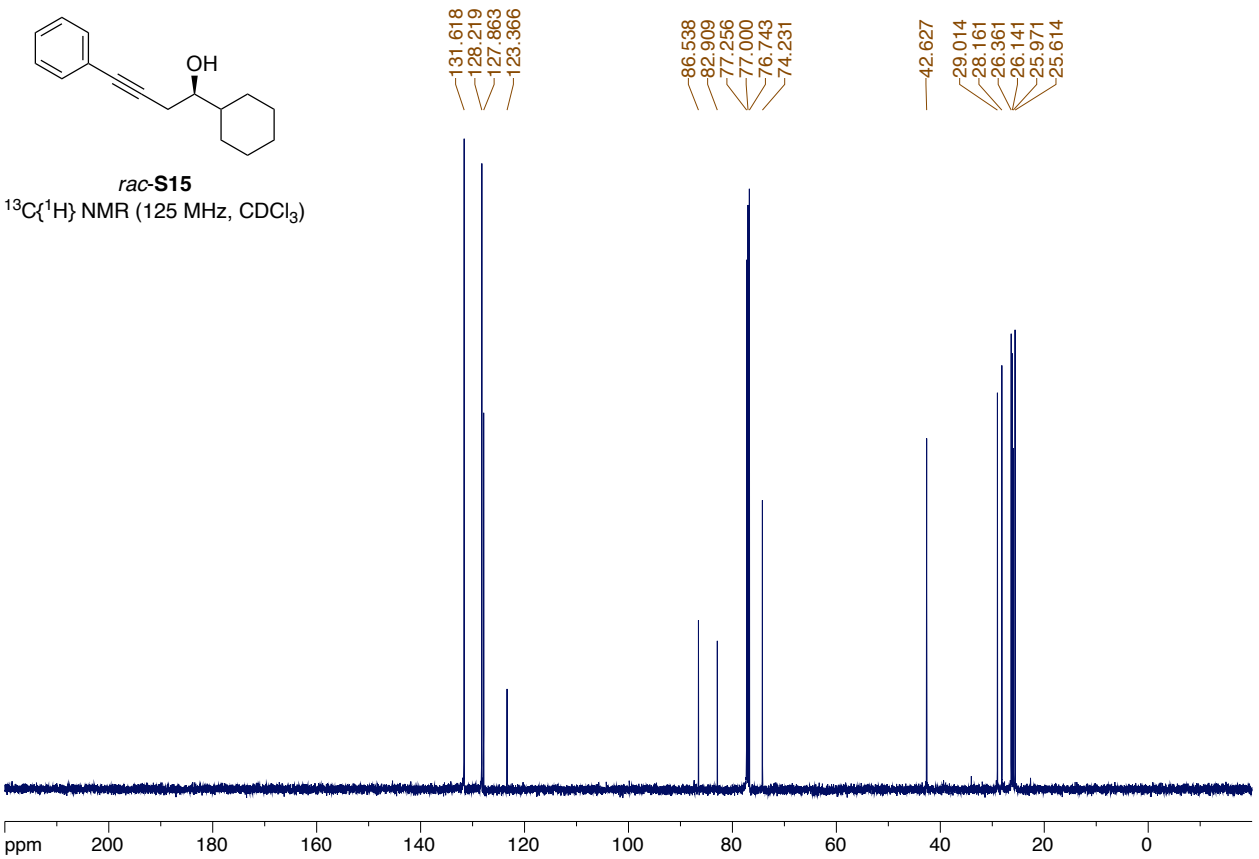

7.763
7.752
7.748
7.746
7.489
7.487
7.475
7.460
7.457
7.428
7.413
7.398
7.396
7.240
6.263
6.244
4.038
4.029
4.019
4.011
4.002
3.993
3.983
2.539
2.535
2.530
2.526
2.521
2.501
2.496
2.491
2.487
2.482
2.477
2.472
2.457
2.452
2.448
2.443
2.438
2.142
2.137
2.132
2.128
2.123
2.118
2.114
2.109
2.104
1.833
1.830
1.804
1.778
1.772
1.760
1.752
1.745
1.735
1.727
1.720
1.644
1.638
1.627
1.621
1.614
1.607
1.605
1.598
1.591
1.581
1.574
1.567
1.521
1.507
1.492
1.478
1.463
1.449
1.276
1.269
1.262
1.251
1.245
1.238
1.226
1.219
1.210
n-Pr
NHBz
rac-3d
1H NMR (500 MHz, CDCl3)
1.05
0.93
2.07
4.25
2.06
3.1
2.06
1.99
1
2.1
2.12
5.31
ppm
9
8
7
6
5
4
3
2
1
0
-1


166.974
134.945
131.299
128.512
126.826
82.811
77.257
77.000
76.743
75.813
52.170
40.472
29.711
29.257
26.203
26.045
26.003
22.397
22.118
20.711
13.462
n-Pr
NHBz
rac-3d
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0



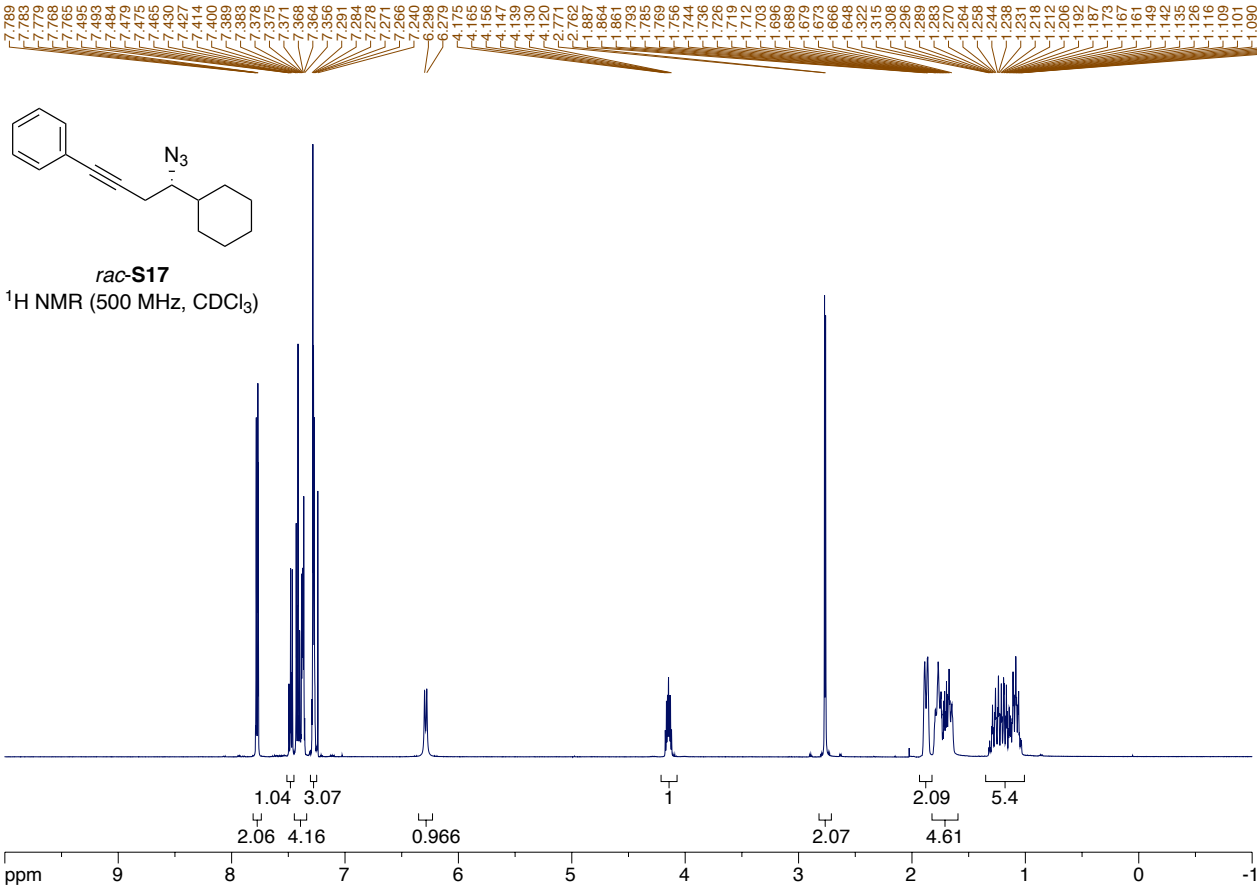
rac-**S15**

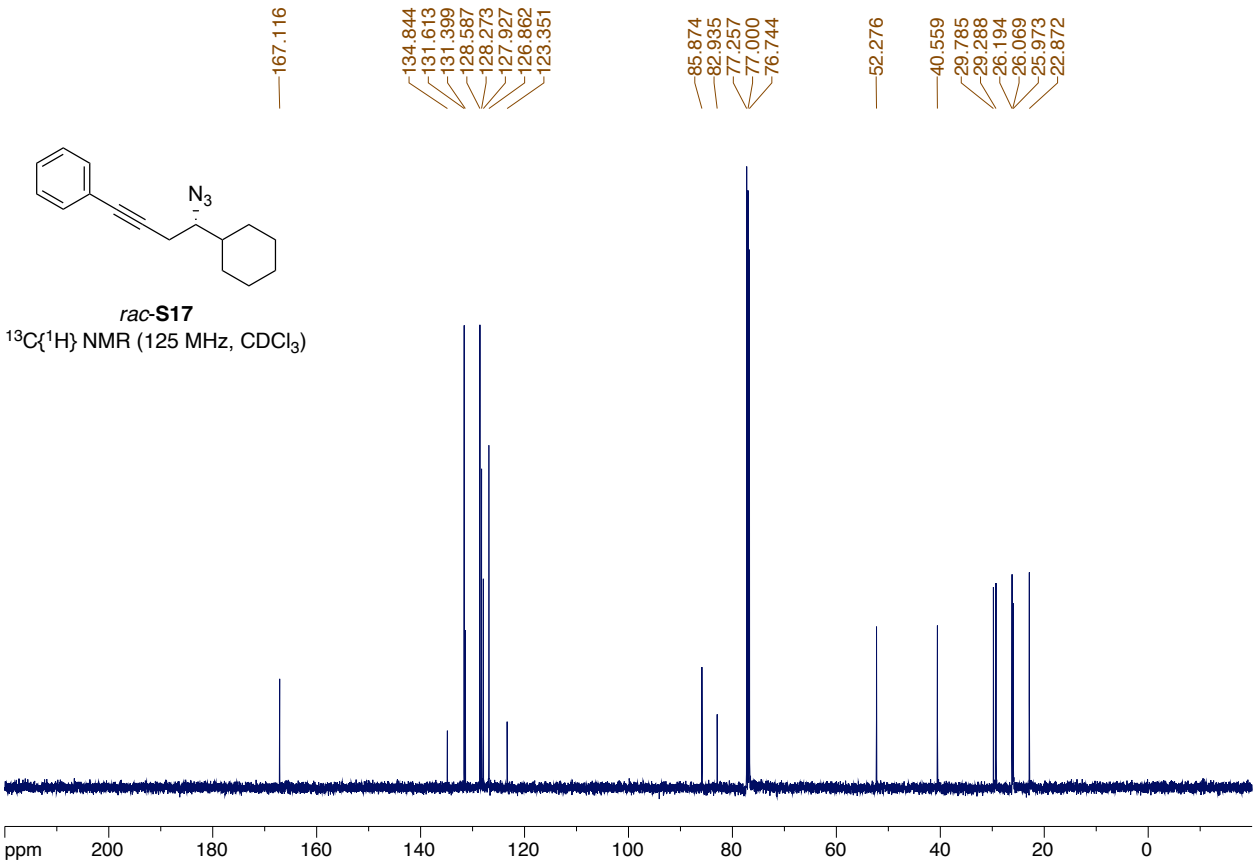
^{1}H NMR (500 MHz, $CDCl_3$)

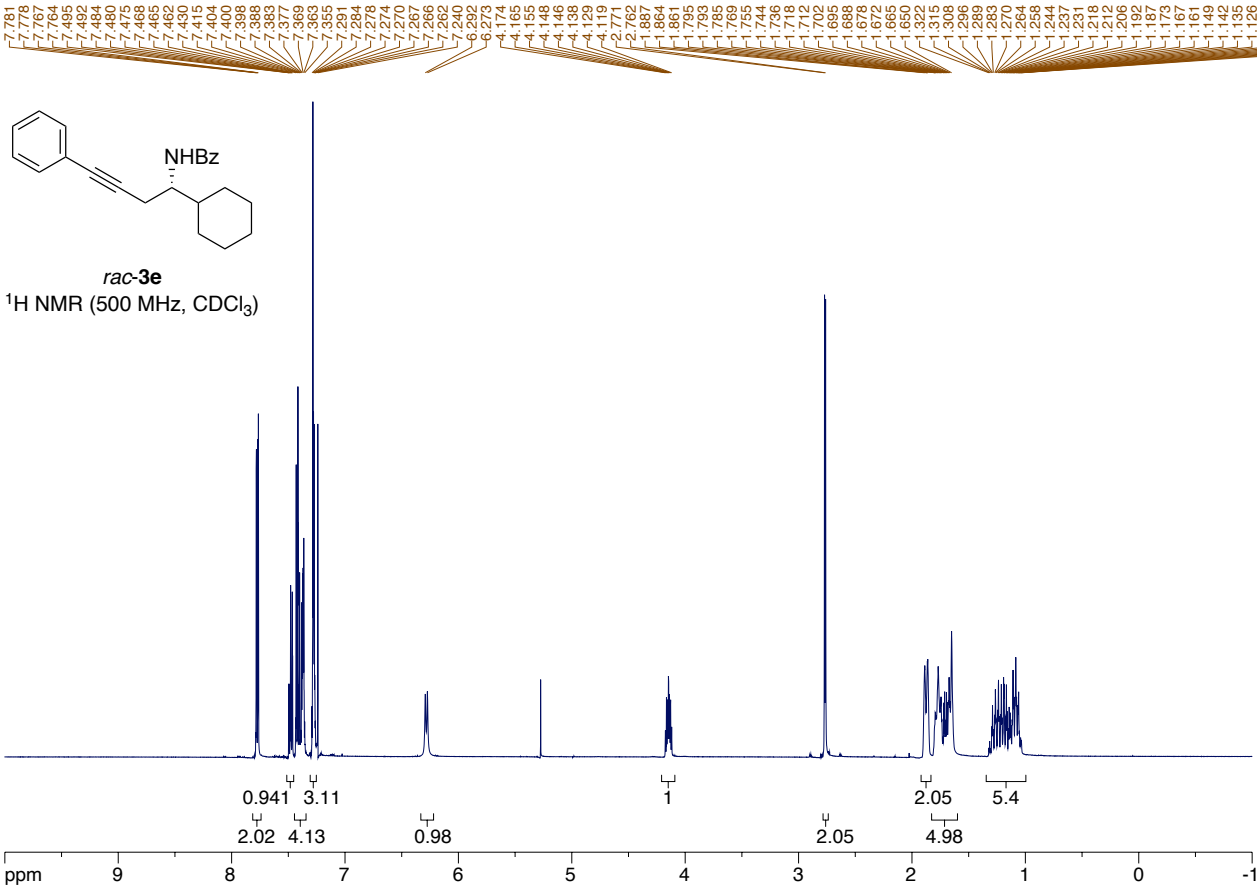


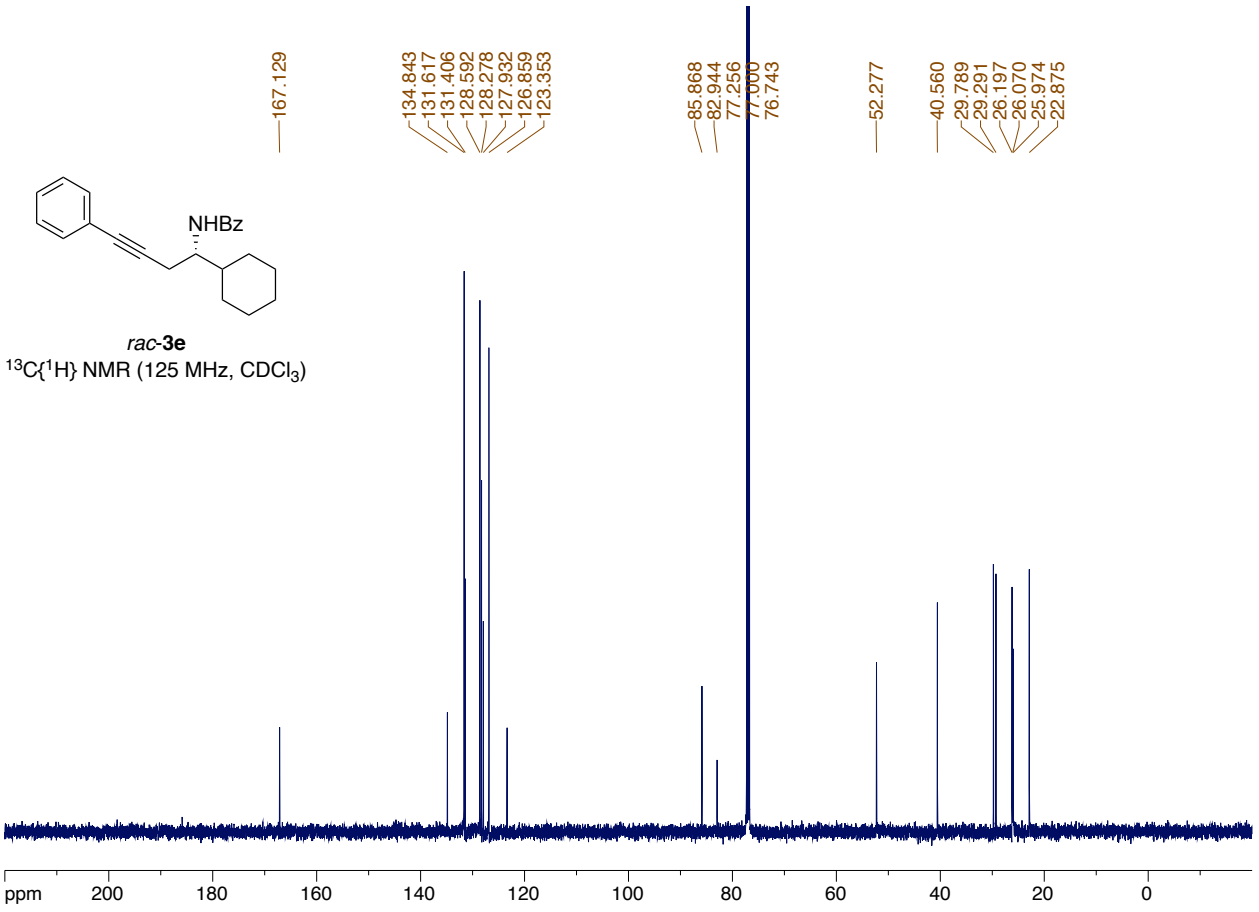
rac-**S15**

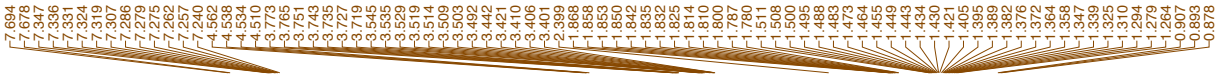
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

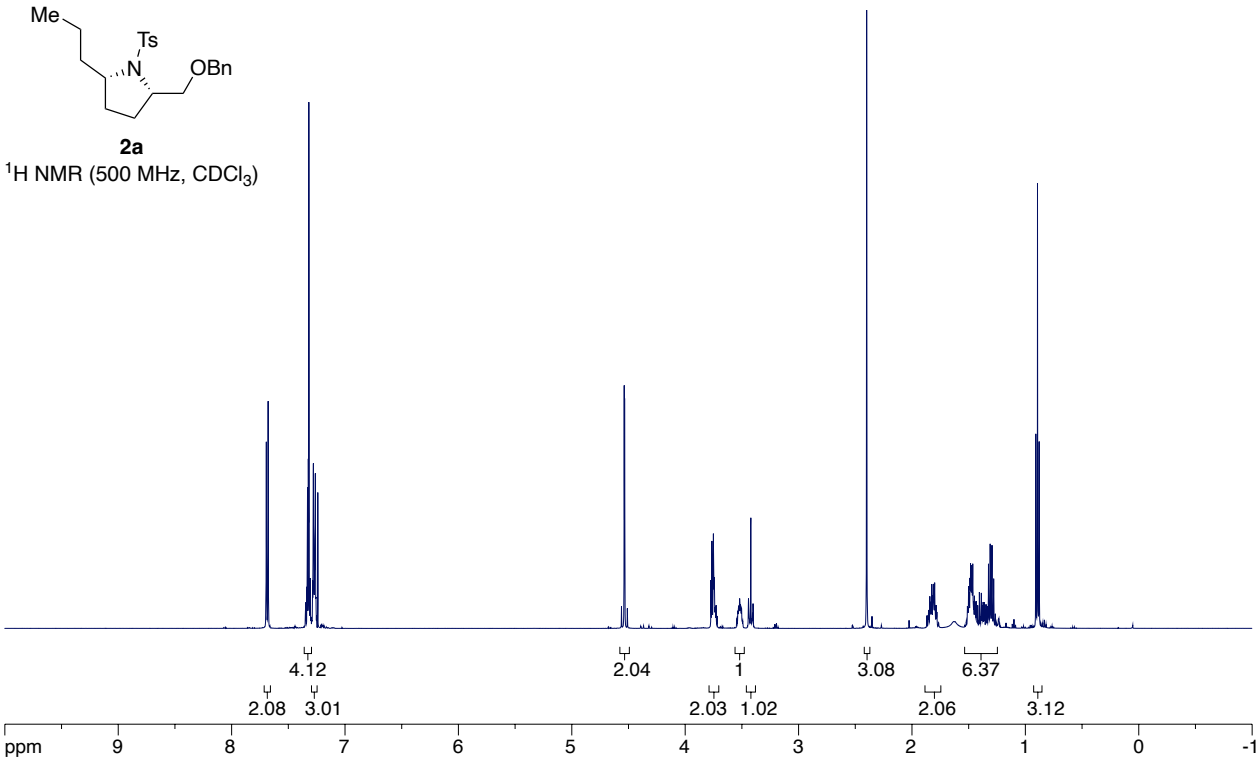

7.789
7.783
7.779
7.768
7.765
7.495
7.493
7.484
7.479
7.475
7.465
7.430
7.427
7.414
7.400
7.389
7.383
7.378
7.375
7.371
7.368
7.364
7.356
7.291
7.284
7.278
7.271
7.266
7.240
6.298
6.279
4.175
4.165
4.156
4.147
4.139
4.130
4.120
2.771
2.762
1.887
1.864
1.861
1.793
1.785
1.769
1.756
1.744
1.736
1.726
1.719
1.712
1.703
1.696
1.689
1.679
1.673
1.666
1.648
1.322
1.315
1.308
1.296
1.289
1.283
1.270
1.264
1.258
1.244
1.238
1.231
1.218
1.212
1.206
1.192
1.187
1.173
1.167
1.161
1.149
1.142
1.135
1.126
1.116
1.109
1.101
1.090
N3
rac-S17
1H NMR (500 MHz, CDCl3)
1.04
3.07
1
2.09
5.4
2.06
4.16
0.966
2.07
4.61
ppm
9
8
7
6
5
4
3
2
1
0
-1


167.116
134.844
131.613
131.399
128.587
128.273
127.927
126.862
123.351
85.874
82.935
77.257
77.000
76.744
52.276
40.559
29.785
29.288
26.194
26.069
25.973
22.872
N3
rac-S17
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0


7.781
7.778
7.767
7.764
7.495
7.492
7.484
7.480
7.475
7.468
7.465
7.462
7.430
7.415
7.404
7.400
7.398
7.388
7.383
7.377
7.369
7.363
7.355
7.291
7.284
7.278
7.274
7.270
7.267
7.266
7.262
7.240
6.292
6.273
4.174
4.165
4.155
4.148
4.146
4.138
4.129
4.119
2.771
2.762
1.887
1.864
1.861
1.795
1.793
1.785
1.769
1.755
1.744
1.736
1.718
1.712
1.702
1.695
1.688
1.678
1.672
1.665
1.650
1.322
1.315
1.308
1.296
1.289
1.283
1.270
1.264
1.258
1.244
1.237
1.231
1.218
1.212
1.206
1.192
1.187
1.173
1.167
1.161
1.149
1.142
1.135
1.126
NHBz
rac-3e
1H NMR (500 MHz, CDCl3)
0.941
3.11
1
2.05
5.4
2.02
4.13
0.98
2.05
4.98
ppm
9
8
7
6
5
4
3
2
1
0
-1

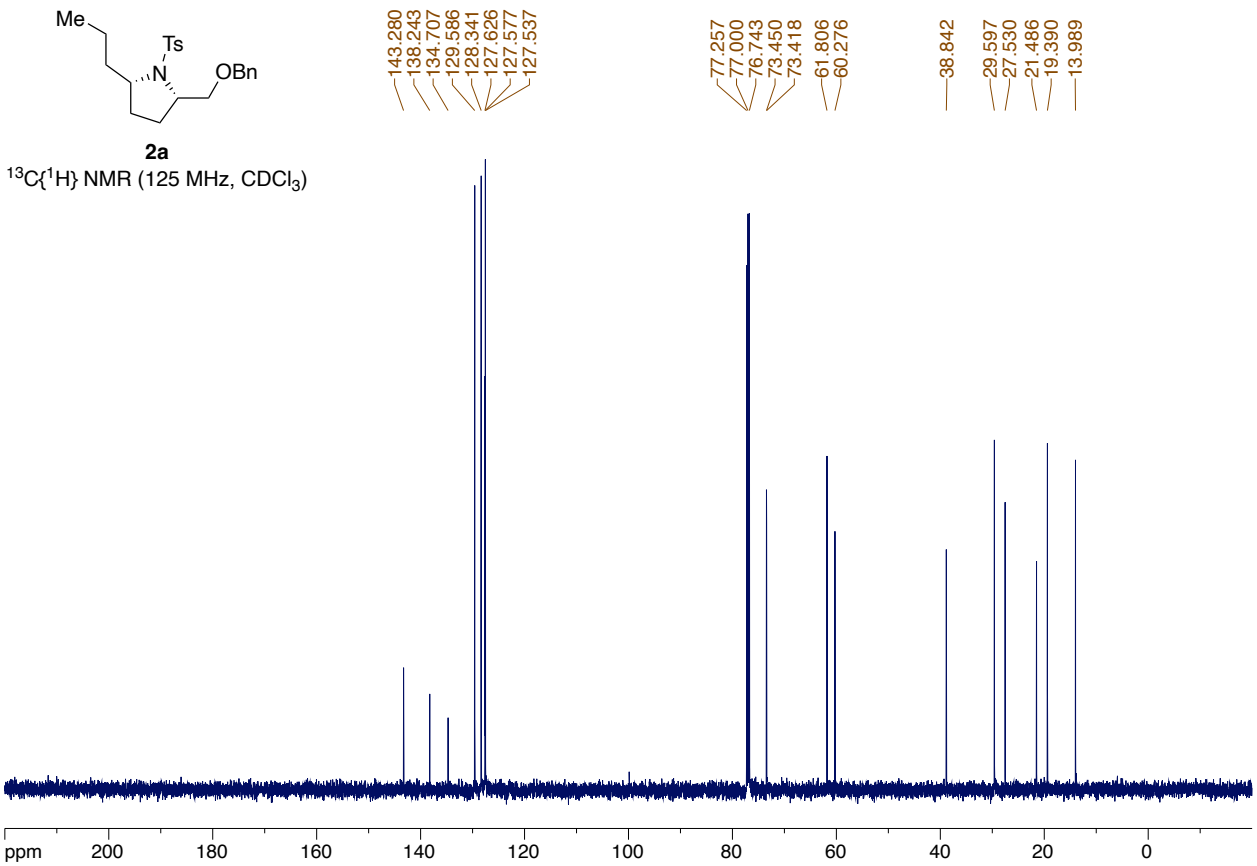

167.129
134.843
131.617
131.406
128.592
128.278
127.932
126.859
123.353
85.868
82.944
77.256
77.000
76.743
52.277
40.560
29.789
29.291
26.197
26.070
25.974
22.875
NHBz
rac-3e
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0





2a

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

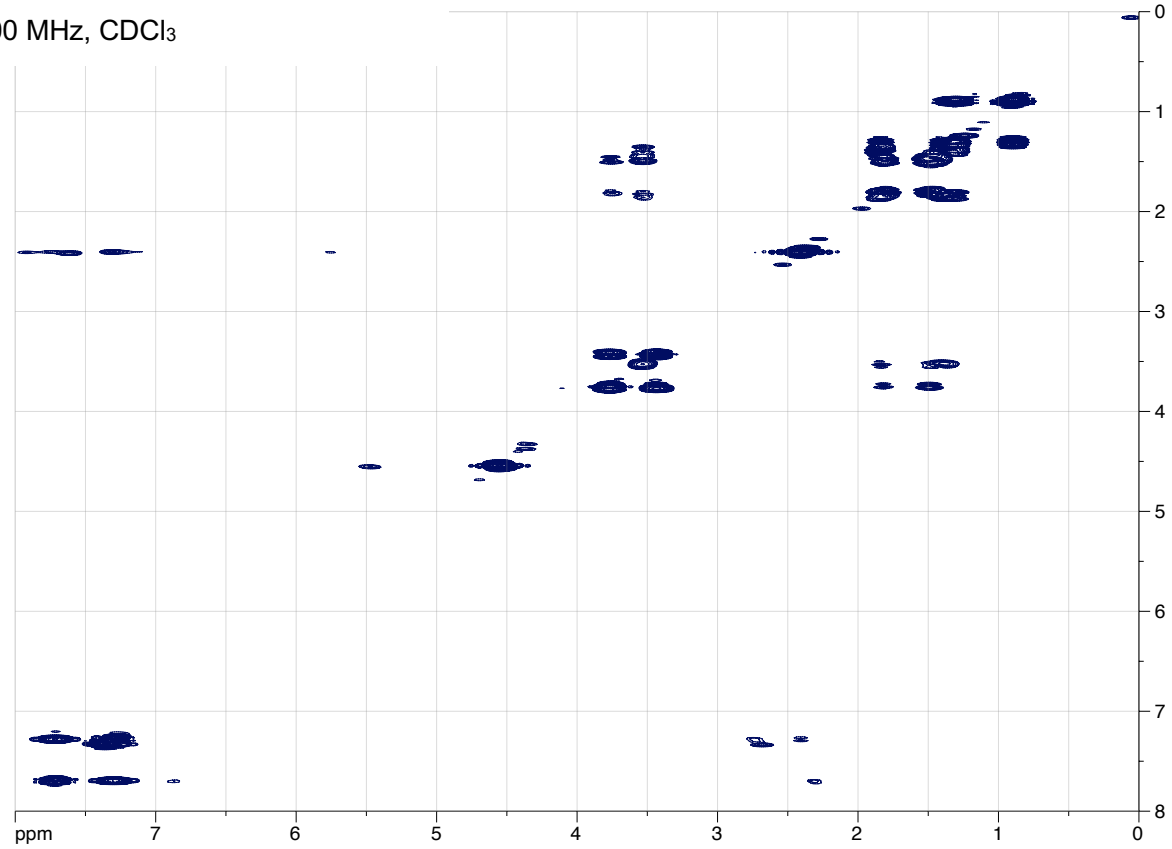


2a

$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

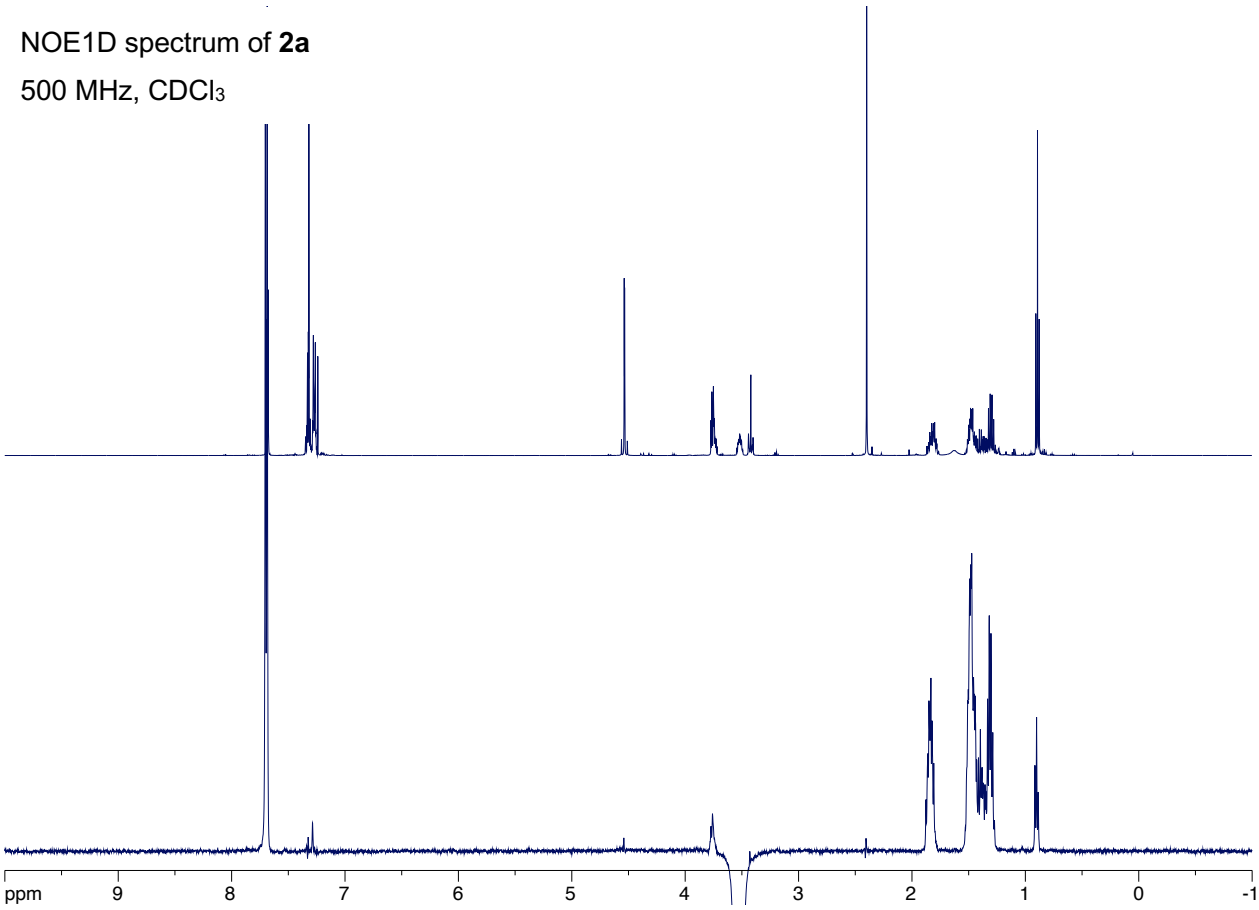
^{1}H-^{1}H COSY spectrum of **2a**

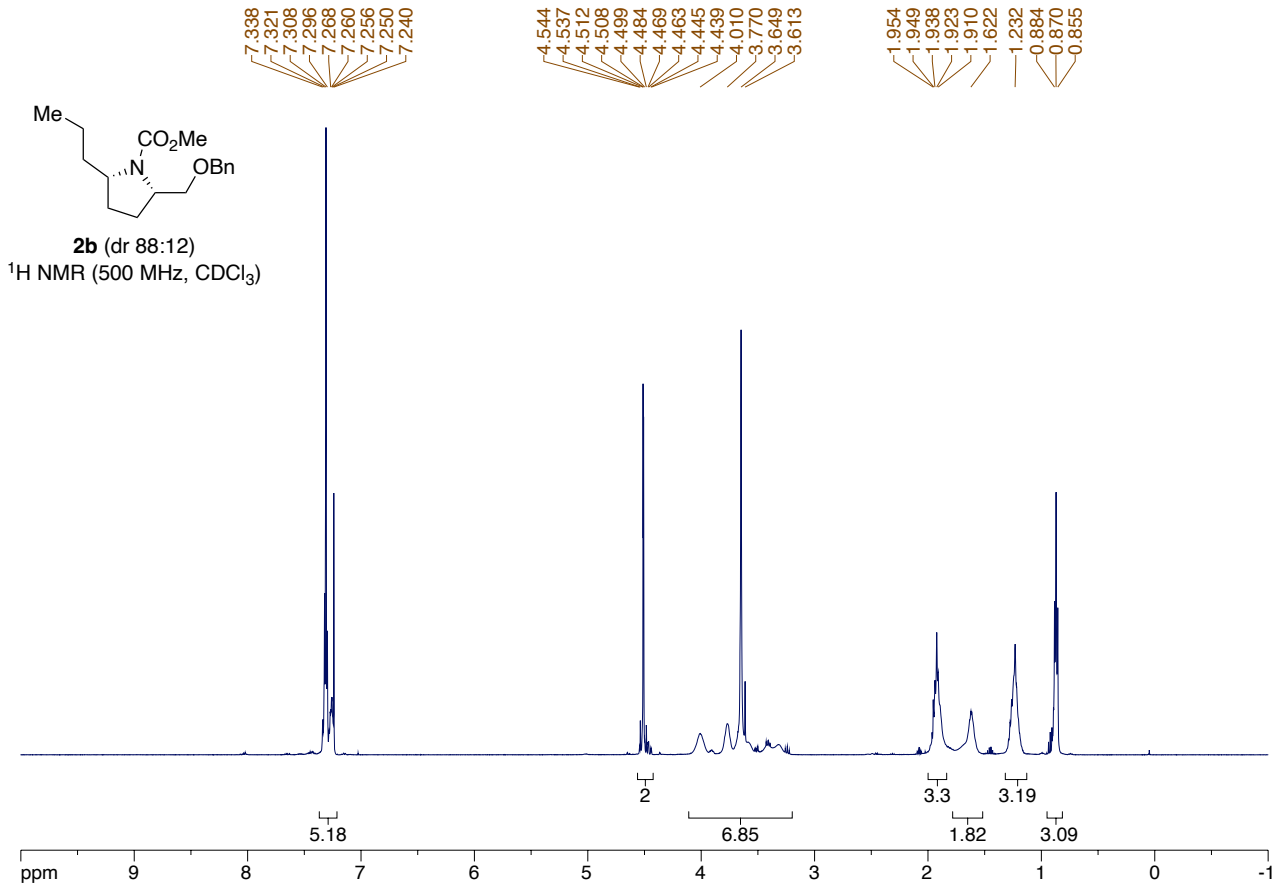
500 MHz, $CDCl_3$

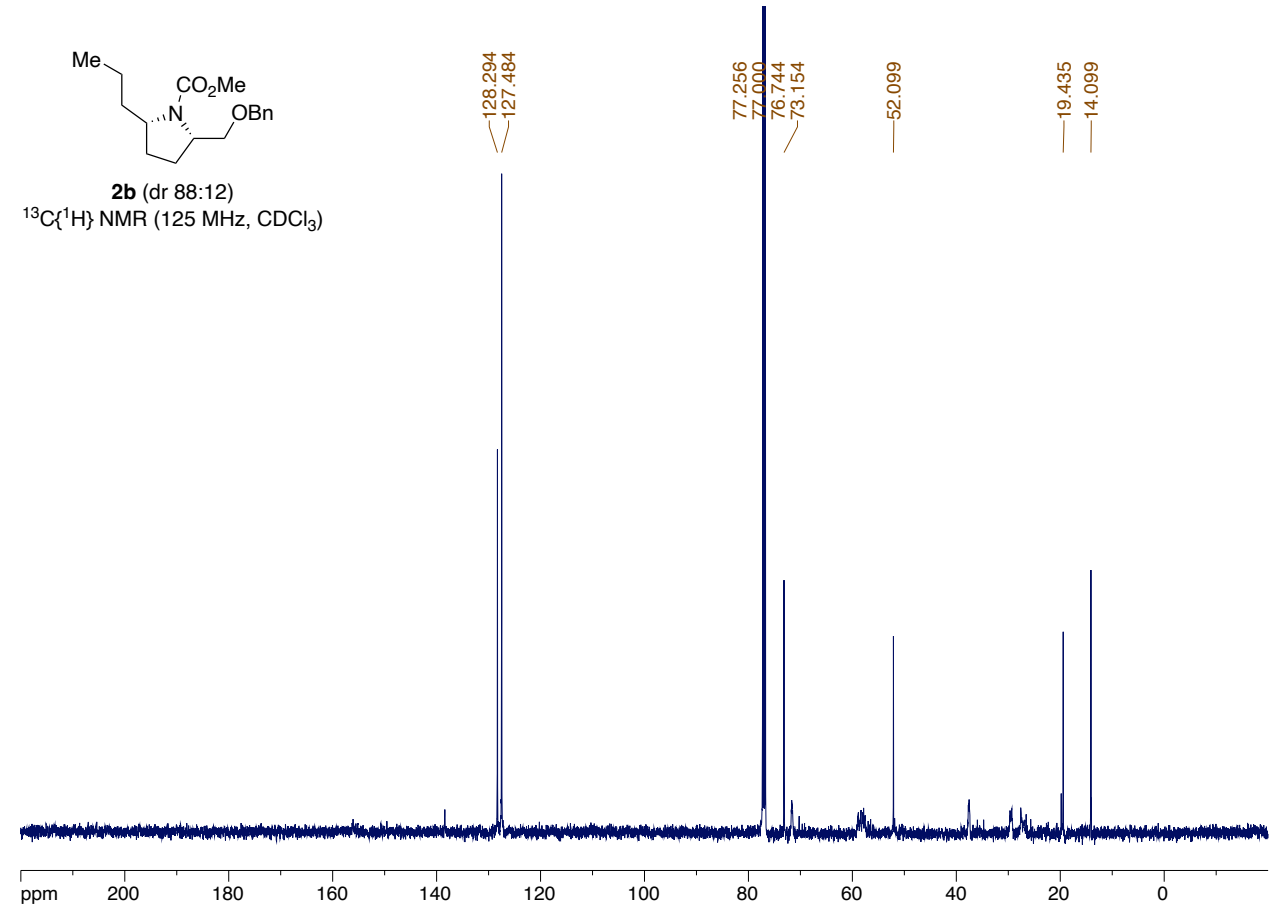


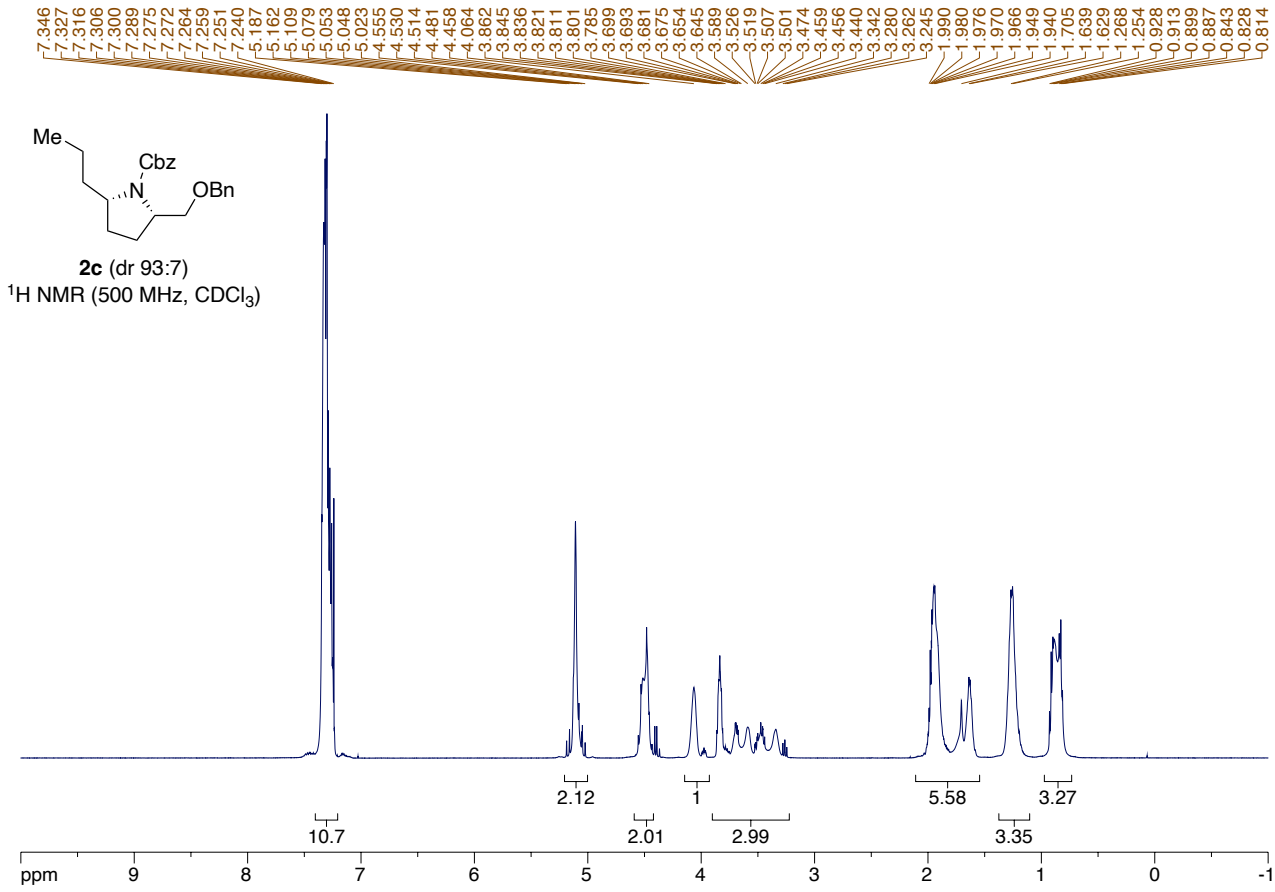
NOE1D spectrum of **2a**

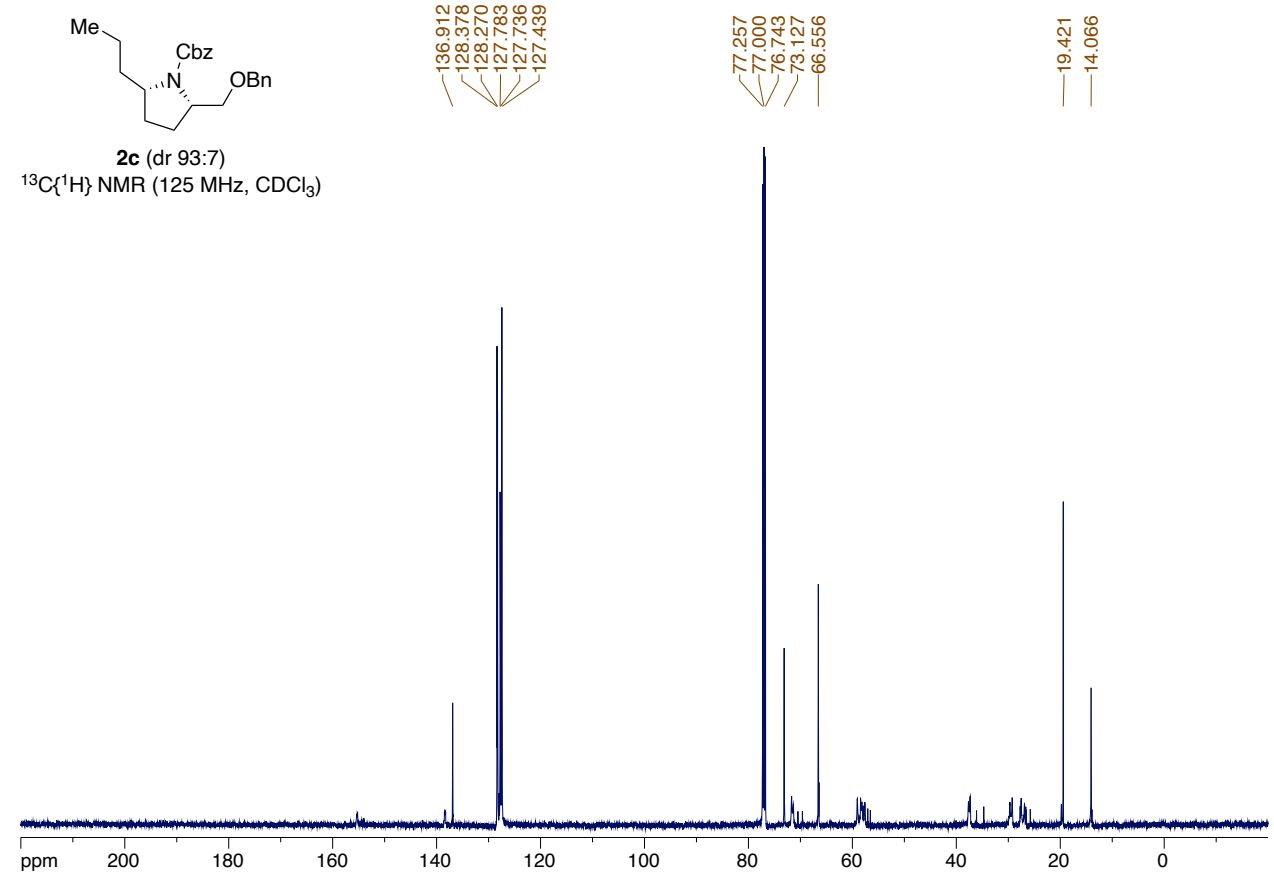
500 MHz, $CDCl_3$

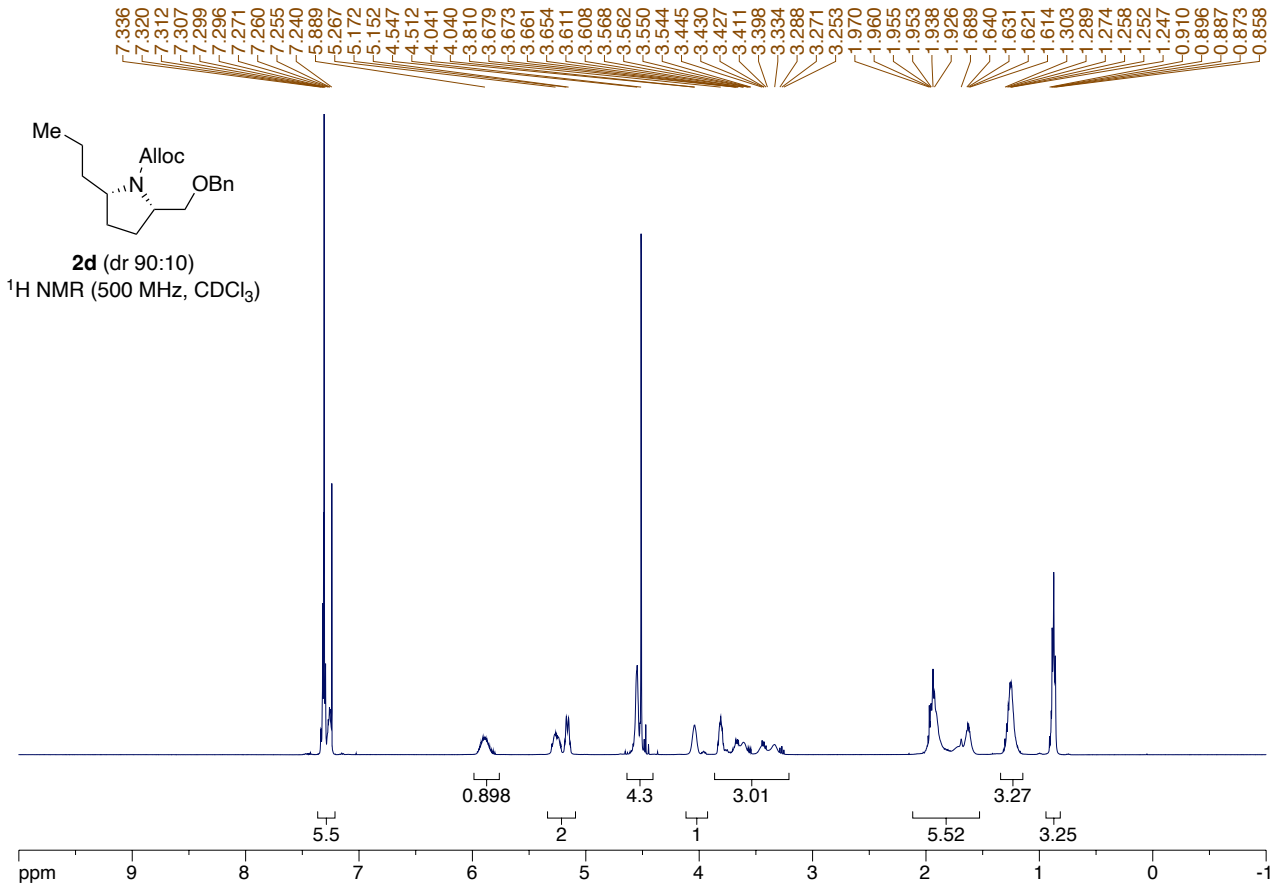


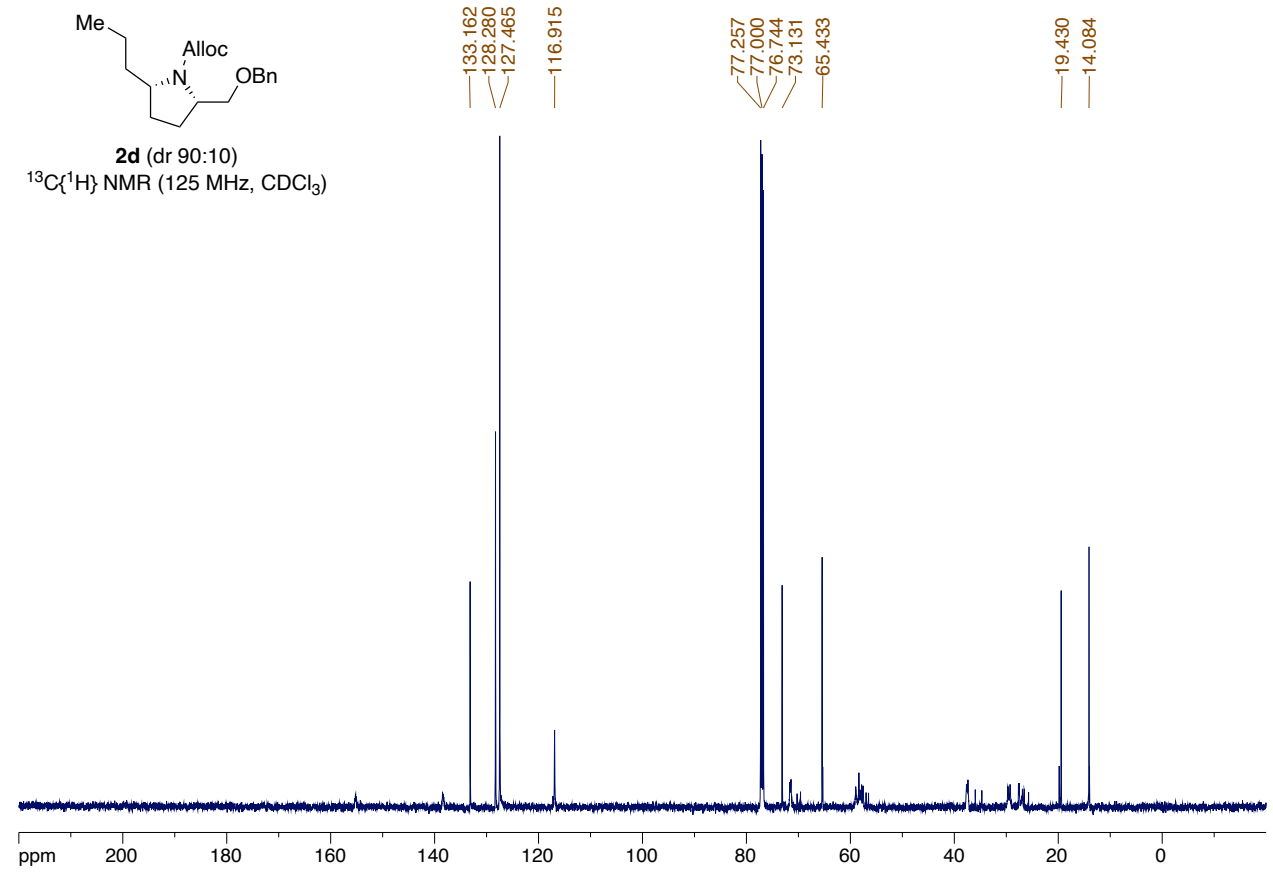

7.338
7.321
7.308
7.296
7.268
7.260
7.256
7.250
7.240
4.544
4.537
4.512
4.508
4.499
4.484
4.469
4.463
4.445
4.439
4.010
3.770
3.649
3.613
1.954
1.949
1.938
1.923
1.910
1.622
1.232
0.884
0.870
0.855
Me
CO2Me
N
OBn
2b (dr 88:12)
1H NMR (500 MHz, CDCl3)
2
3.3
3.19
5.18
6.85
1.82
3.09
ppm
9
8
7
6
5
4
3
2
1
0
-1

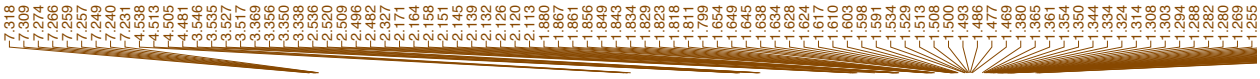

Me
CO2Me
N
OBn
2b (dr 88:12)
13C{1H} NMR (125 MHz, CDCl3)
128.294
127.484
77.256
77.000
76.744
73.154
52.099
19.435
14.099
ppm
200
180
160
140
120
100
80
60
40
20
0

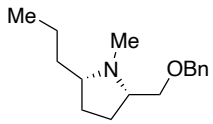

Me
Cbz
N
OBn
2c (dr 93:7)
1H NMR (500 MHz, CDCl3)
7.346
7.327
7.316
7.306
7.300
7.289
7.275
7.272
7.264
7.259
7.251
7.240
5.187
5.162
5.109
5.079
5.053
5.048
5.023
4.555
4.530
4.514
4.481
4.458
4.064
3.862
3.845
3.836
3.821
3.811
3.801
3.785
3.699
3.693
3.681
3.675
3.654
3.645
3.589
3.526
3.519
3.507
3.501
3.474
3.459
3.456
3.440
3.342
3.280
3.262
3.245
1.990
1.980
1.976
1.970
1.966
1.949
1.940
1.705
1.639
1.629
1.268
1.254
0.928
0.913
0.899
0.887
0.843
0.828
0.814
2.12
1
5.58
3.27
10.7
2.01
2.99
3.35
ppm
9
8
7
6
5
4
3
2
1
0
-1


Me
Cbz
N
OBn
2c (dr 93:7)
13C{1H} NMR (125 MHz, CDCl3)
136.912
128.378
128.270
127.783
127.736
127.439
77.257
77.000
76.743
73.127
66.556
19.421
14.066
ppm
200
180
160
140
120
100
80
60
40
20
0


7.336
7.320
7.312
7.307
7.299
7.296
7.271
7.260
7.255
7.240
5.889
5.267
5.172
5.152
4.547
4.512
4.041
4.040
3.810
3.679
3.673
3.661
3.654
3.611
3.608
3.568
3.562
3.550
3.544
3.445
3.430
3.427
3.411
3.398
3.334
3.288
3.271
3.253
1.970
1.960
1.955
1.953
1.938
1.926
1.689
1.640
1.631
1.621
1.614
1.303
1.289
1.274
1.258
1.252
1.247
0.910
0.896
0.887
0.873
0.858
Me
Alloc
N
OBn
2d (dr 90:10)
1H NMR (500 MHz, CDCl3)
0.898
4.3
3.01
3.27
5.5
2
1
5.52
3.25
ppm
9
8
7
6
5
4
3
2
1
0
-1

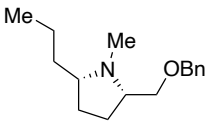

Me
Alloc
N
OBn
2d (dr 90:10)
13C{1H} NMR (125 MHz, CDCl3)
133.162
128.280
127.465
116.915
77.257
77.000
76.744
73.131
65.433
19.430
14.084
ppm
200
180
160
140
120
100
80
60
40
20
0





S18

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

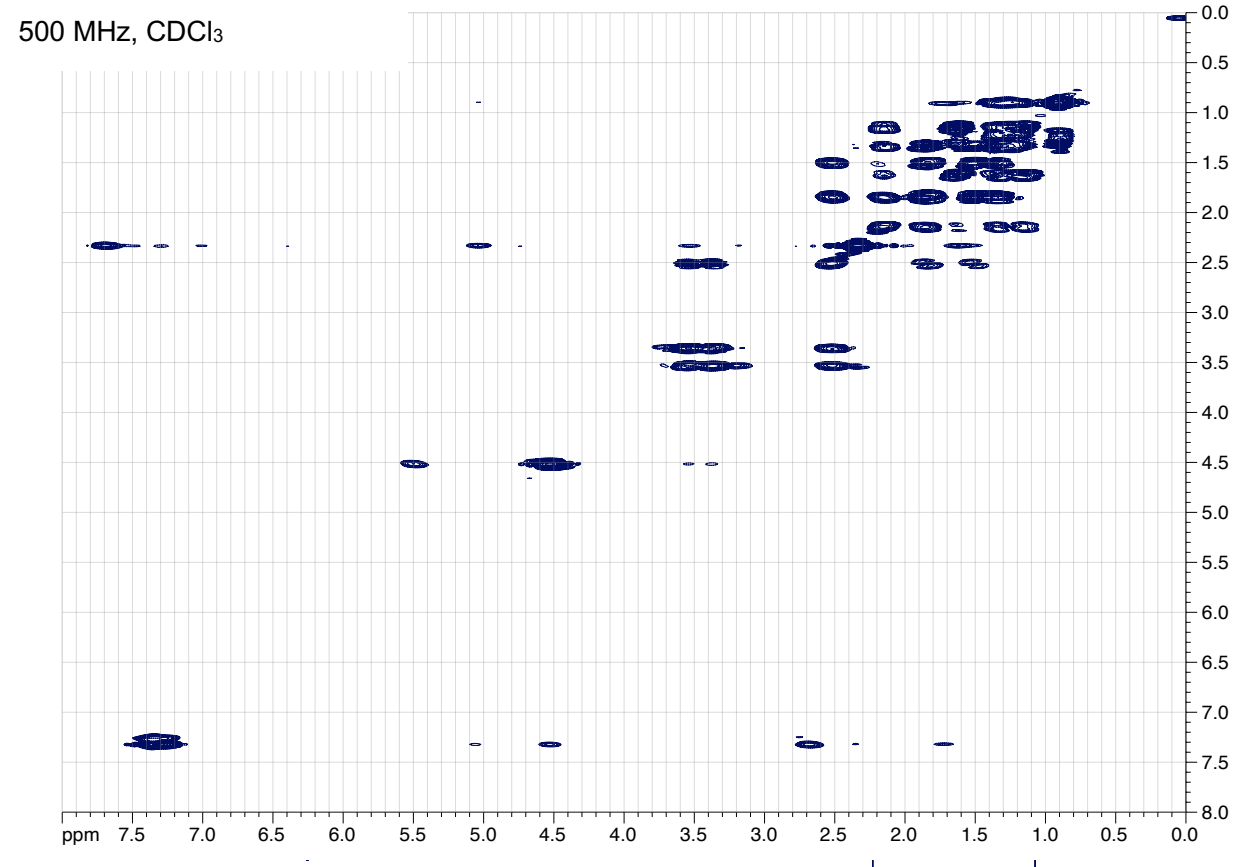


S18

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

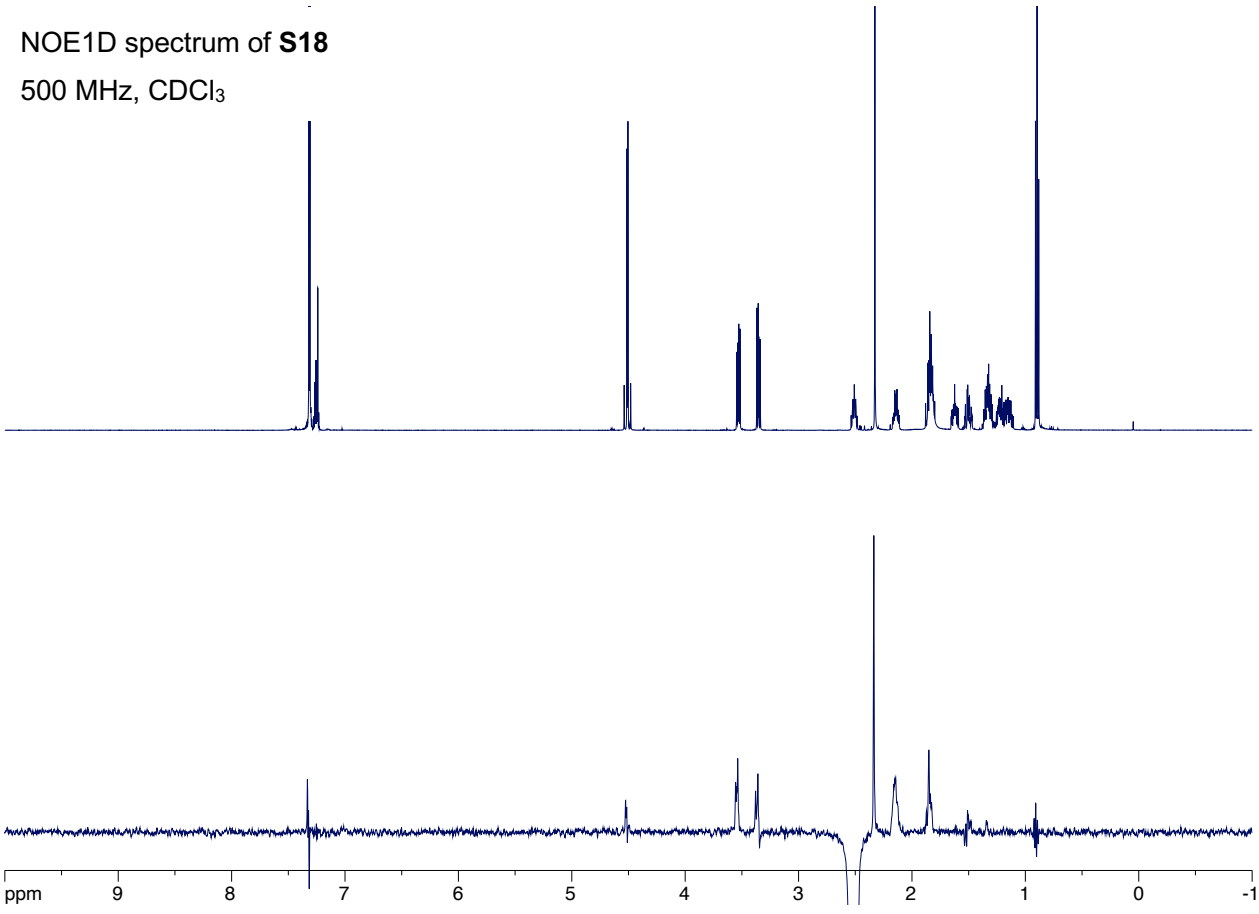
^{1}H-^{1}H COSY spectrum of **S18**

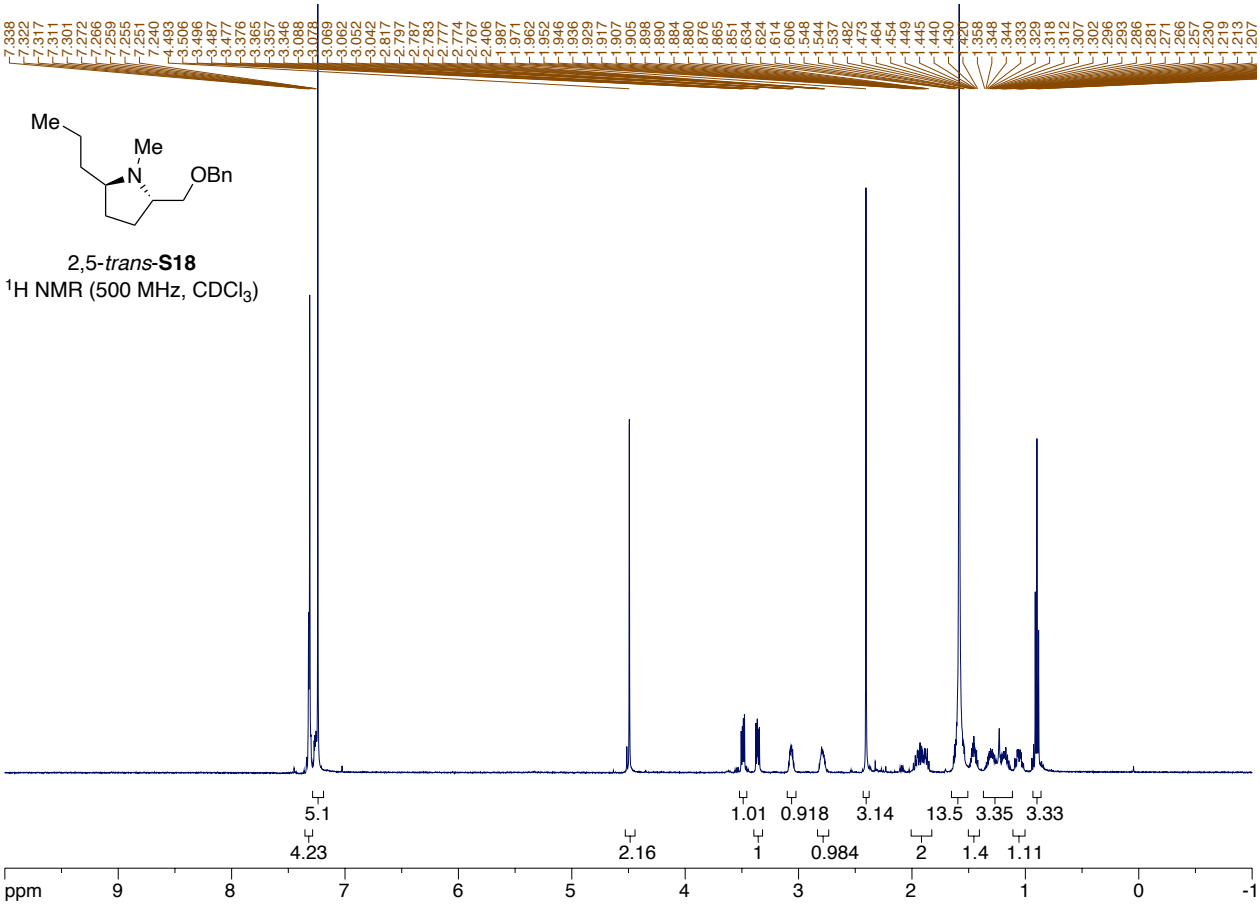
500 MHz, $CDCl_3$



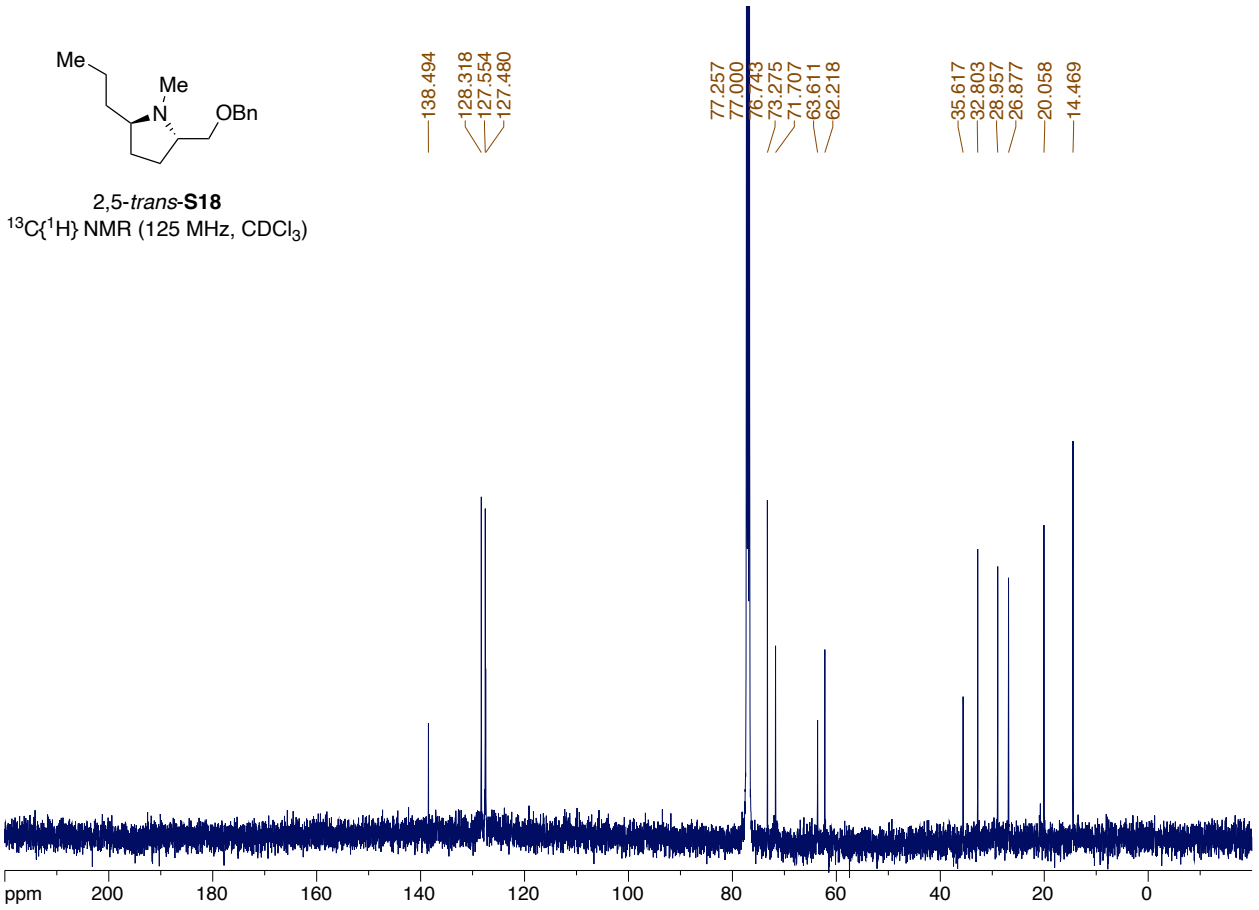
NOE1D spectrum of **S18**

500 MHz, $CDCl_3$





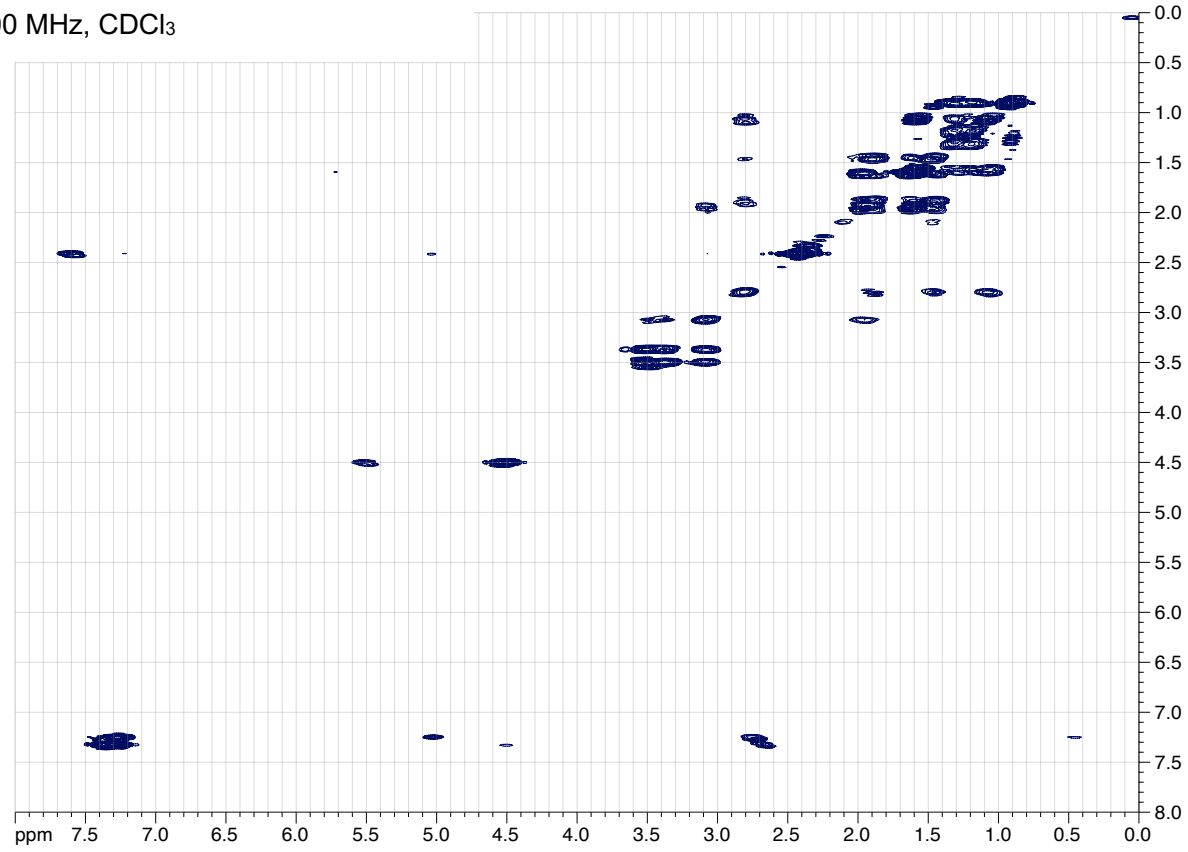
2,5-*trans*-**S18**
^{1}H NMR (500 MHz, $CDCl_3$)



2,5-*trans*-**S18**
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

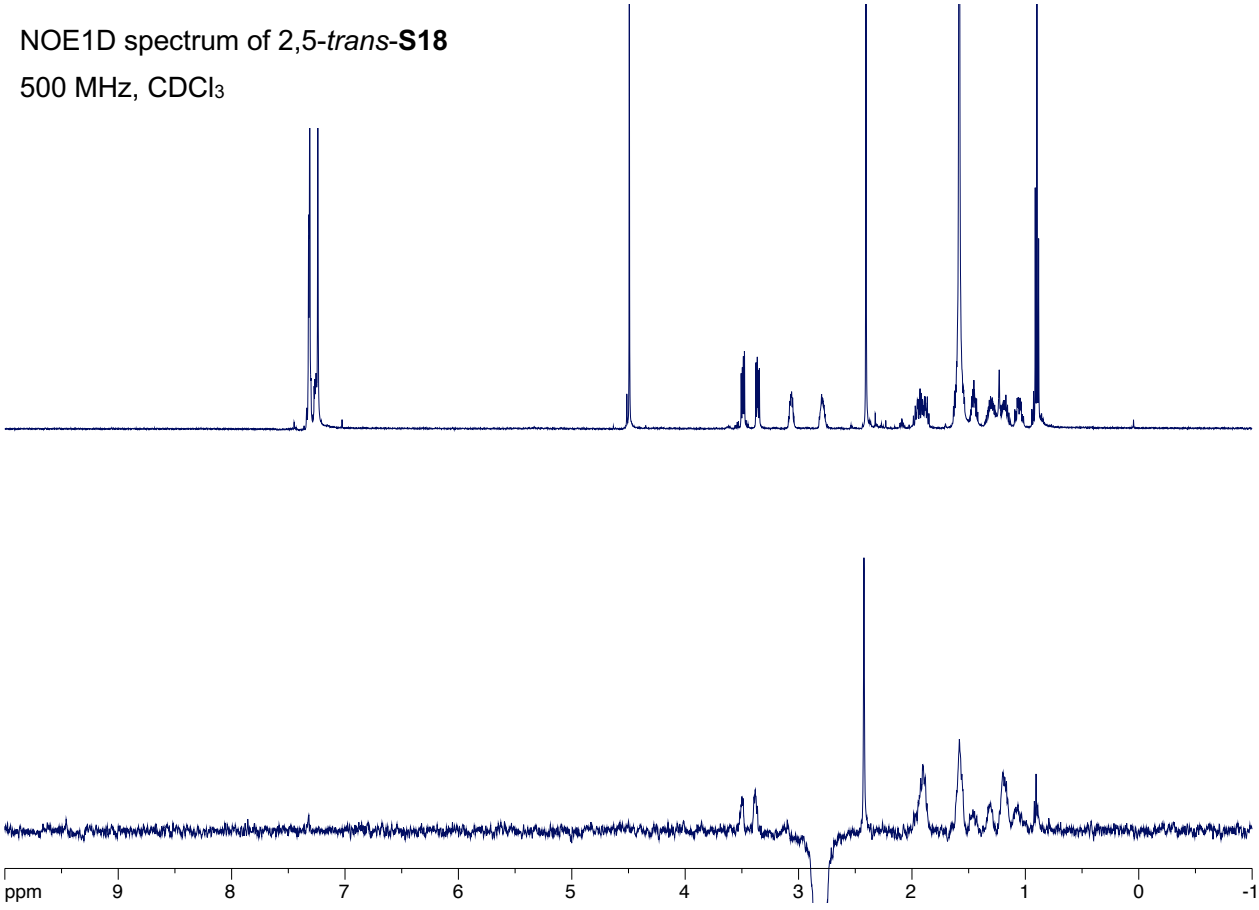
^{1}H-^{1}H COSY spectrum of 2,5-*trans*-**S18**

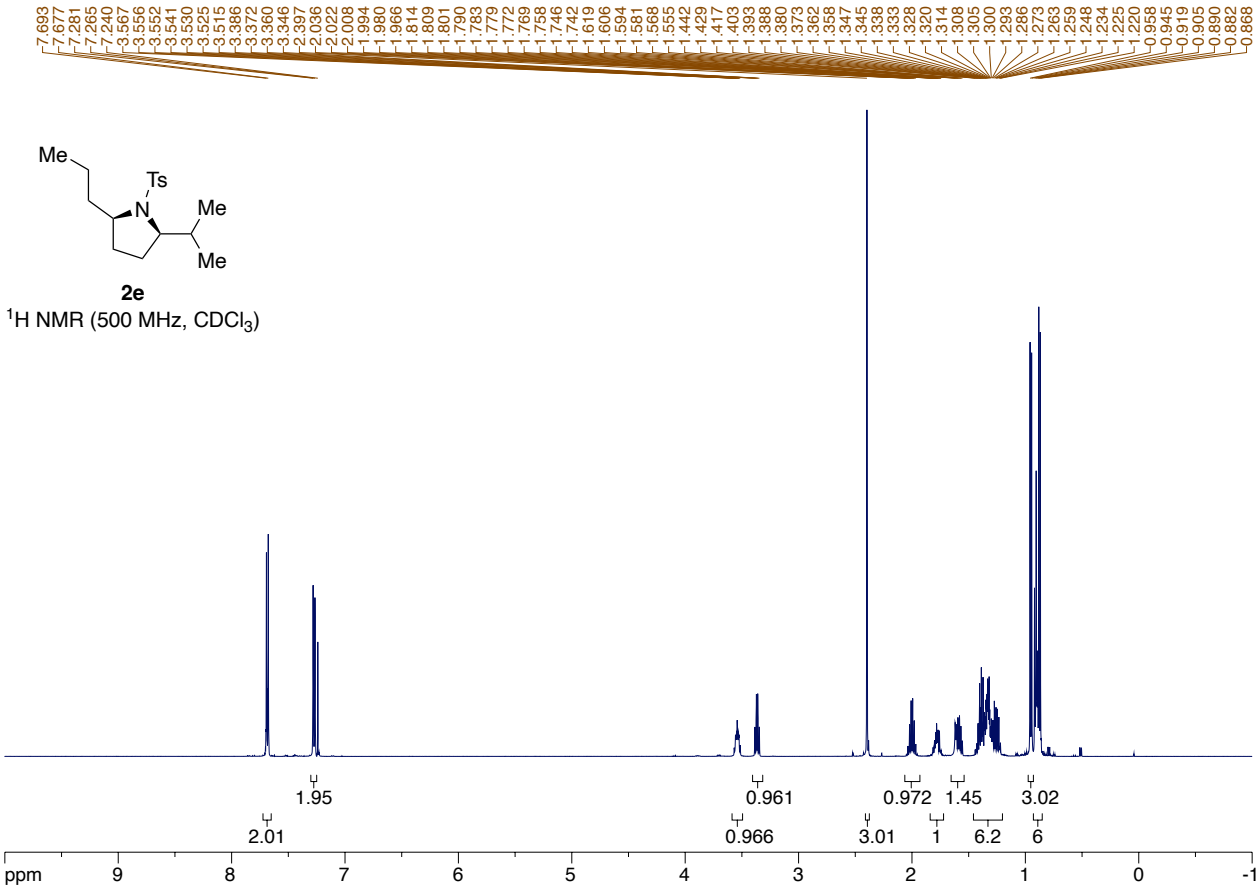
500 MHz, $CDCl_3$

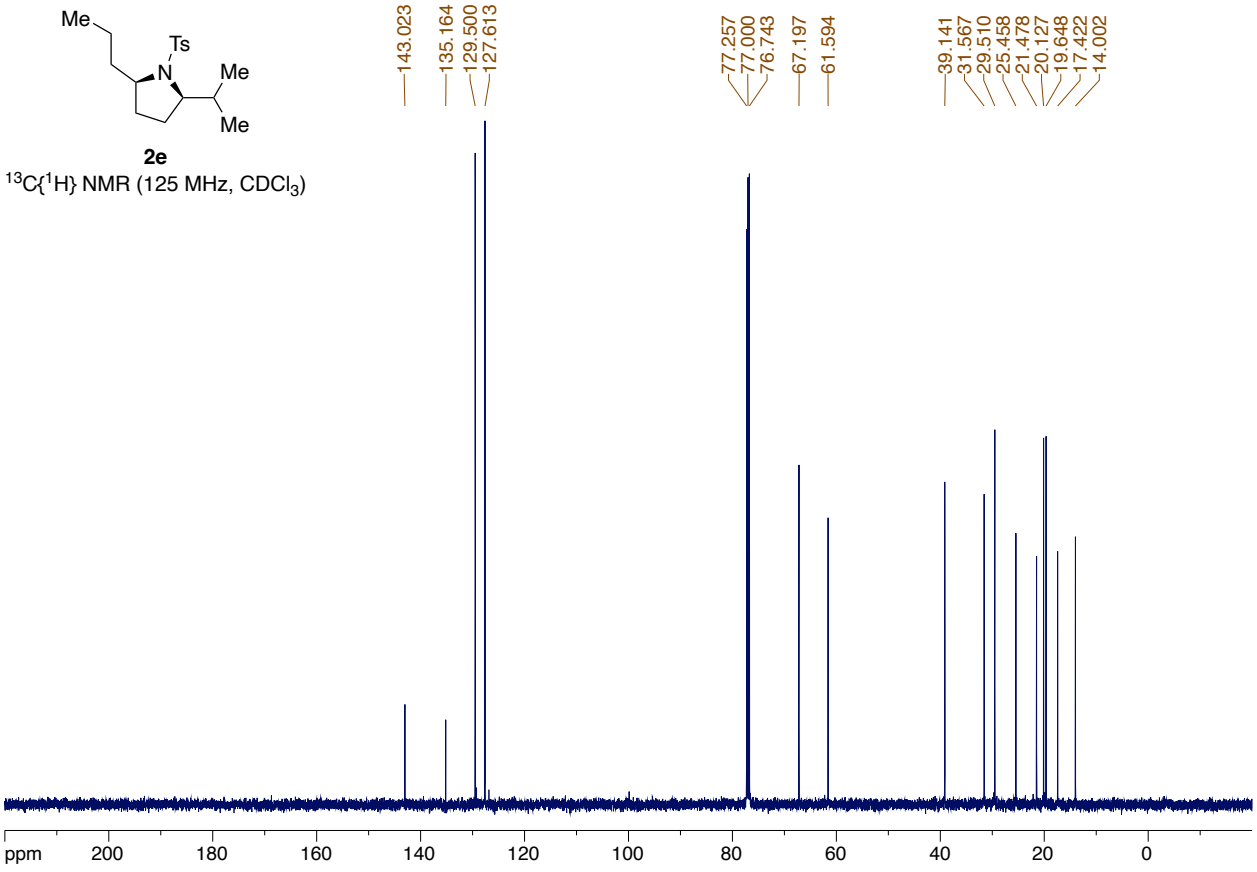


NOE1D spectrum of 2,5-*trans*-**S18**

500 MHz, $CDCl_3$

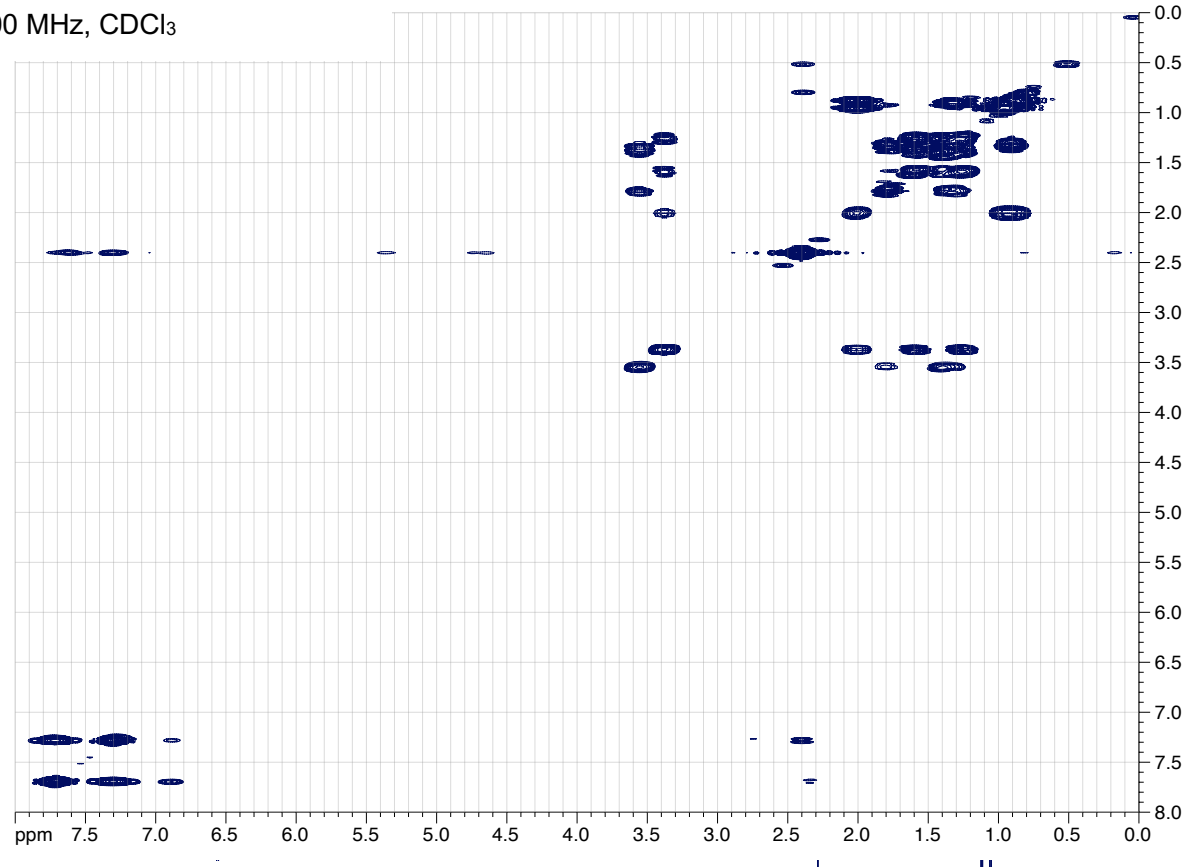



7.693
7.677
7.281
7.265
7.240
3.567
3.556
3.552
3.541
3.530
3.525
3.515
3.386
3.372
3.360
3.346
2.397
2.036
2.022
2.008
1.994
1.980
1.966
1.814
1.809
1.801
1.790
1.783
1.779
1.772
1.769
1.758
1.746
1.742
1.619
1.606
1.594
1.581
1.568
1.555
1.442
1.429
1.417
1.403
1.393
1.388
1.380
1.373
1.362
1.358
1.347
1.345
1.338
1.333
1.328
1.320
1.314
1.308
1.305
1.300
1.293
1.286
1.273
1.263
1.259
1.248
1.234
1.225
1.220
0.958
0.945
0.919
0.905
0.890
0.882
0.868
Me
Ts
N
Me
Me
2e
1H NMR (500 MHz, CDCl3)
1.95
2.01
0.961
0.966
0.972
3.01
1
1.45
6.2
3.02
6
ppm
9
8
7
6
5
4
3
2
1
0
-1


Me
Ts
N
Me
Me
2e
13C{1H} NMR (125 MHz, CDCl3)
143.023
135.164
129.500
127.613
77.257
77.000
76.743
67.197
61.594
39.141
31.567
29.510
25.458
21.478
20.127
19.648
17.422
14.002
ppm
200
180
160
140
120
100
80
60
40
20
0

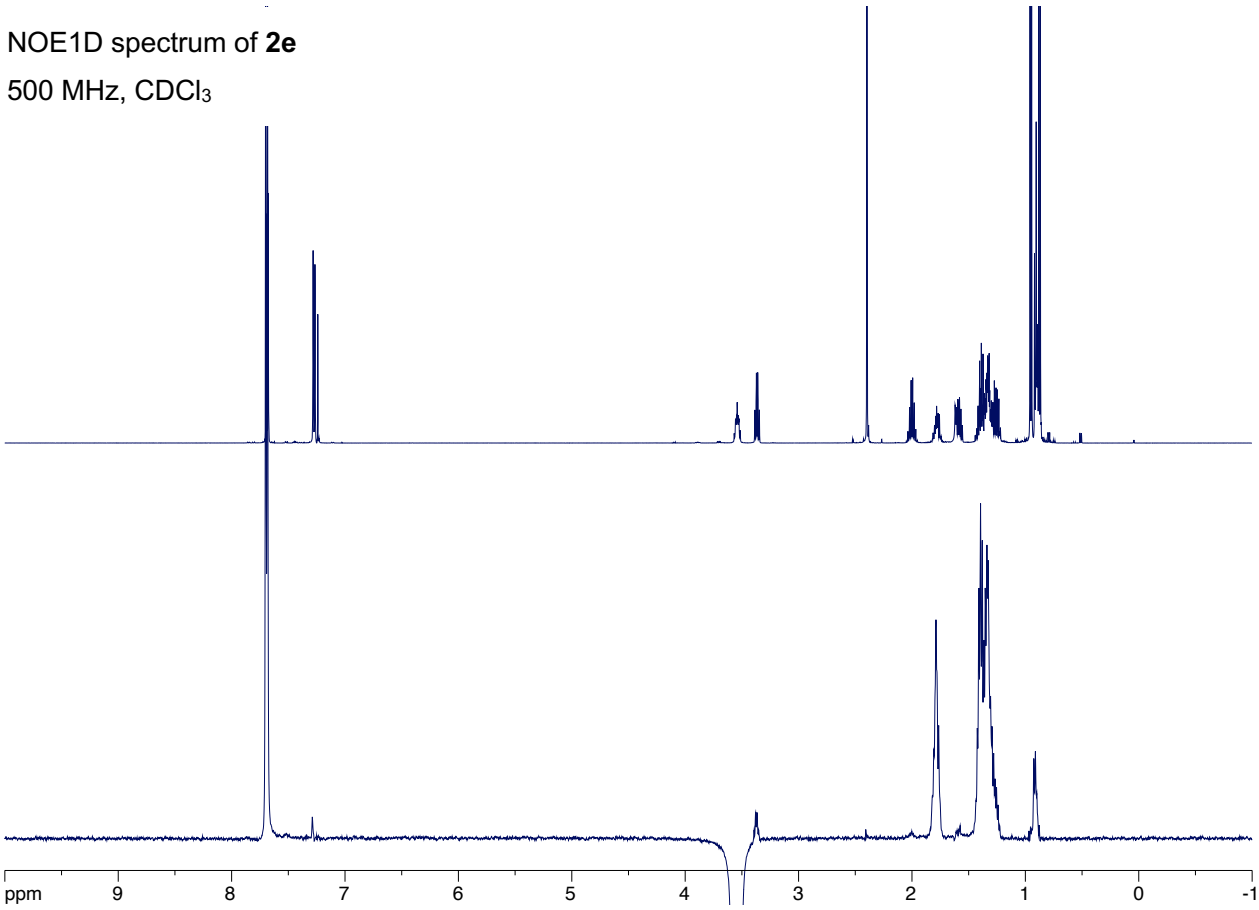
^{1}H-^{1}H COSY spectrum of **2e**

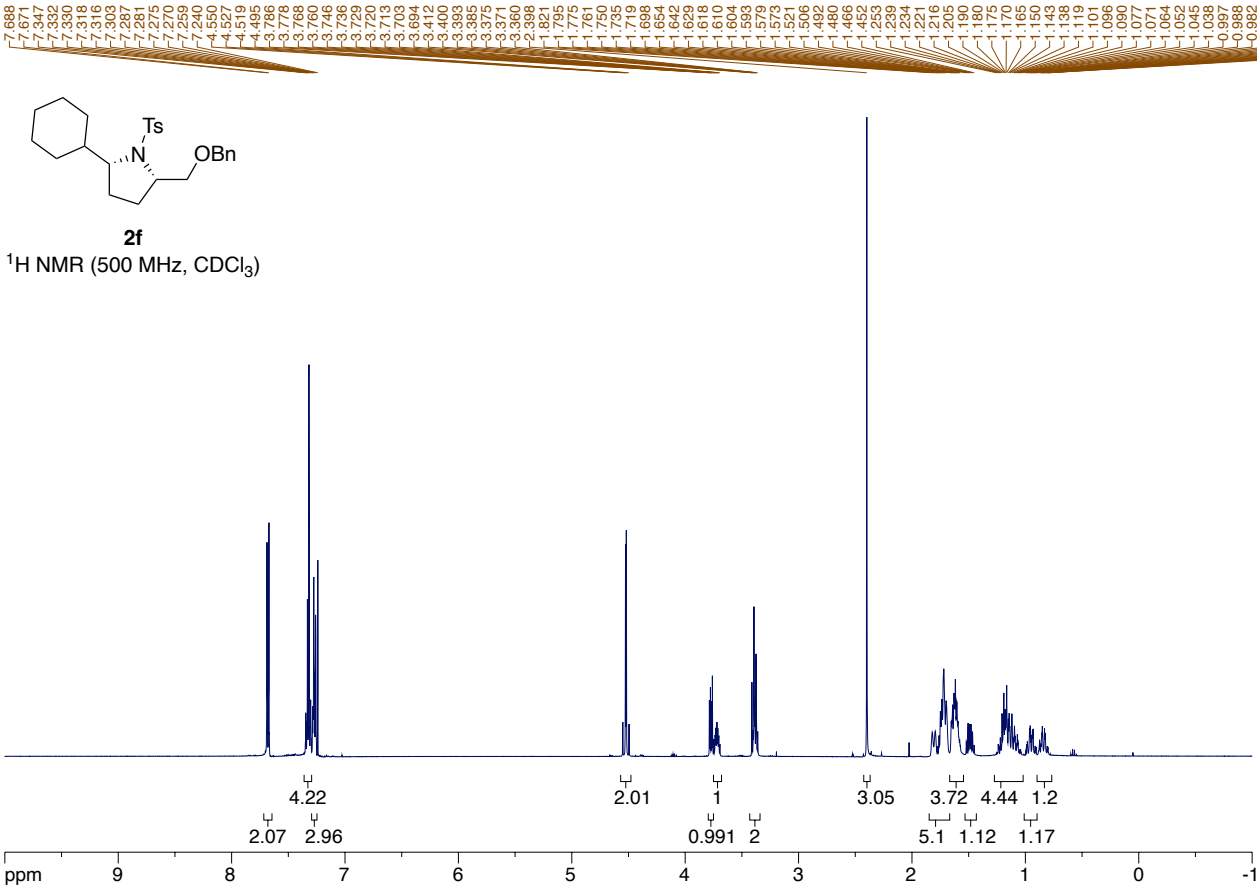
500 MHz, $CDCl_3$

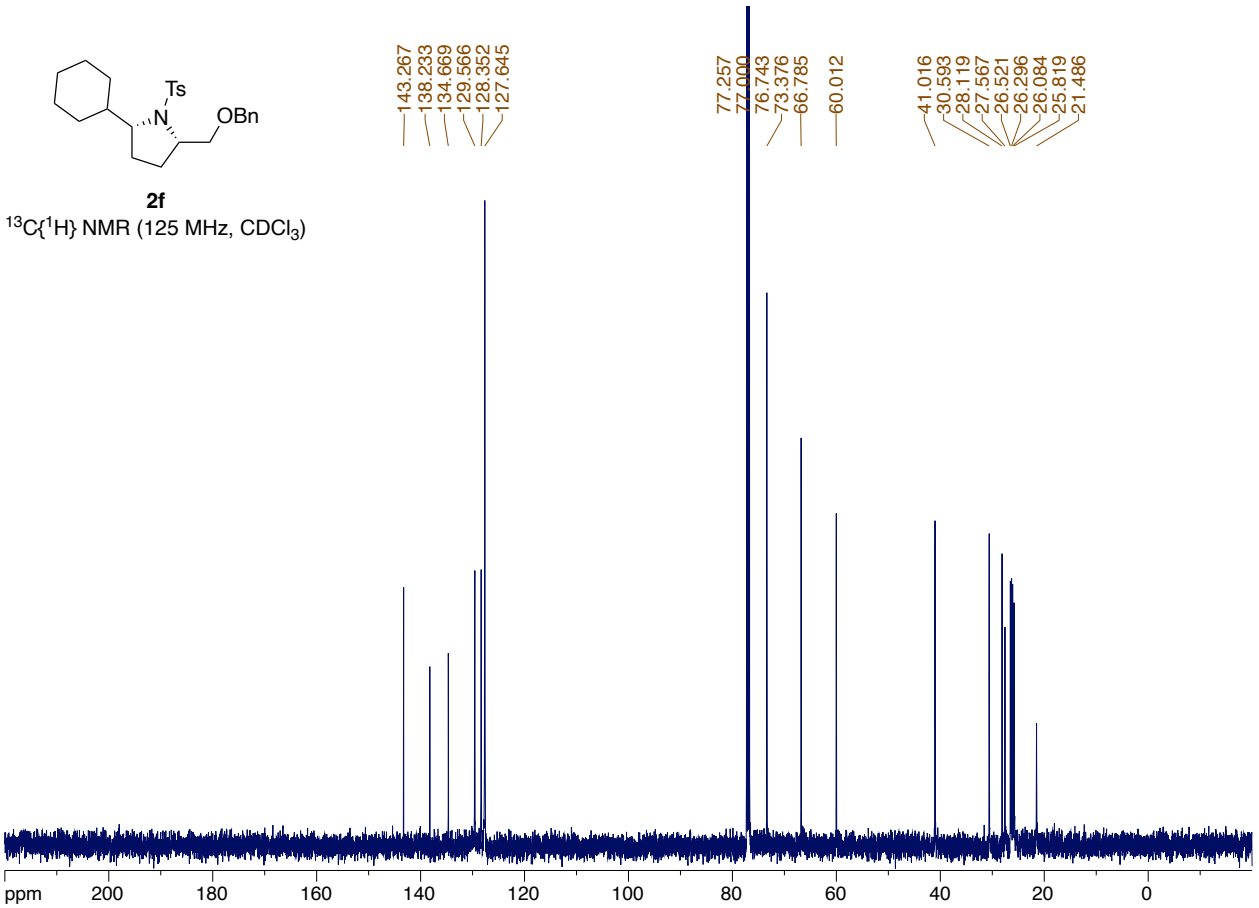


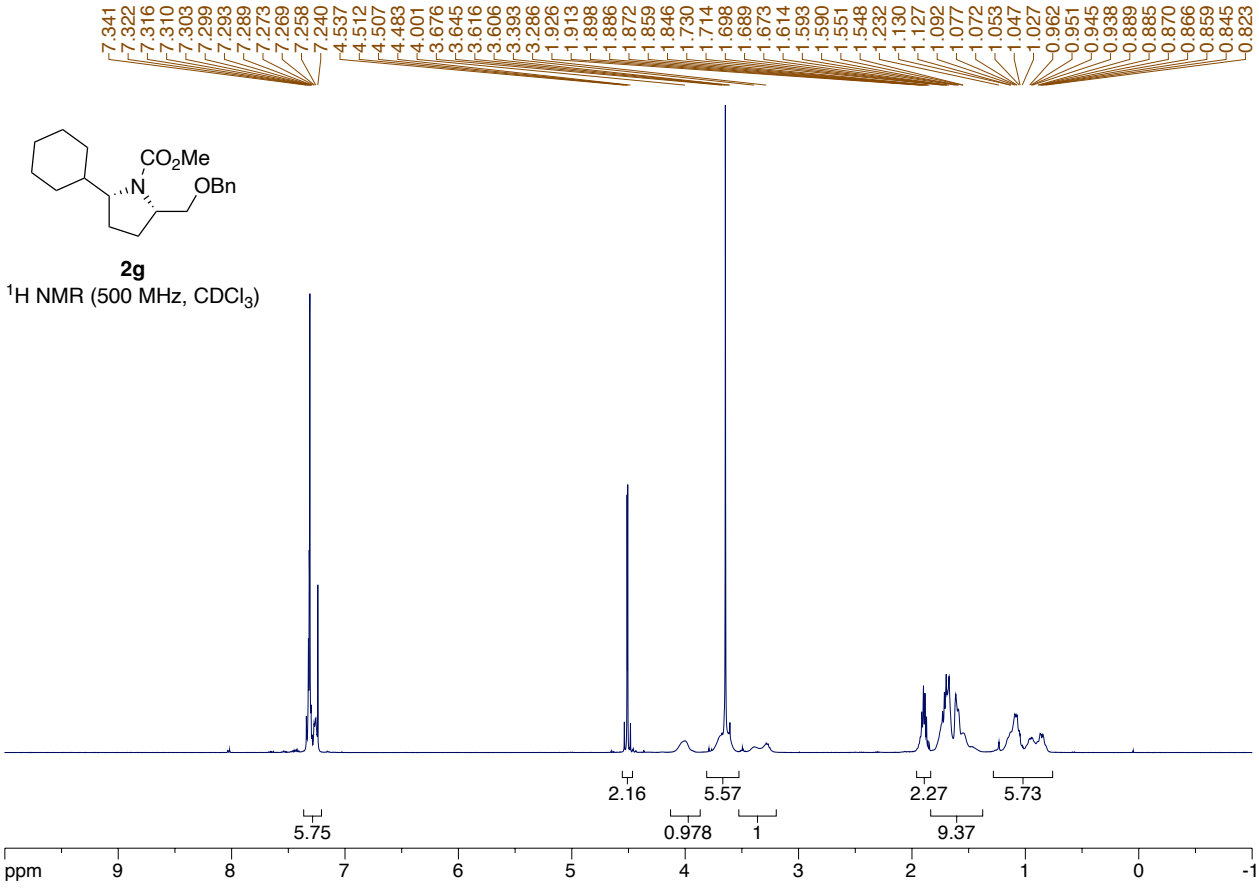
NOE1D spectrum of **2e**

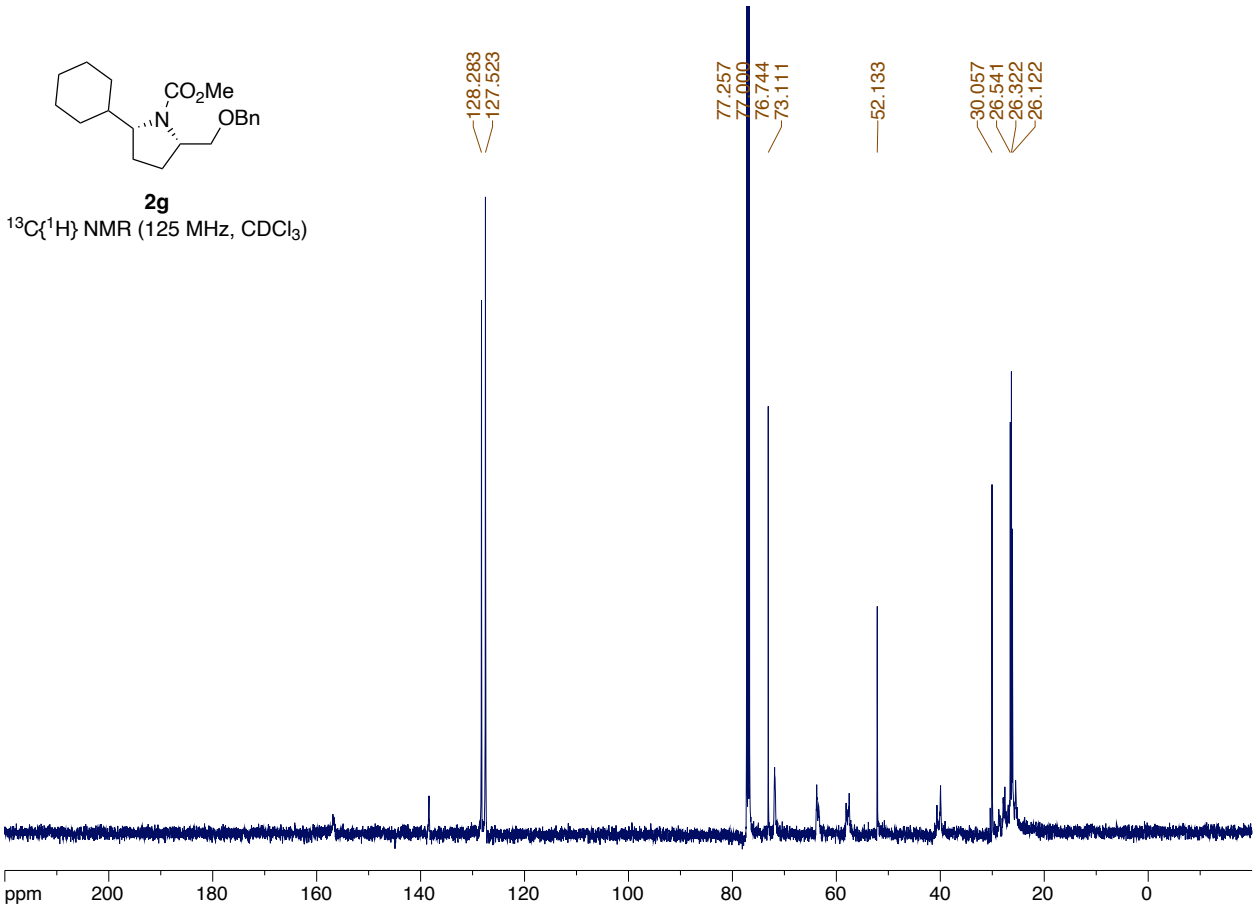
500 MHz, $CDCl_3$

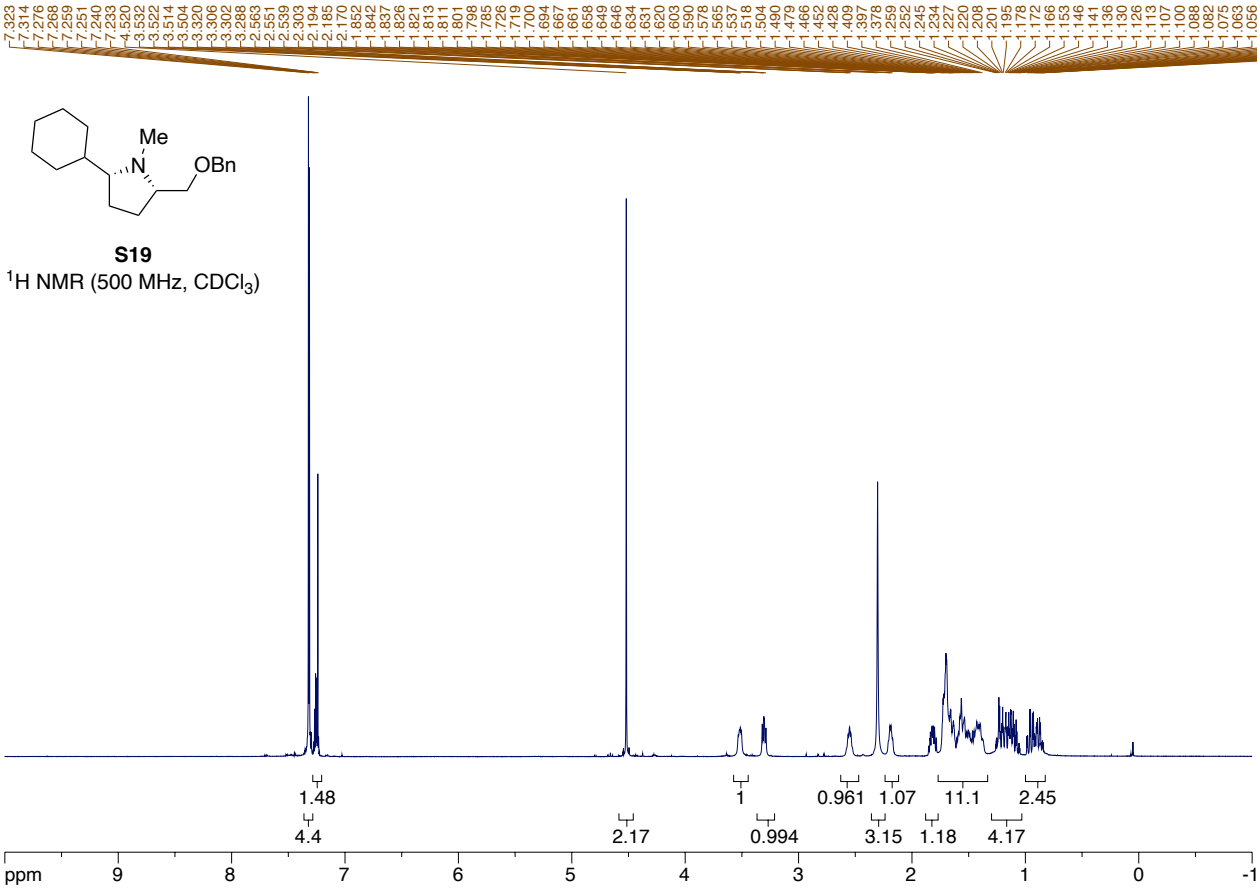



7.688
7.671
7.347
7.332
7.330
7.318
7.316
7.303
7.287
7.281
7.275
7.270
7.259
7.240
4.550
4.527
4.519
4.495
3.786
3.778
3.768
3.760
3.746
3.736
3.729
3.720
3.713
3.703
3.694
3.412
3.400
3.393
3.385
3.375
3.371
3.360
2.398
1.821
1.795
1.775
1.761
1.750
1.735
1.719
1.698
1.654
1.642
1.629
1.618
1.610
1.604
1.593
1.579
1.573
1.521
1.506
1.492
1.480
1.466
1.452
1.253
1.239
1.234
1.221
1.216
1.205
1.190
1.180
1.175
1.170
1.165
1.150
1.143
1.138
1.119
1.101
1.096
1.090
1.077
1.071
1.064
1.052
1.045
1.038
0.997
0.988
0.982
Ts
N
OBn
2f
1H NMR (500 MHz, CDCl3)
4.22
2.01
1
3.05
3.72
4.44
1.2
2.07
2.96
0.991
2
5.1
1.12
1.17
ppm
9
8
7
6
5
4
3
2
1
0
-1


143.267
138.233
134.669
129.566
128.352
127.645
77.257
77.000
76.743
73.376
66.785
60.012
41.016
30.593
28.119
27.567
26.521
26.296
26.084
25.819
21.486
Ts
N
OBn
2f
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0

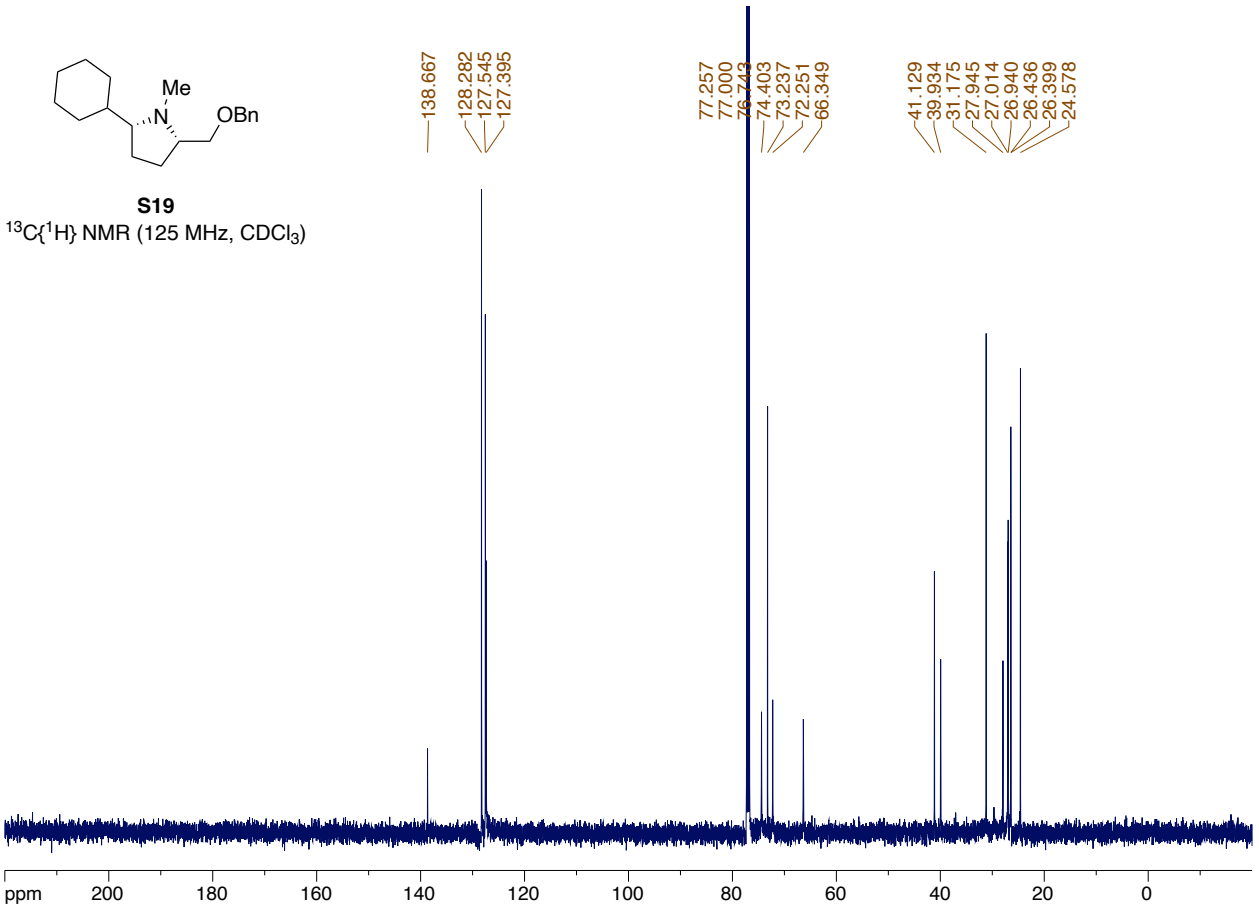

7.341
7.322
7.316
7.310
7.303
7.299
7.293
7.289
7.273
7.269
7.258
7.240
4.537
4.512
4.507
4.483
4.001
3.676
3.645
3.616
3.606
3.393
3.286
1.926
1.913
1.898
1.886
1.872
1.859
1.846
1.730
1.714
1.698
1.689
1.673
1.614
1.593
1.590
1.551
1.548
1.232
1.130
1.127
1.092
1.077
1.072
1.053
1.047
1.027
0.962
0.951
0.945
0.938
0.889
0.885
0.870
0.866
0.859
0.845
0.823
CO2Me
N
OBn
2g
1H NMR (500 MHz, CDCl3)
2.16
5.57
2.27
5.73
5.75
0.978
1
9.37
ppm
9
8
7
6
5
4
3
2
1
0
-1


CO2Me
N
OBn
2g
13C{1H} NMR (125 MHz, CDCl3)
128.283
127.523
77.257
77.000
76.744
73.111
52.133
30.057
26.541
26.322
26.122
ppm
200
180
160
140
120
100
80
60
40
20
0



S19

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

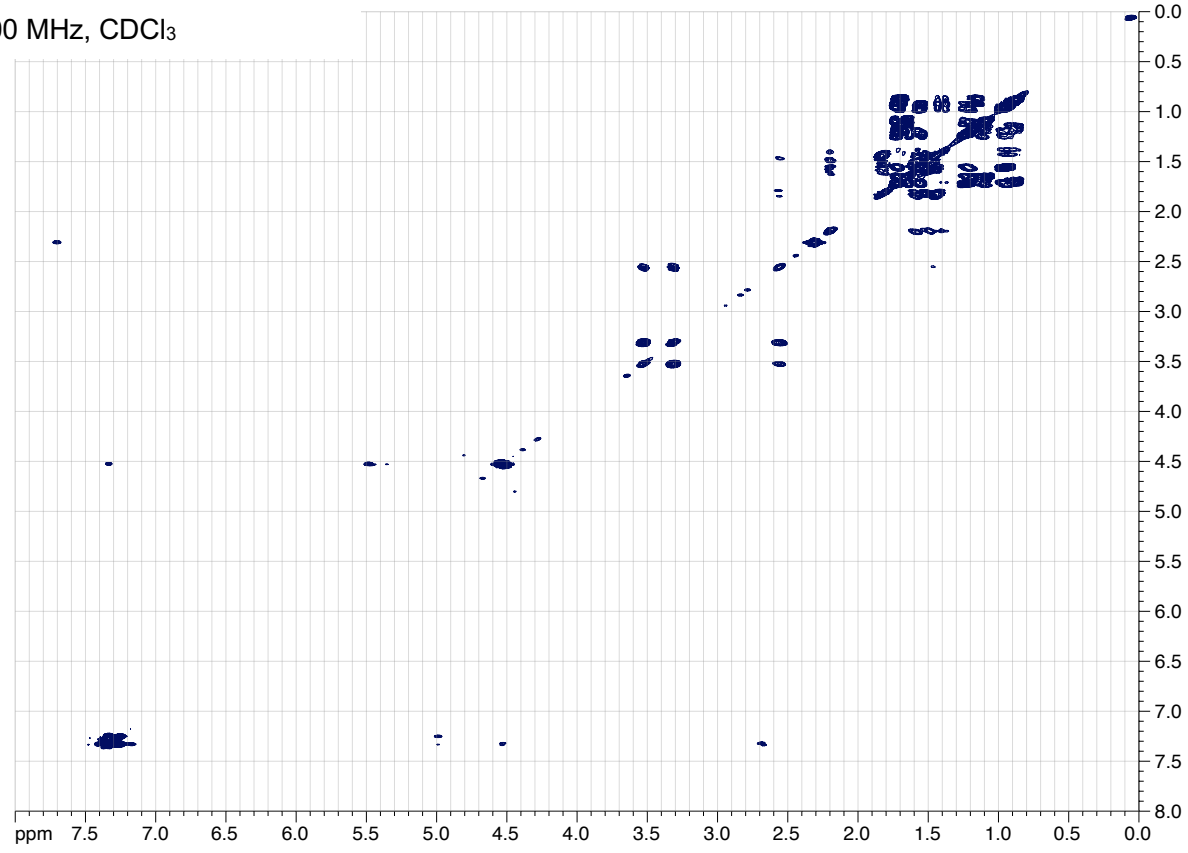


S19

$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)

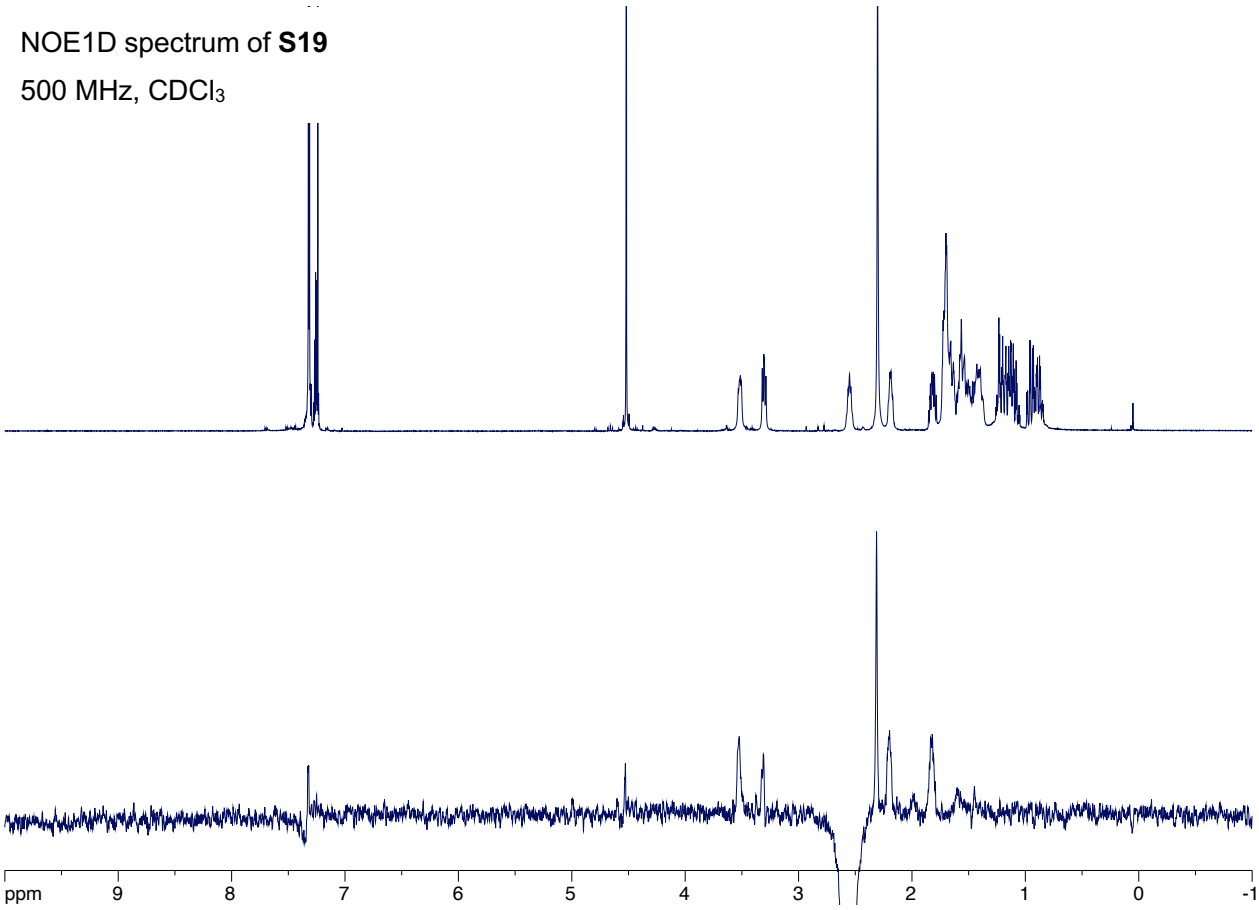
^{1}H-^{1}H COSY spectrum of **S19**

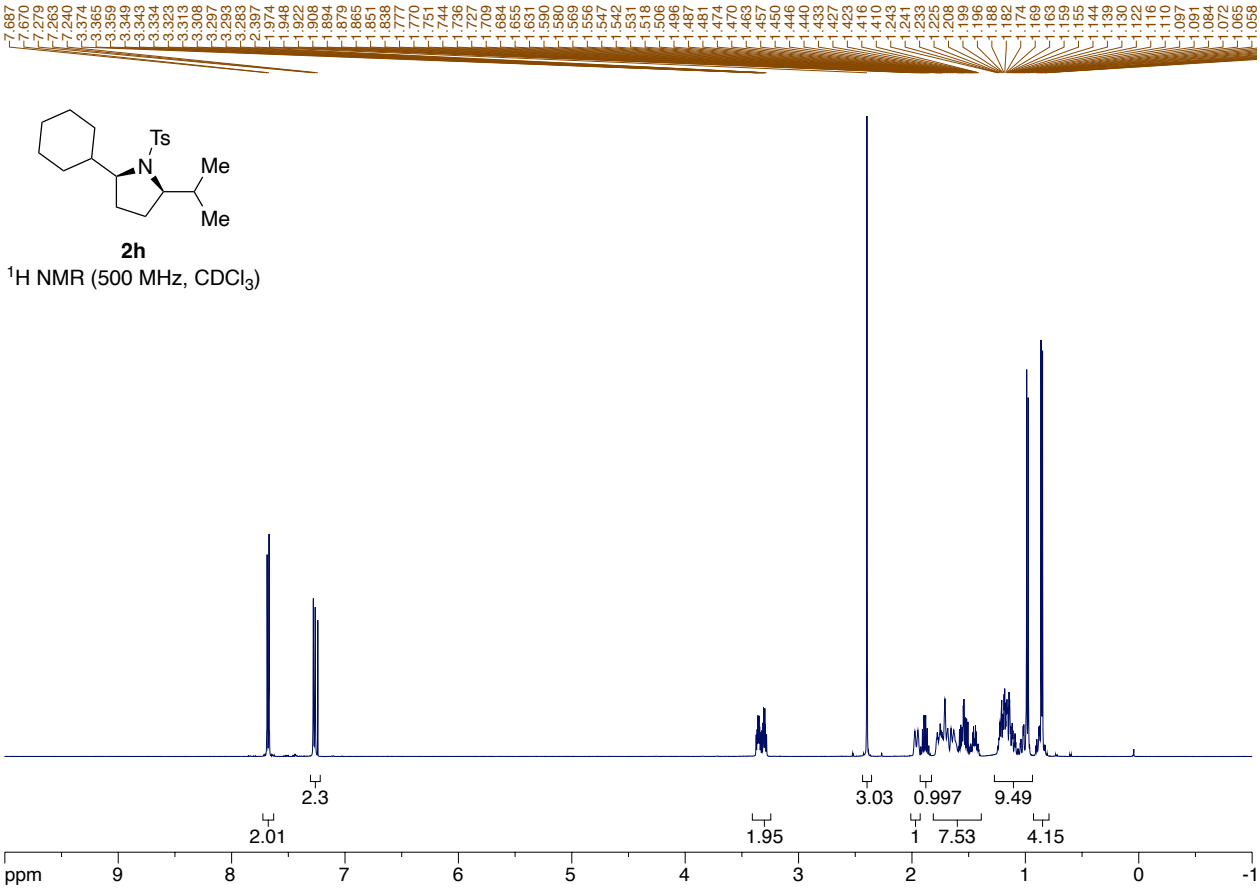
500 MHz, $CDCl_3$

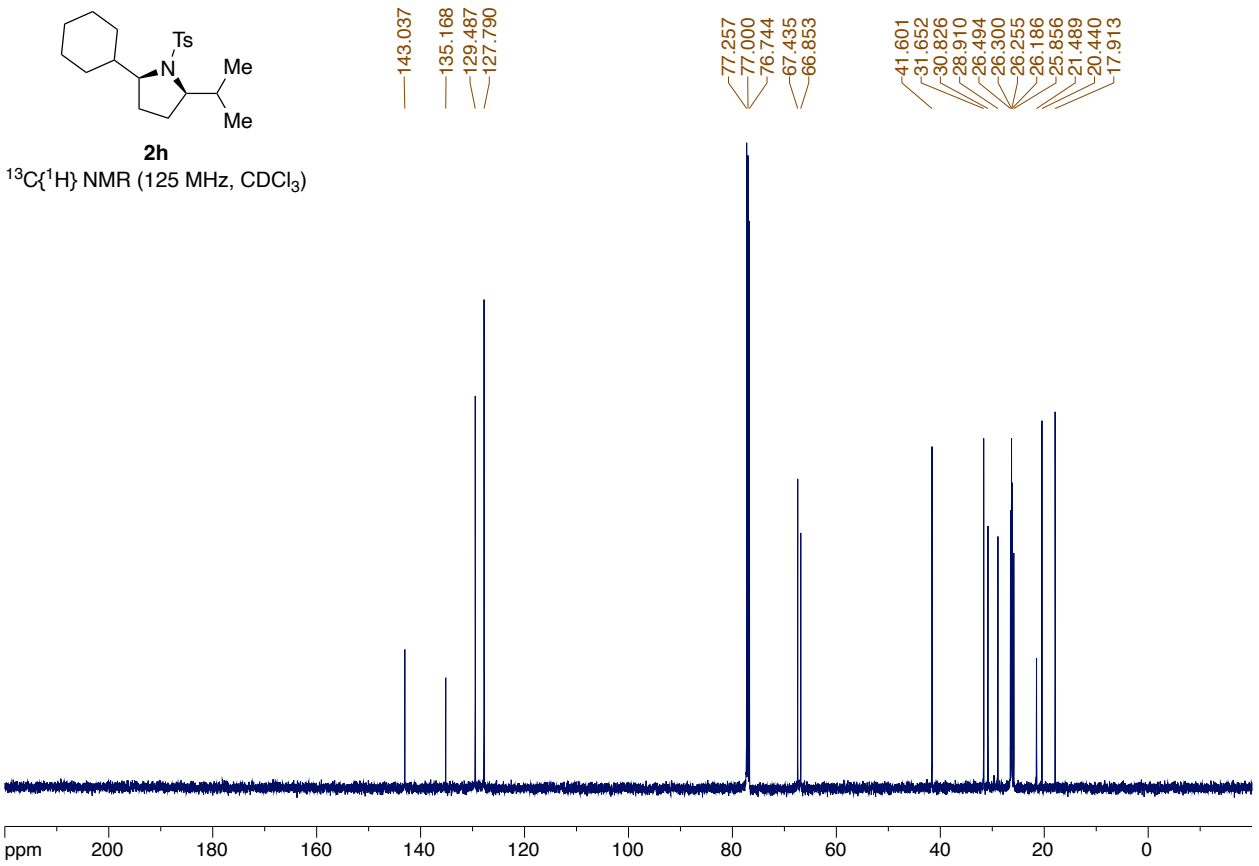


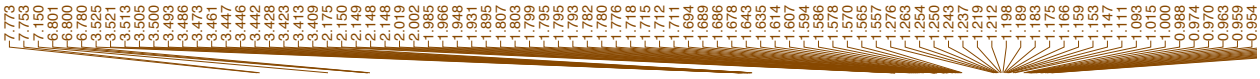
NOE1D spectrum of **S19**

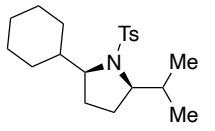
500 MHz, $CDCl_3$




7.687
7.670
7.279
7.263
7.240
3.374
3.365
3.359
3.349
3.343
3.334
3.323
3.313
3.308
3.297
3.293
3.283
2.397
1.974
1.948
1.922
1.908
1.894
1.879
1.865
1.851
1.838
1.777
1.770
1.751
1.744
1.736
1.727
1.709
1.684
1.655
1.631
1.590
1.580
1.569
1.556
1.547
1.542
1.531
1.518
1.506
1.496
1.487
1.481
1.474
1.470
1.463
1.457
1.450
1.446
1.440
1.433
1.427
1.423
1.416
1.410
1.243
1.241
1.233
1.225
1.208
1.199
1.196
1.188
1.182
1.174
1.169
1.163
1.159
1.155
1.144
1.139
1.130
1.122
1.116
1.110
1.097
1.091
1.084
1.072
1.065
1.058
Ts
N
Me
Me
2h
1H NMR (500 MHz, CDCl3)
2.3
3.03
0.997
9.49
2.01
1.95
1
7.53
4.15
ppm
9
8
7
6
5
4
3
2
1
0
-1

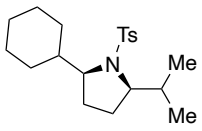

Ts
N
Me
Me
2h
13C{1H} NMR (125 MHz, CDCl3)
143.037
135.168
129.487
127.790
77.257
77.000
76.744
67.435
66.853
41.601
31.652
30.826
28.910
26.494
26.300
26.255
26.186
25.856
21.489
20.440
17.913
ppm
200
180
160
140
120
100
80
60
40
20
0





2h

^{1}H NMR (400 MHz, C_6D_6)

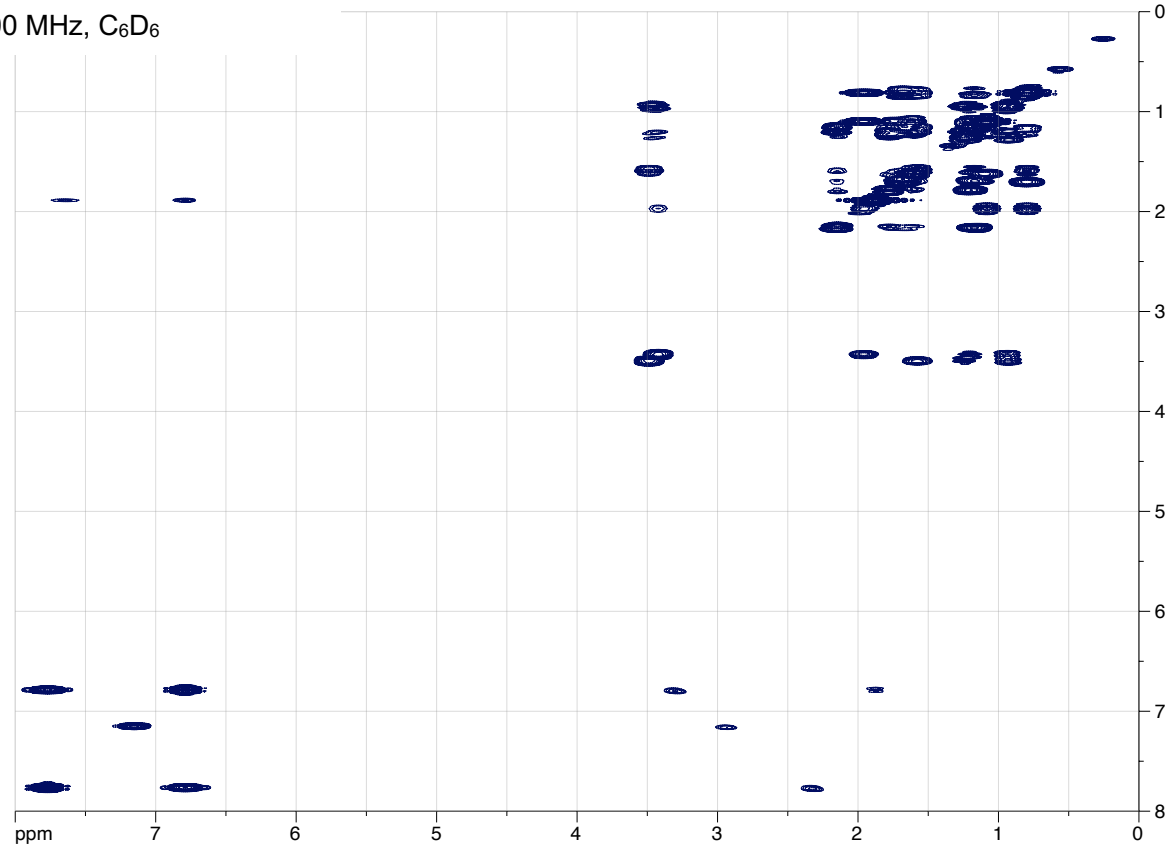


2h

^{13}C{^{1}H} NMR (100 MHz, C_6D_6)

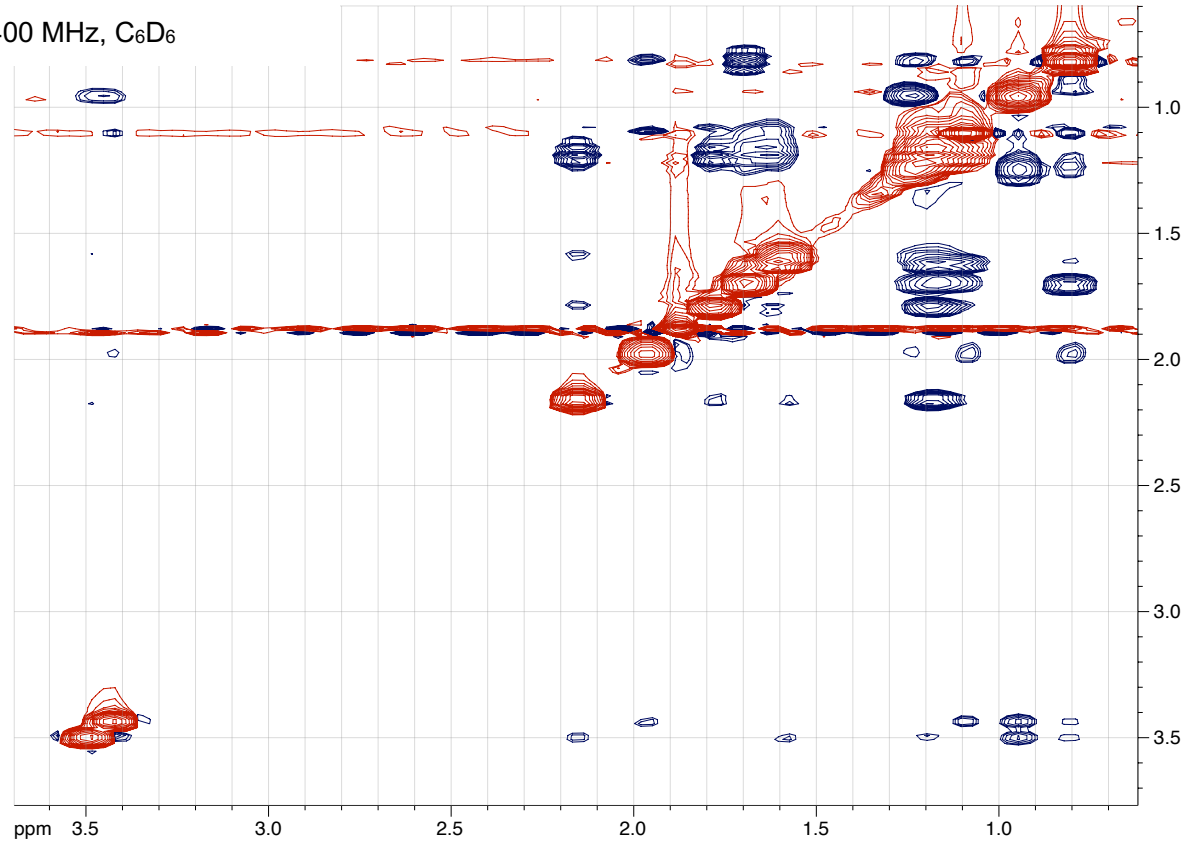
^{1}H-^{1}H COSY spectrum of **2h**

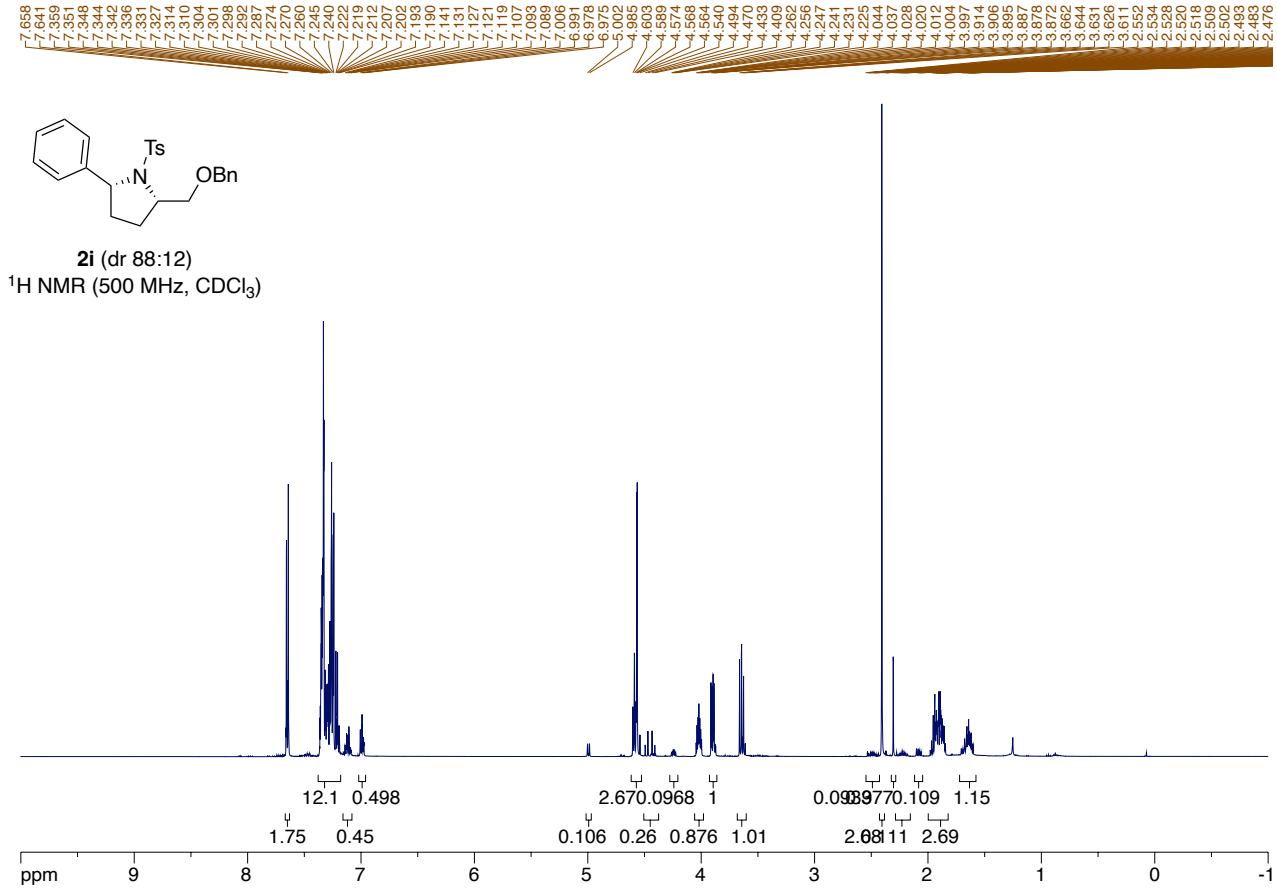
500 MHz, C_6D_6

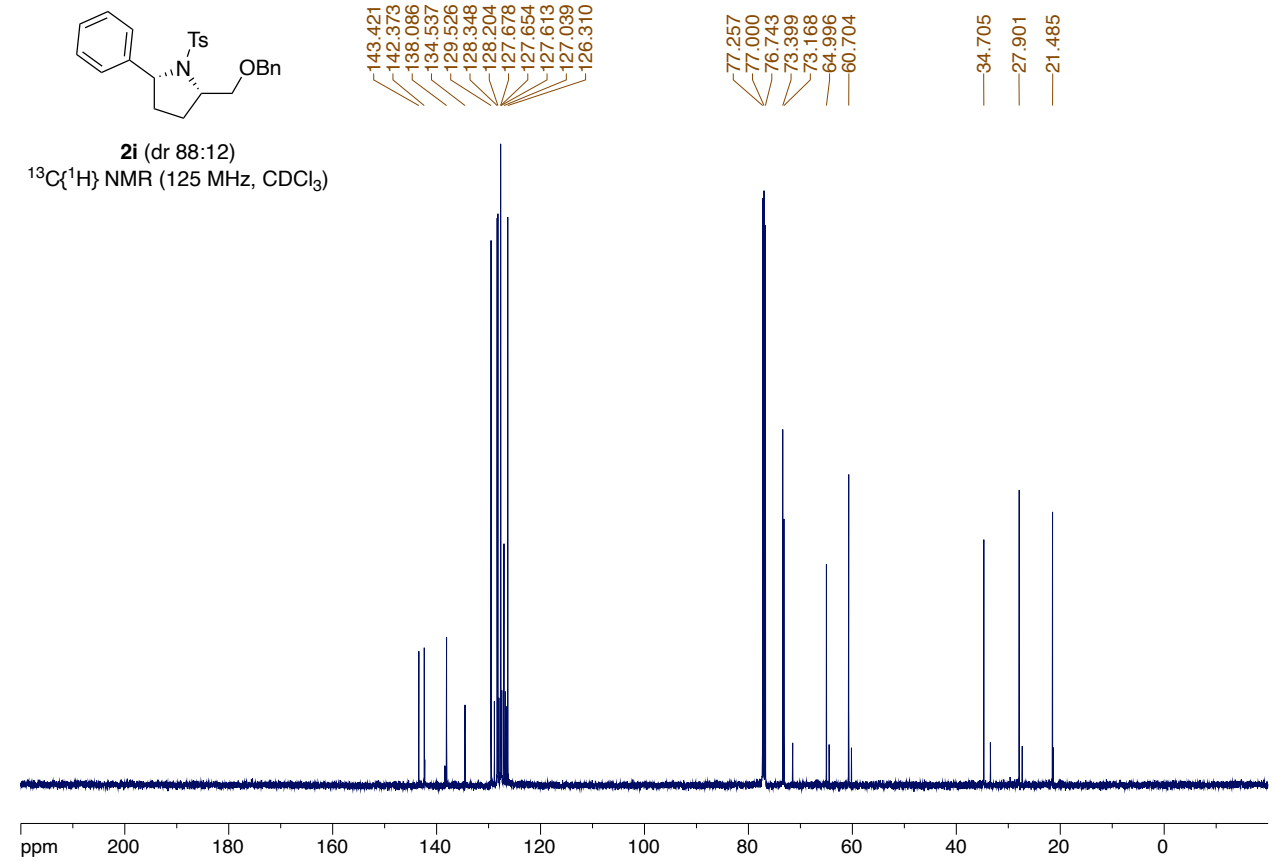


NOESY2D spectrum of **2h**

400 MHz, C_6D_6

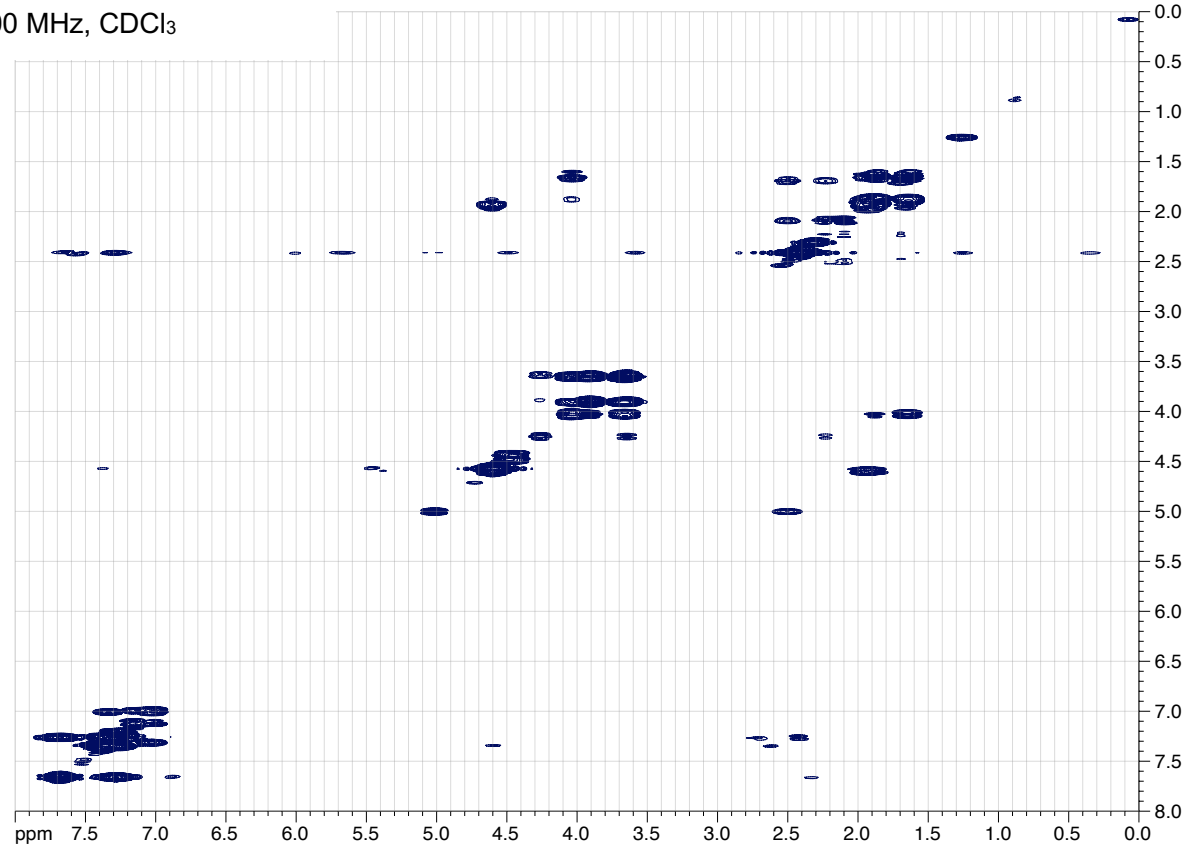



Ts
N
OBn
2i (dr 88:12)
1H NMR (500 MHz, CDCl3)
12.1
0.498
2.67
0.0968
1
0.109
1.15
1.75
0.45
0.106
0.26
0.876
1.01
2.69
ppm


Ts
N
OBn
2i (dr 88:12)
13C{1H} NMR (125 MHz, CDCl3)
143.421
142.373
138.086
134.537
129.526
128.348
128.204
127.678
127.654
127.613
127.039
126.310
77.257
77.000
76.743
73.399
73.168
64.996
60.704
34.705
27.901
21.485
ppm

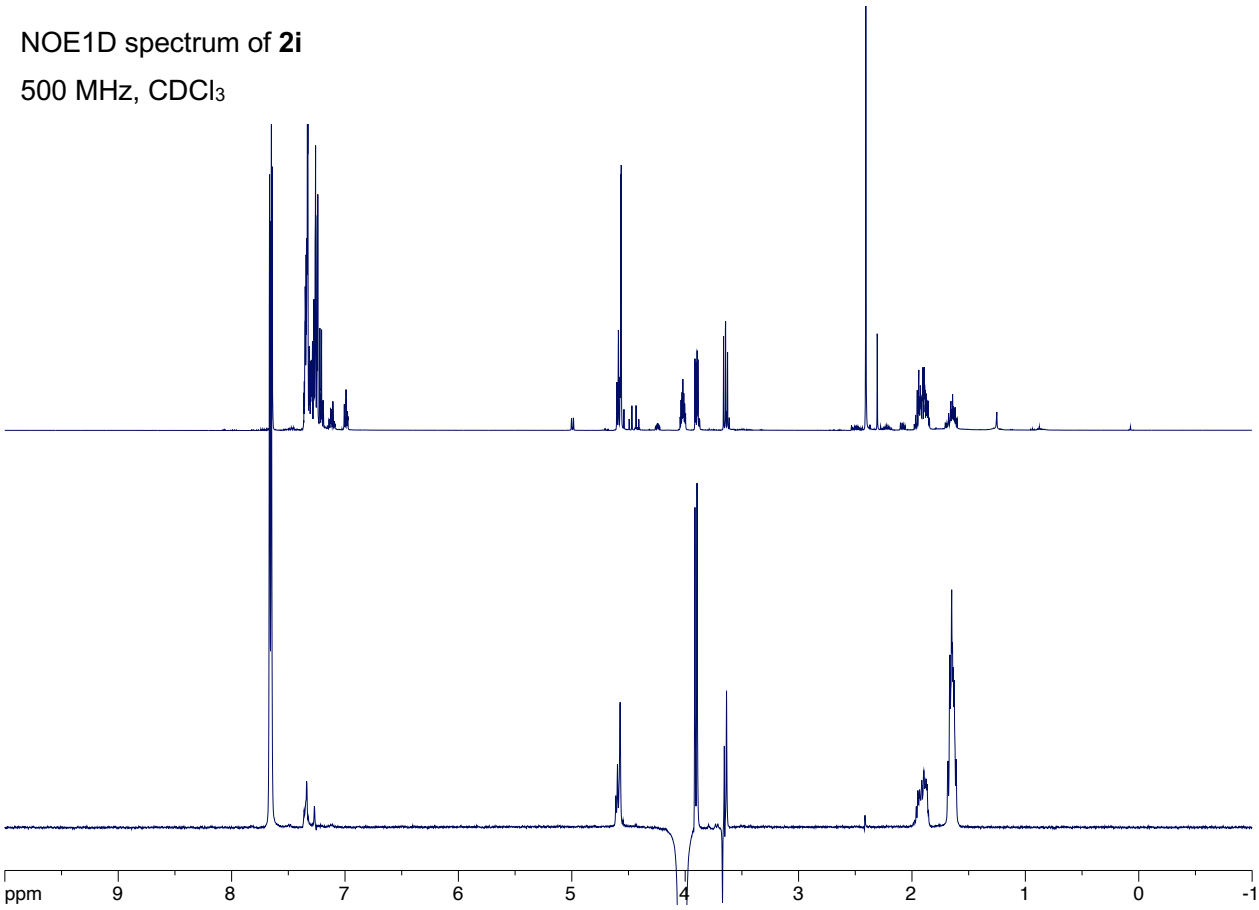
^{1}H-^{1}H COSY spectrum of **2i**

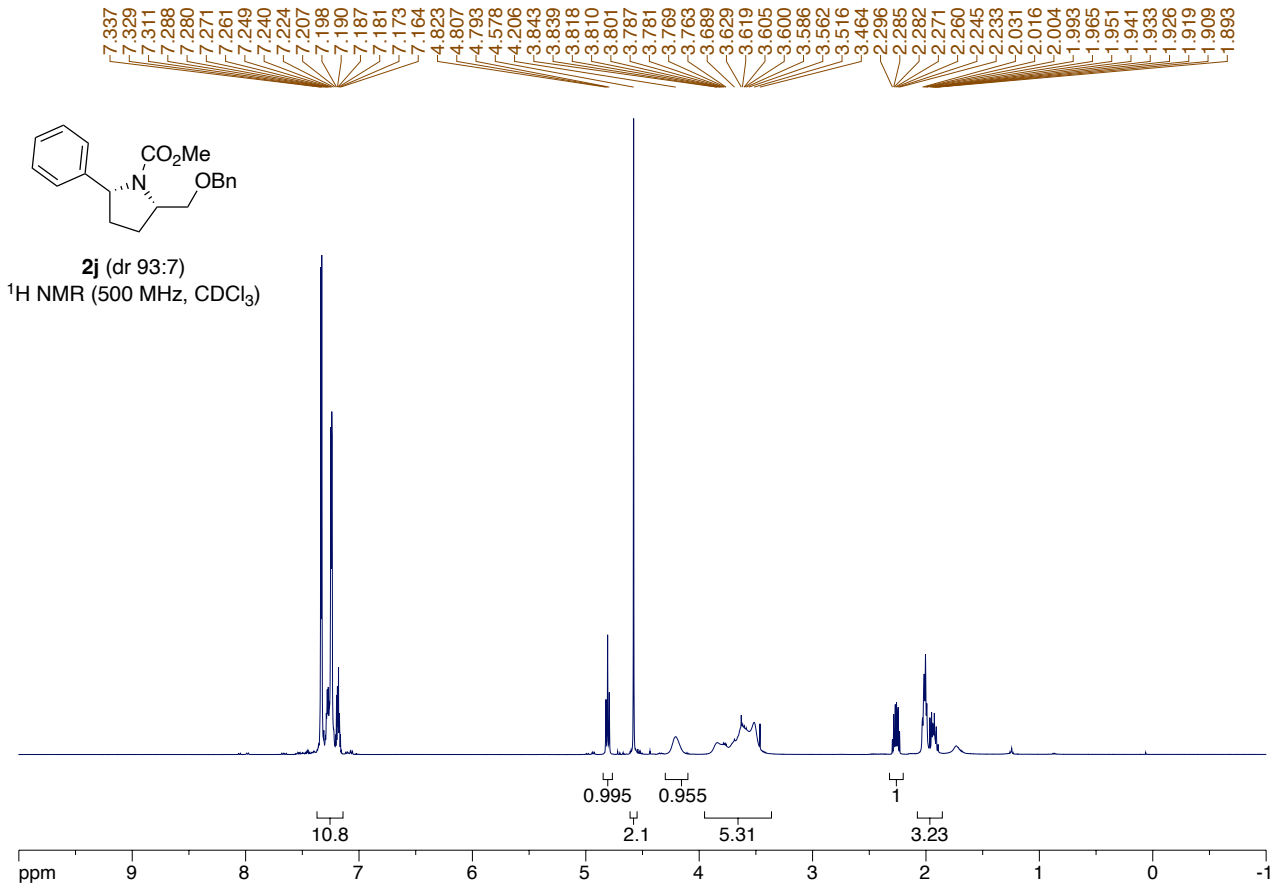
500 MHz, $CDCl_3$

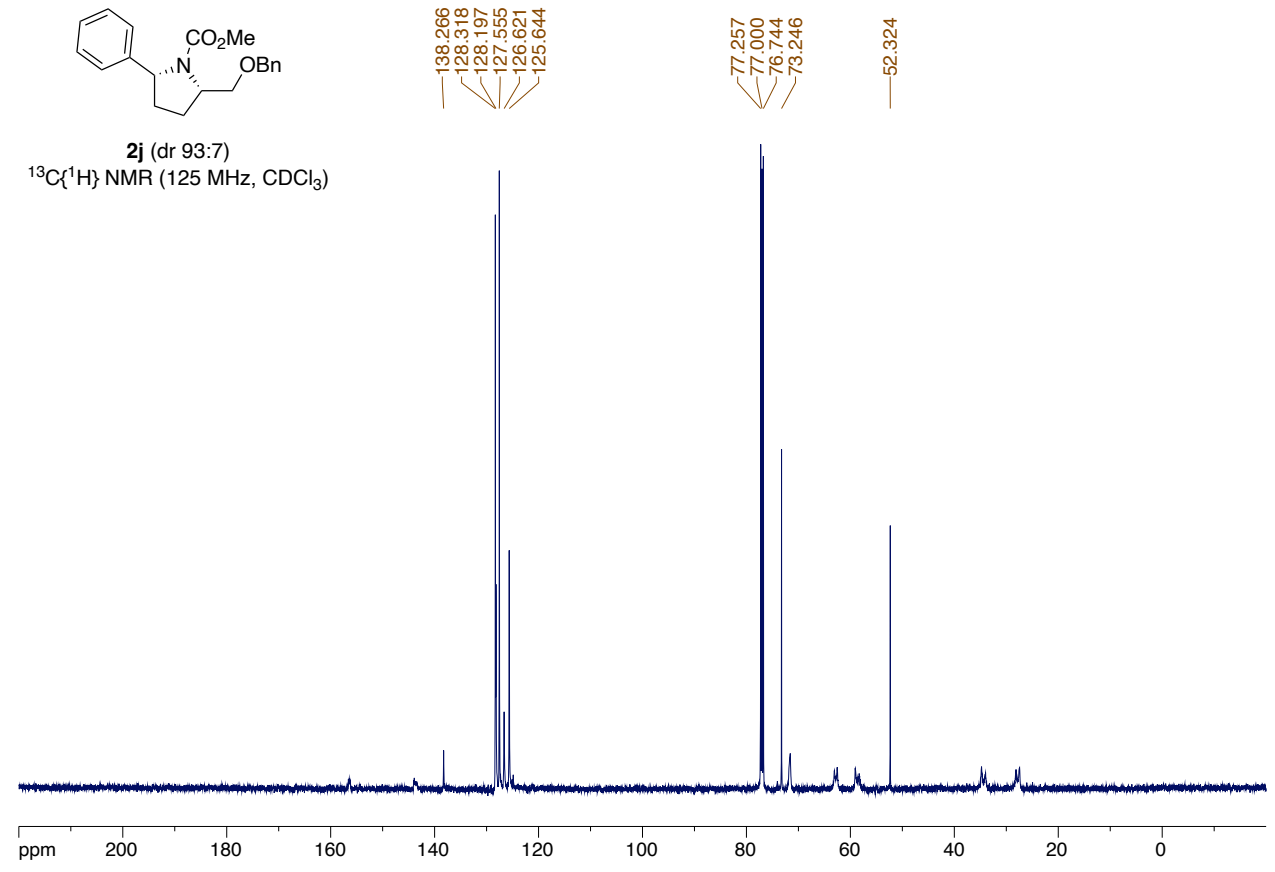


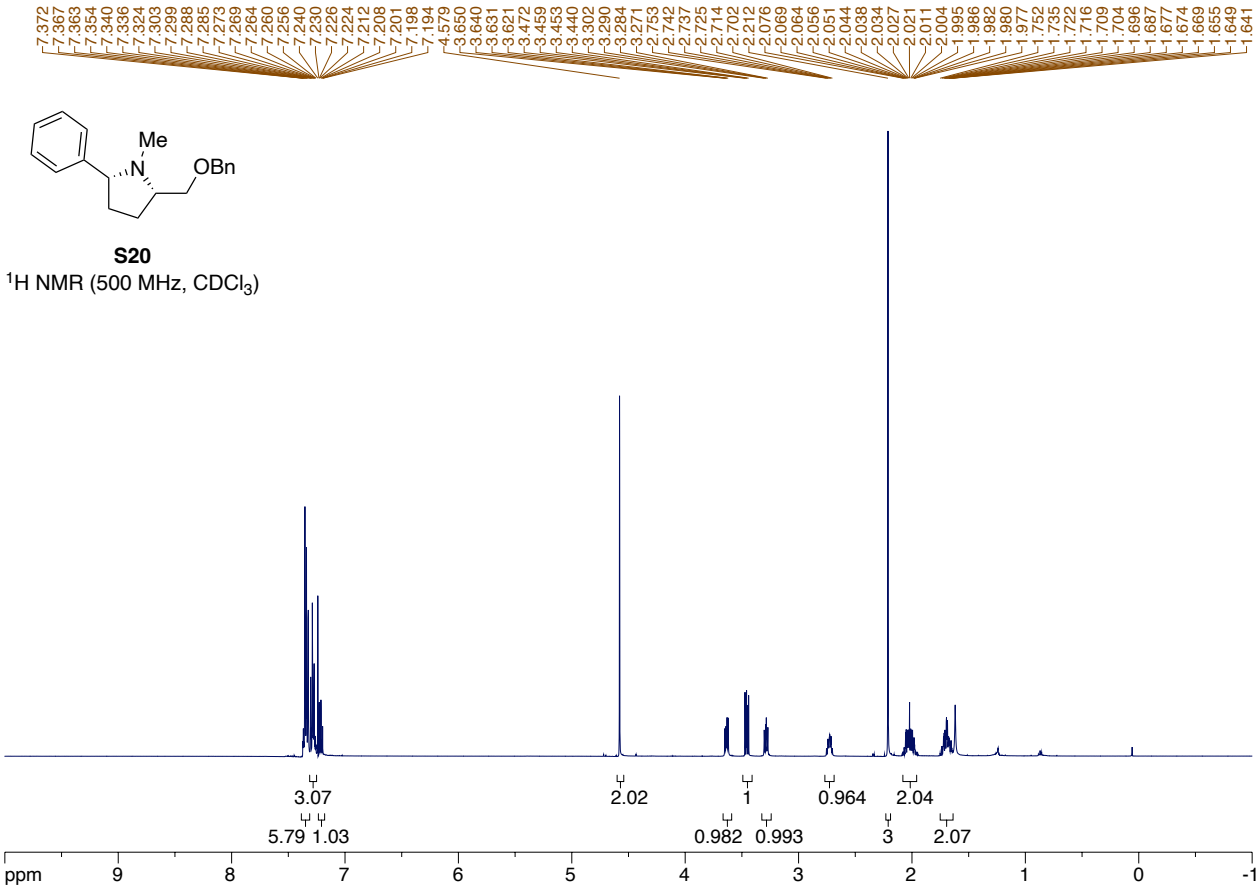
NOE1D spectrum of **2i**

500 MHz, $CDCl_3$



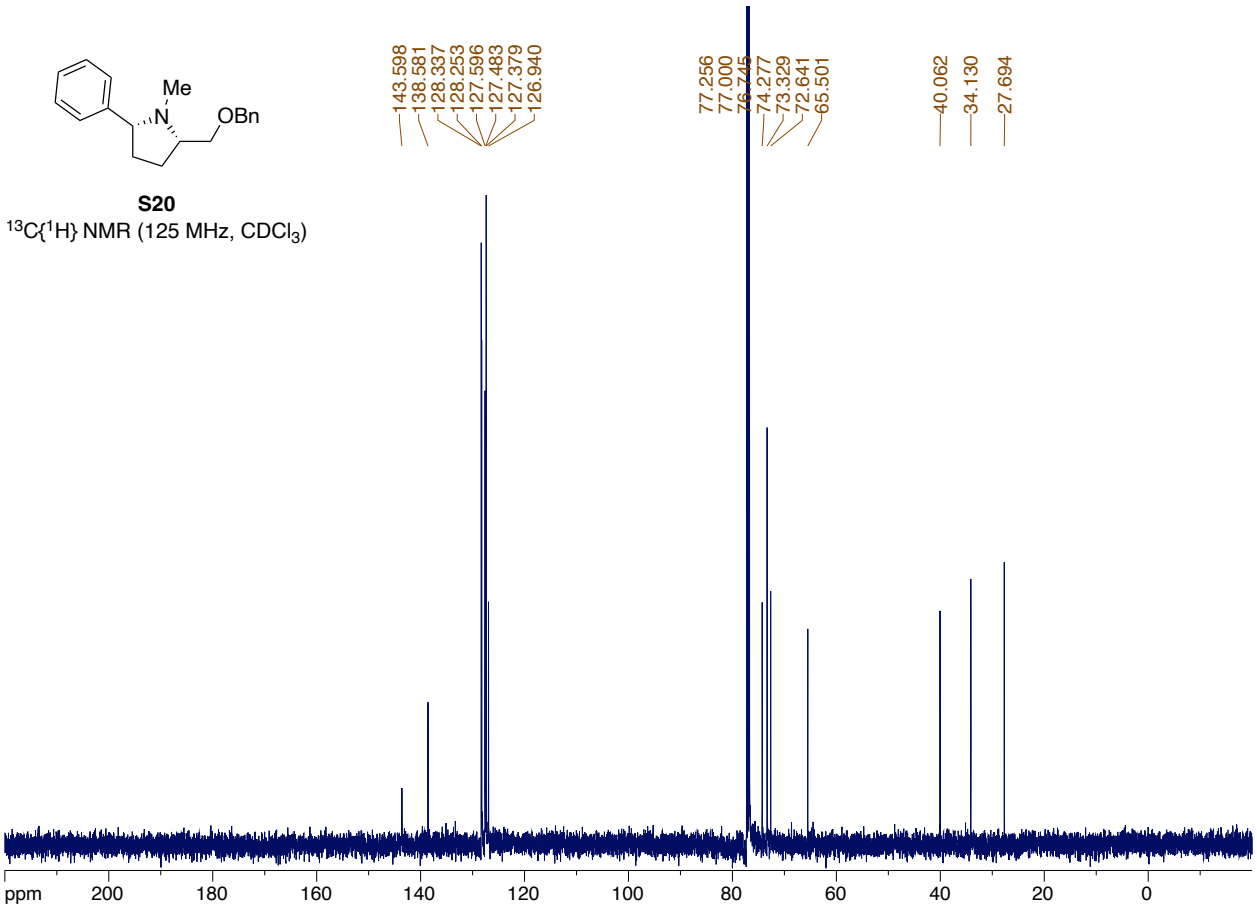

7.337
7.329
7.311
7.288
7.280
7.271
7.261
7.249
7.240
7.224
7.207
7.198
7.190
7.187
7.181
7.173
7.164
4.823
4.807
4.793
4.578
4.206
3.843
3.839
3.818
3.810
3.801
3.787
3.781
3.769
3.763
3.689
3.629
3.619
3.605
3.600
3.586
3.562
3.516
3.464
2.296
2.285
2.282
2.271
2.260
2.245
2.233
2.031
2.016
2.004
1.993
1.965
1.951
1.941
1.933
1.926
1.919
1.909
1.893
CO2Me
N
OBn
2j (dr 93:7)
1H NMR (500 MHz, CDCl3)
0.995
0.955
1
10.8
2.1
5.31
3.23
ppm
9
8
7
6
5
4
3
2
1
0
-1


CO2Me
N
OBn
2j (dr 93:7)
13C{1H} NMR (125 MHz, CDCl3)
138.266
128.318
128.197
127.555
126.621
125.644
77.257
77.000
76.744
73.246
52.324
ppm
200
180
160
140
120
100
80
60
40
20
0



S20

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

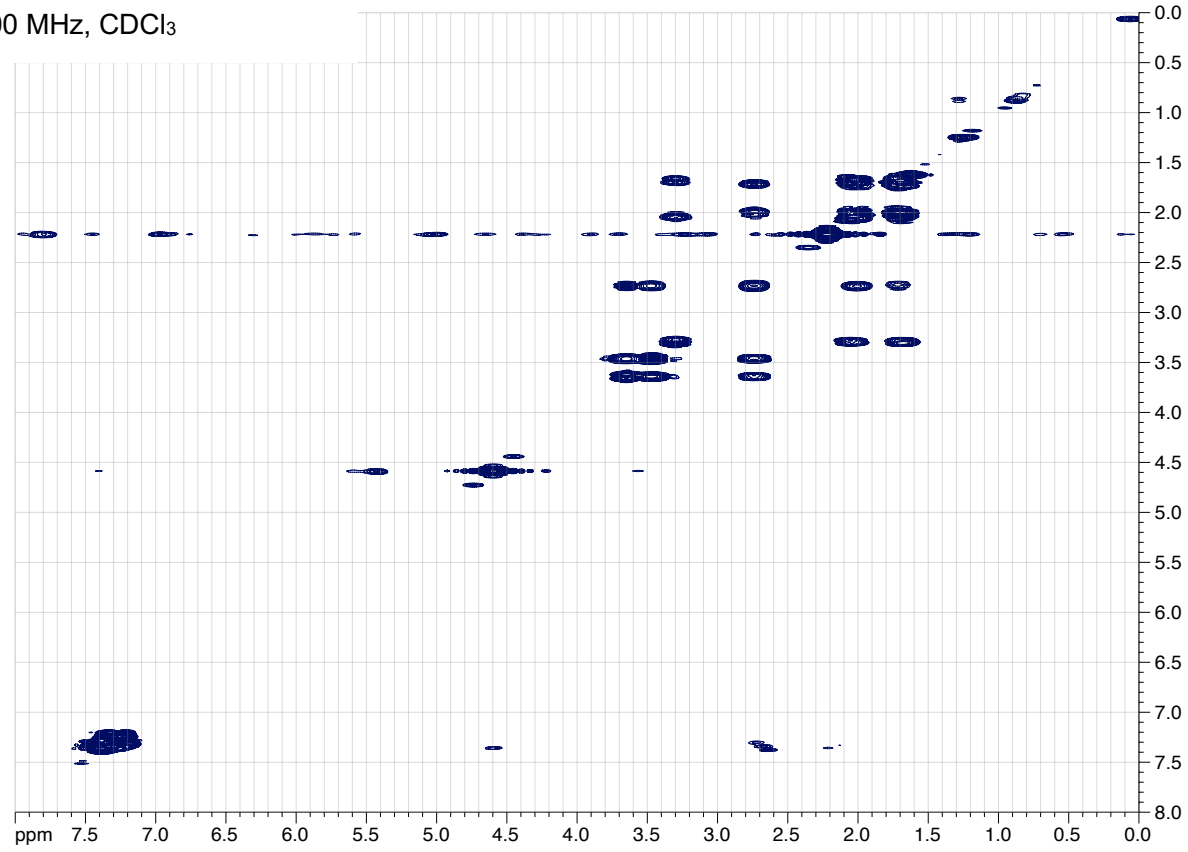


S20

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

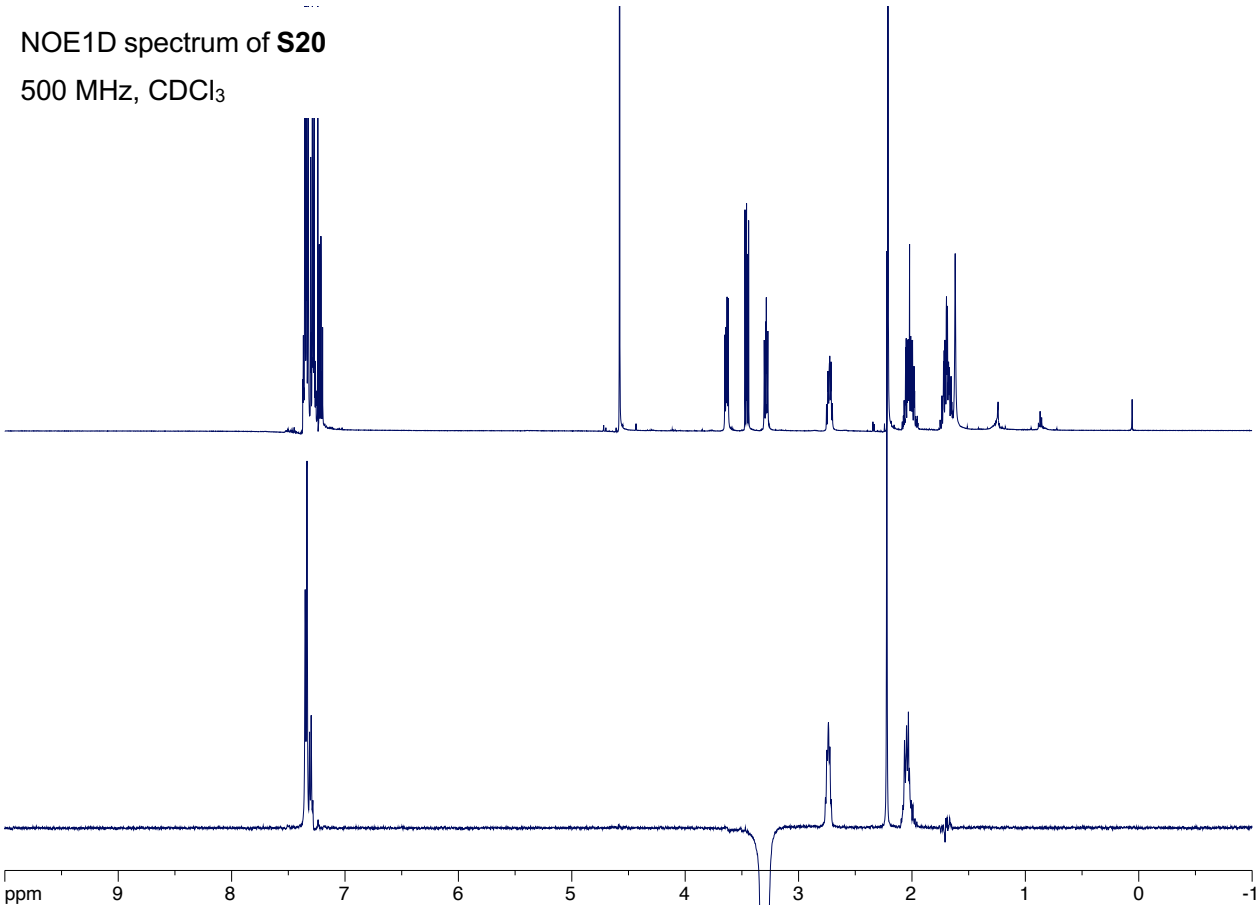
^{1}H-^{1}H COSY spectrum of **S20**

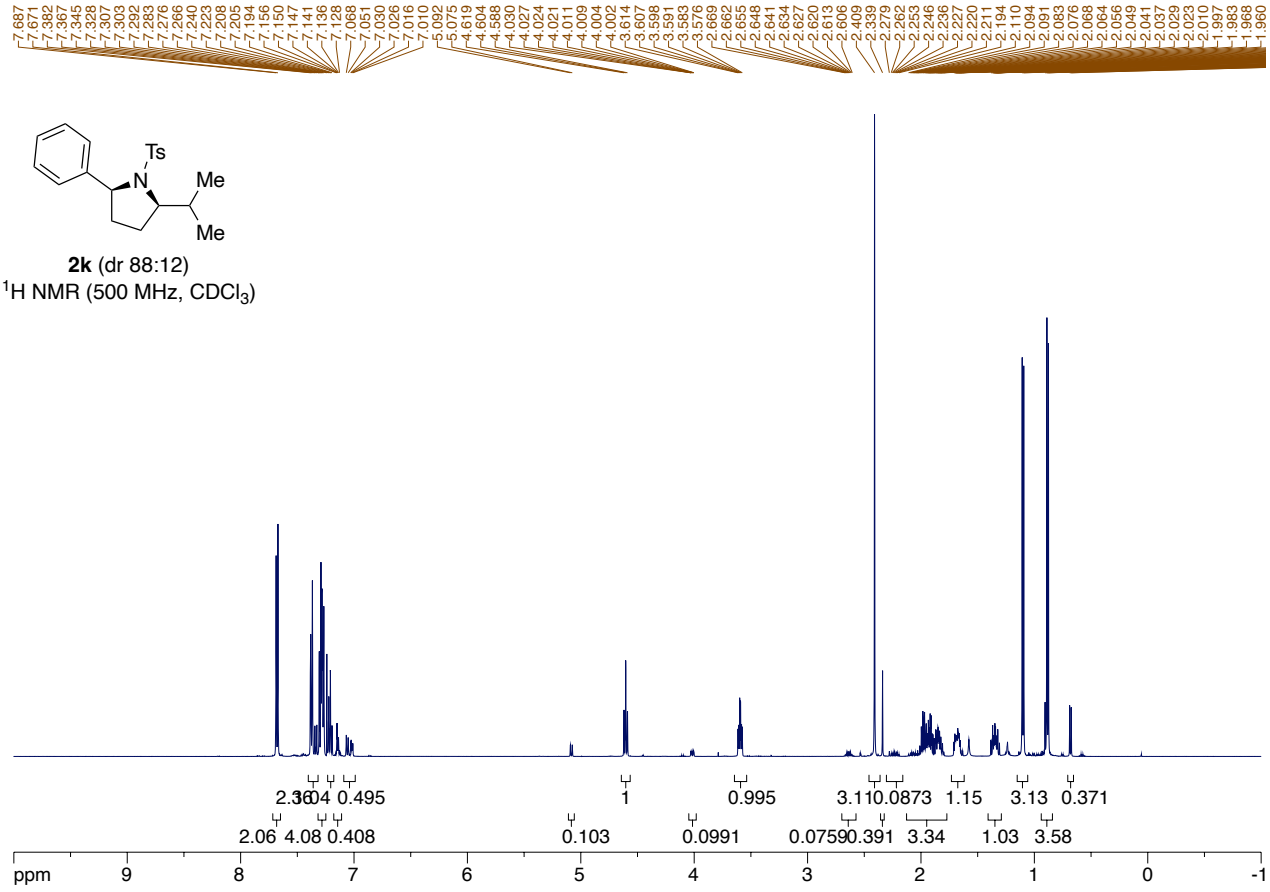
500 MHz, $CDCl_3$

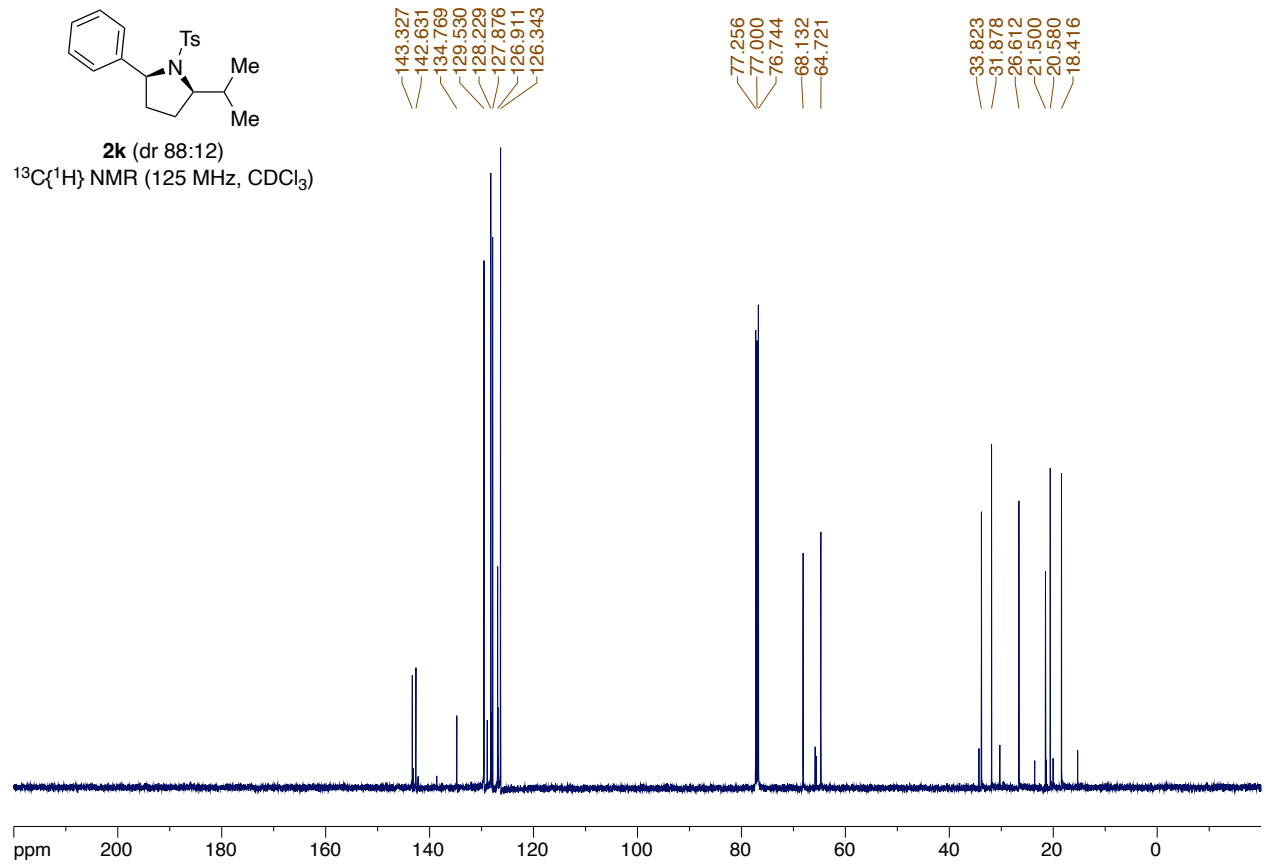


NOE1D spectrum of **S20**

500 MHz, $CDCl_3$

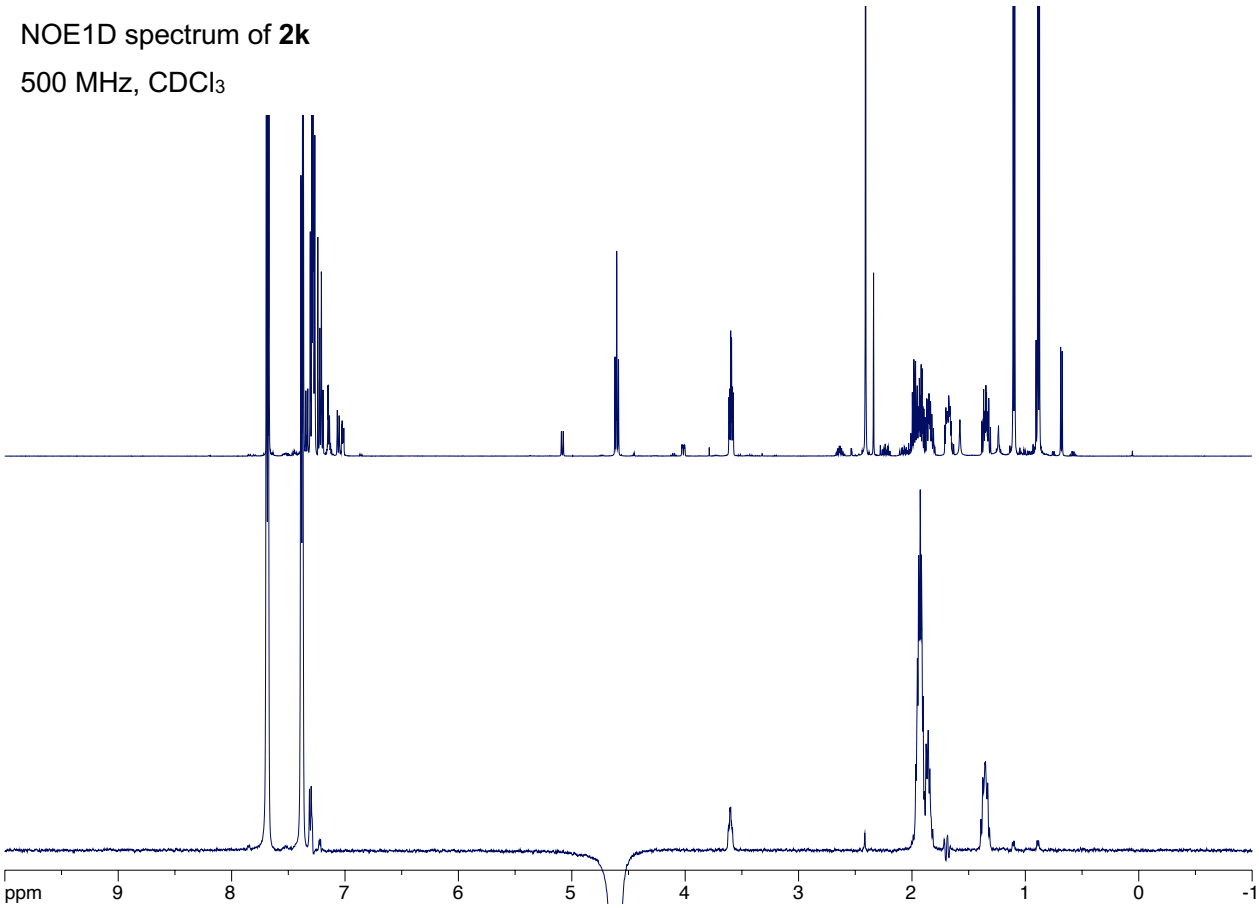


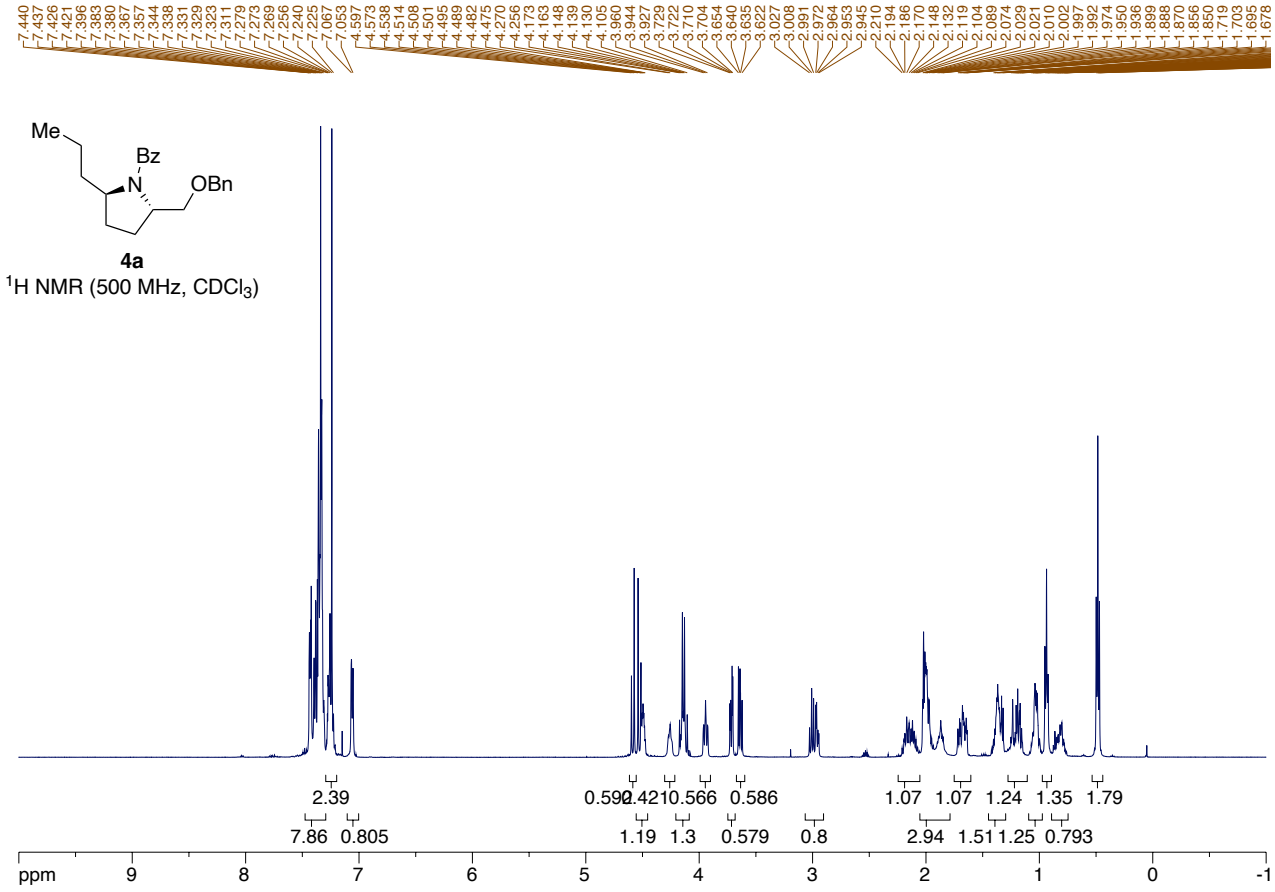

Ts
N
Me
Me
2k (dr 88:12)
1H NMR (500 MHz, CDCl3)
7.687 7.671 7.382 7.367 7.345 7.328 7.307 7.303 7.292 7.283 7.276 7.266 7.240 7.223 7.208 7.205 7.194 7.156 7.150 7.147 7.141 7.136 7.128 7.068 7.051 7.030 7.026 7.016 7.010 5.092 5.075 4.619 4.604 4.588 4.030 4.027 4.024 4.021 4.011 4.009 4.004 4.002 3.614 3.607 3.598 3.591 3.583 3.576 2.669 2.662 2.655 2.648 2.641 2.634 2.627 2.620 2.613 2.606 2.409 2.339 2.279 2.262 2.253 2.246 2.236 2.227 2.220 2.211 2.194 2.110 2.094 2.091 2.083 2.076 2.068 2.064 2.056 2.049 2.041 2.037 2.029 2.023 2.010 1.997 1.983 1.968 1.960
2.36 2.04 0.495
1
0.995
3.11 0.0873 1.15 3.13 0.371
2.06 4.08 0.408
0.103
0.0991
0.0759 0.391 3.34 1.03 3.58
ppm 9 8 7 6 5 4 3 2 1 0 -1

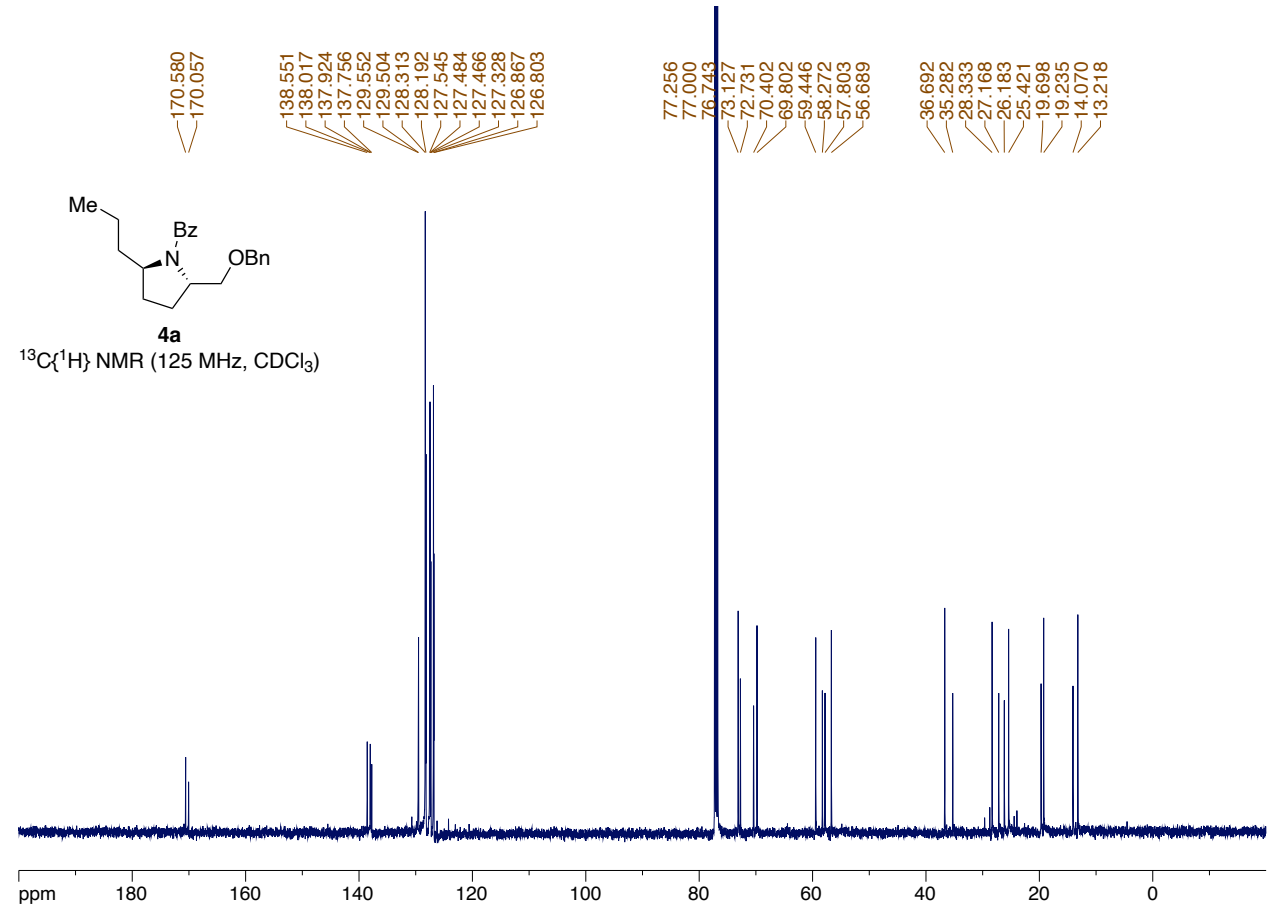

Ts
N
Me
Me
2k (dr 88:12)
13C{1H} NMR (125 MHz, CDCl3)
143.327 142.631 134.769 129.530 128.229 127.876 126.911 126.343
77.256 77.000 76.744 68.132 64.721
33.823 31.878 26.612 21.500 20.580 18.416
ppm 200 180 160 140 120 100 80 60 40 20 0

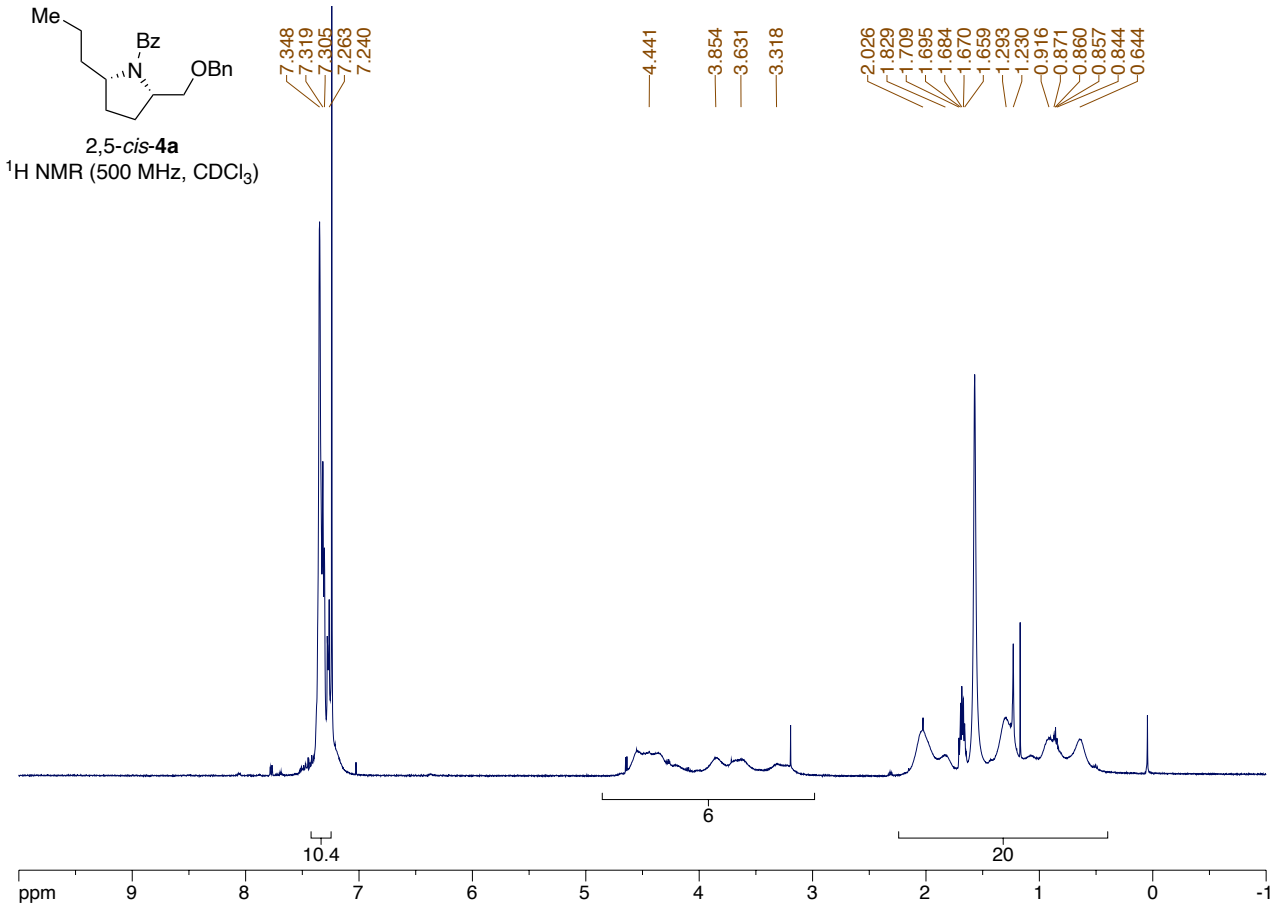
NOE1D spectrum of **2k**

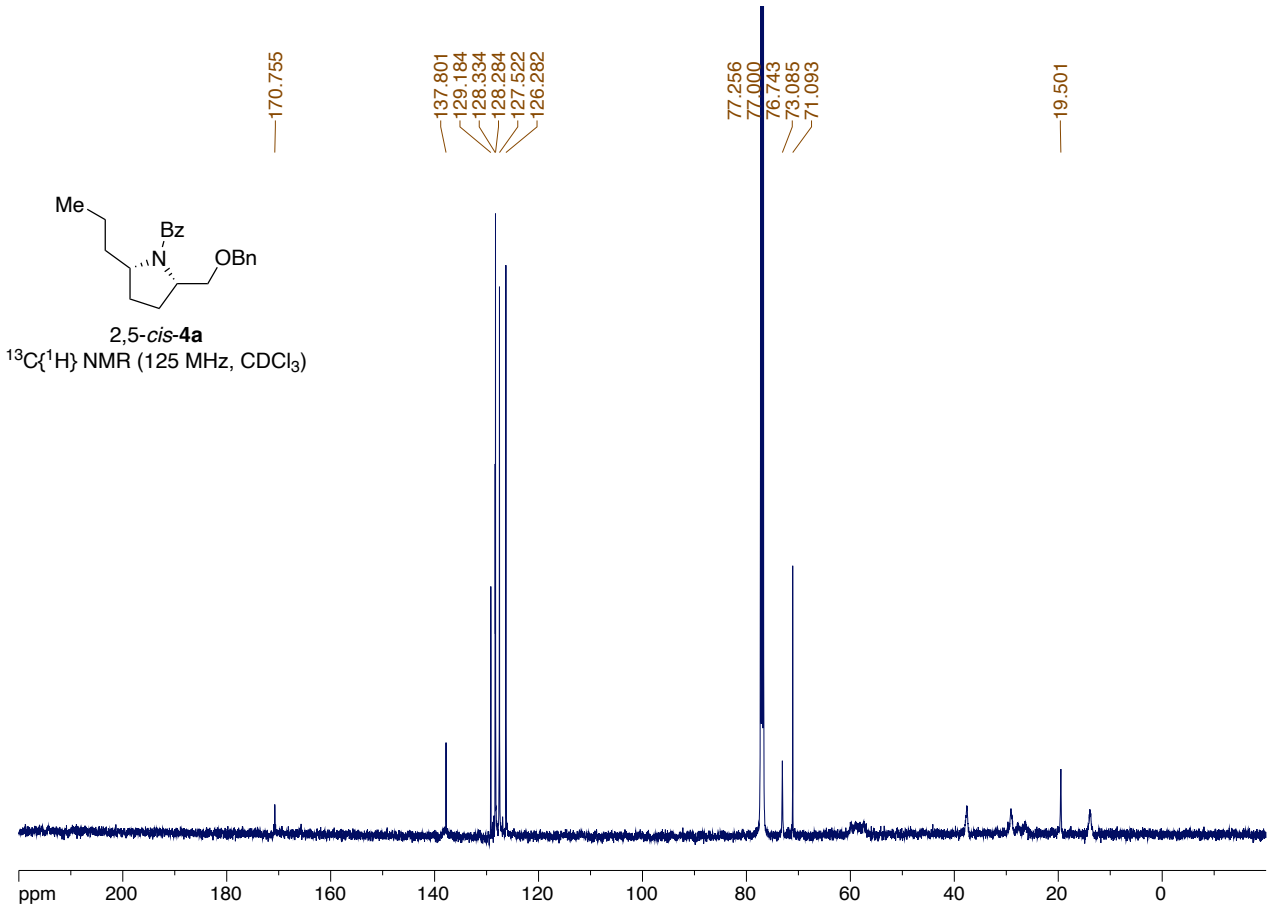
500 MHz, $CDCl_3$

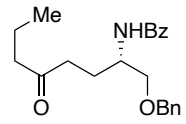



Me
Bz
N
OBn
4a
1H NMR (500 MHz, CDCl3)
2.39
7.86
0.805
0.590
2.42
1.19
10.566
1.3
0.586
0.579
0.8
1.07
2.94
1.07
1.51
1.24
1.25
1.35
0.793
1.79
ppm


Me
Bz
N
OBn
4a
13C{1H} NMR (125 MHz, CDCl3)
ppm

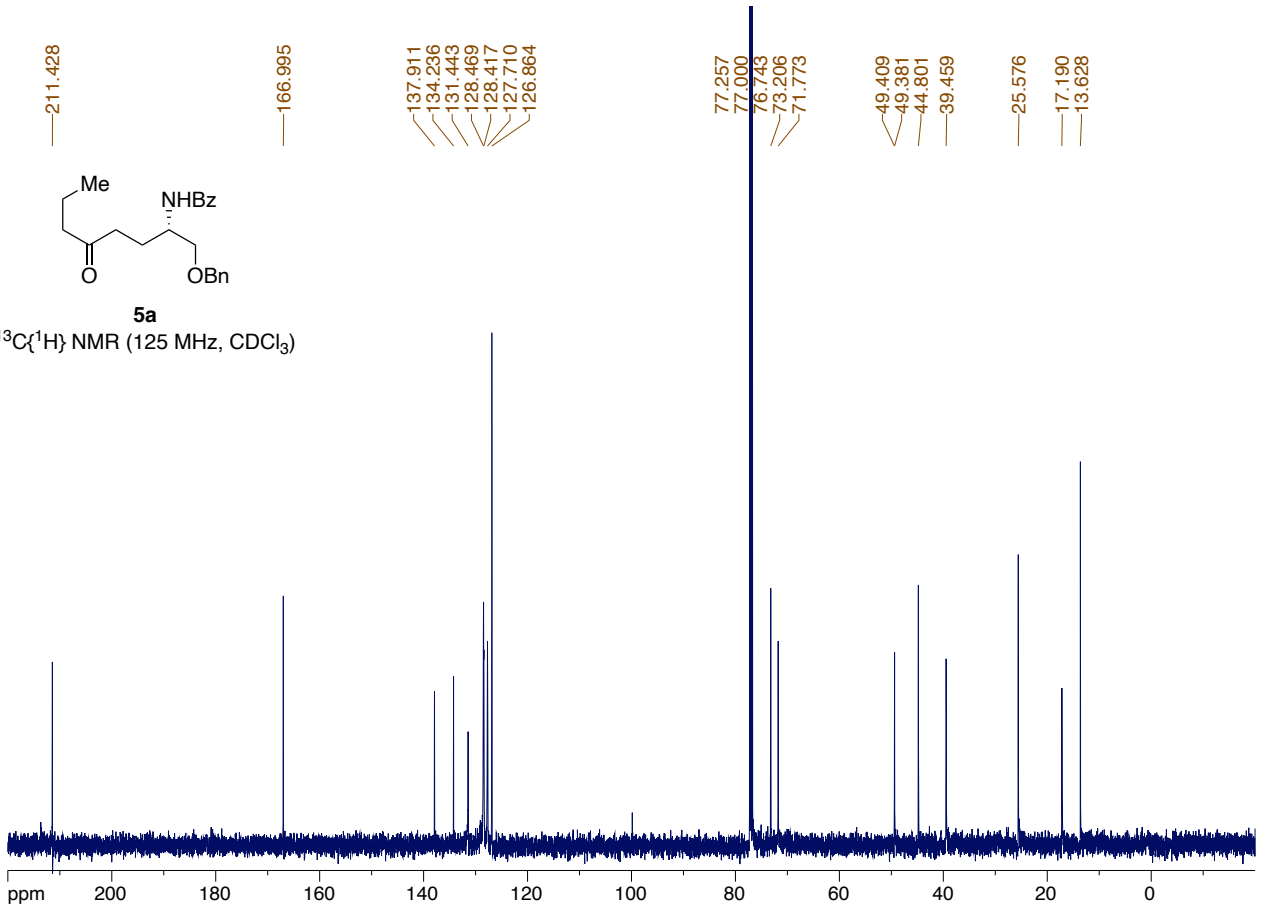

Me
Bz
N
OBn
2,5-*cis*-**4a**
^{1}H NMR (500 MHz, $CDCl_3$)
7.348
7.319
7.305
7.263
7.240
4.441
3.854
3.631
3.318
2.026
1.829
1.709
1.695
1.684
1.670
1.659
1.293
1.230
0.916
0.871
0.860
0.857
0.844
0.644
6
10.4
20
ppm


170.755
137.801
129.184
128.334
128.284
127.522
126.282
77.256
77.000
76.743
73.085
71.093
19.501
Me
Bz
N
OBn
2,5-*cis*-**4a**
$^{13}C\{^1H\}$ NMR (125 MHz, $CDCl_3$)
ppm



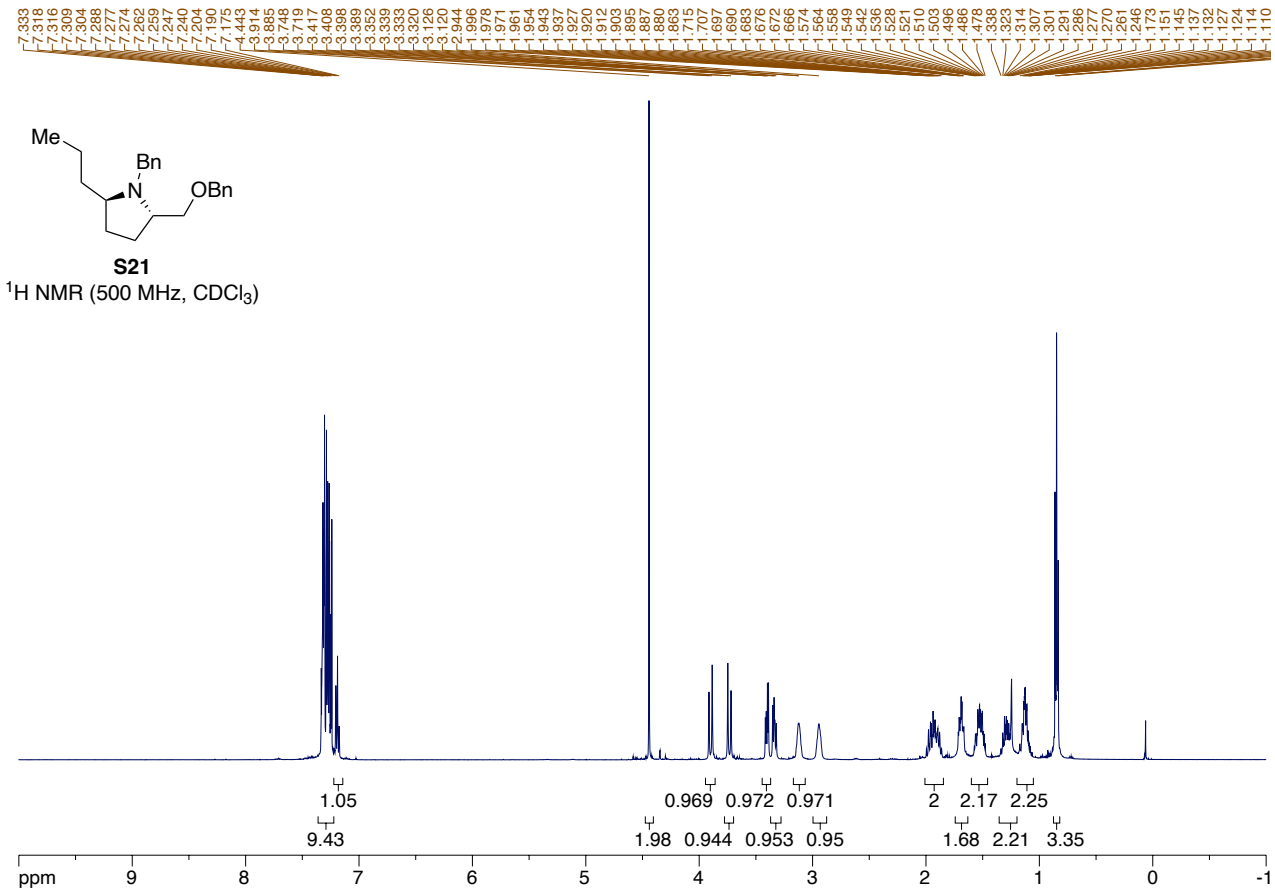
5a

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



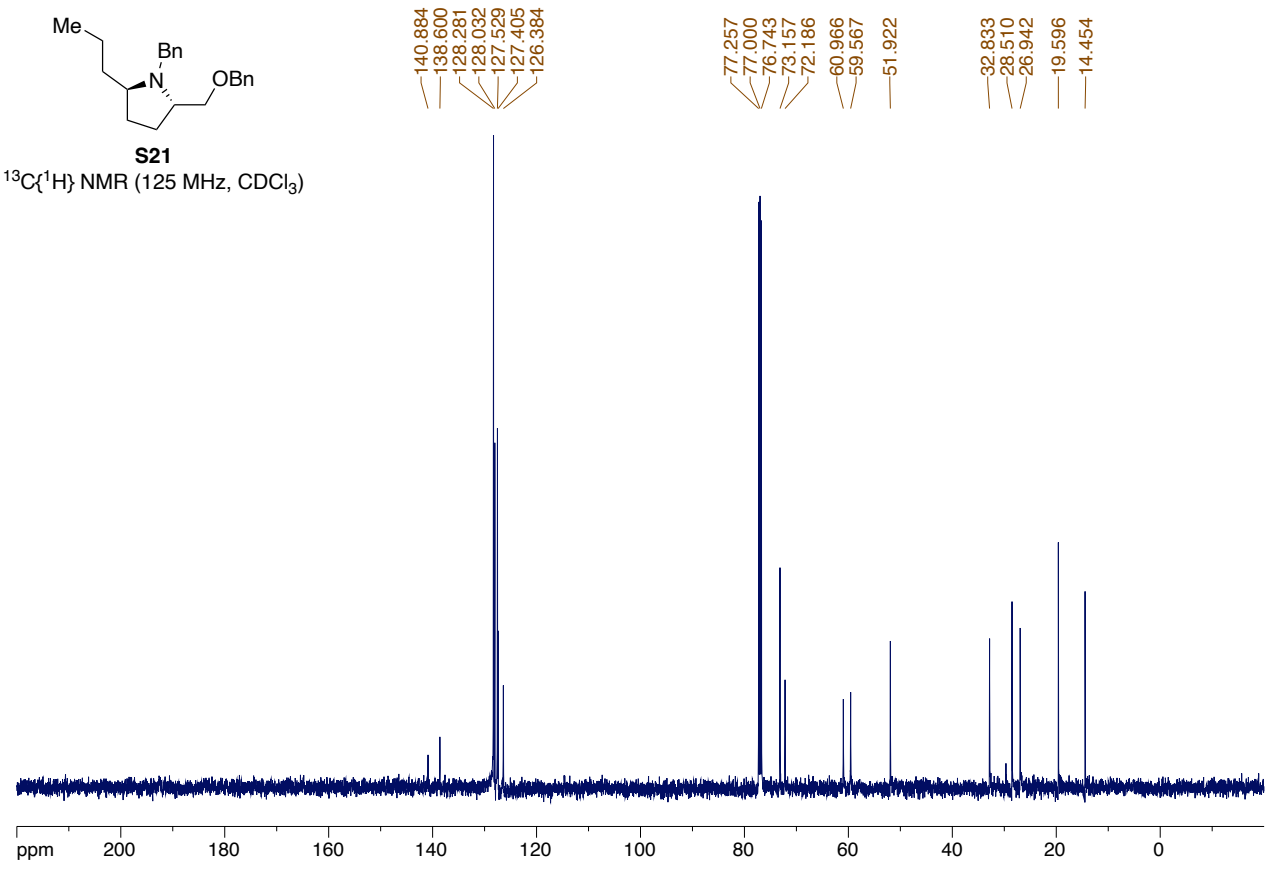
5a

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)



S21

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

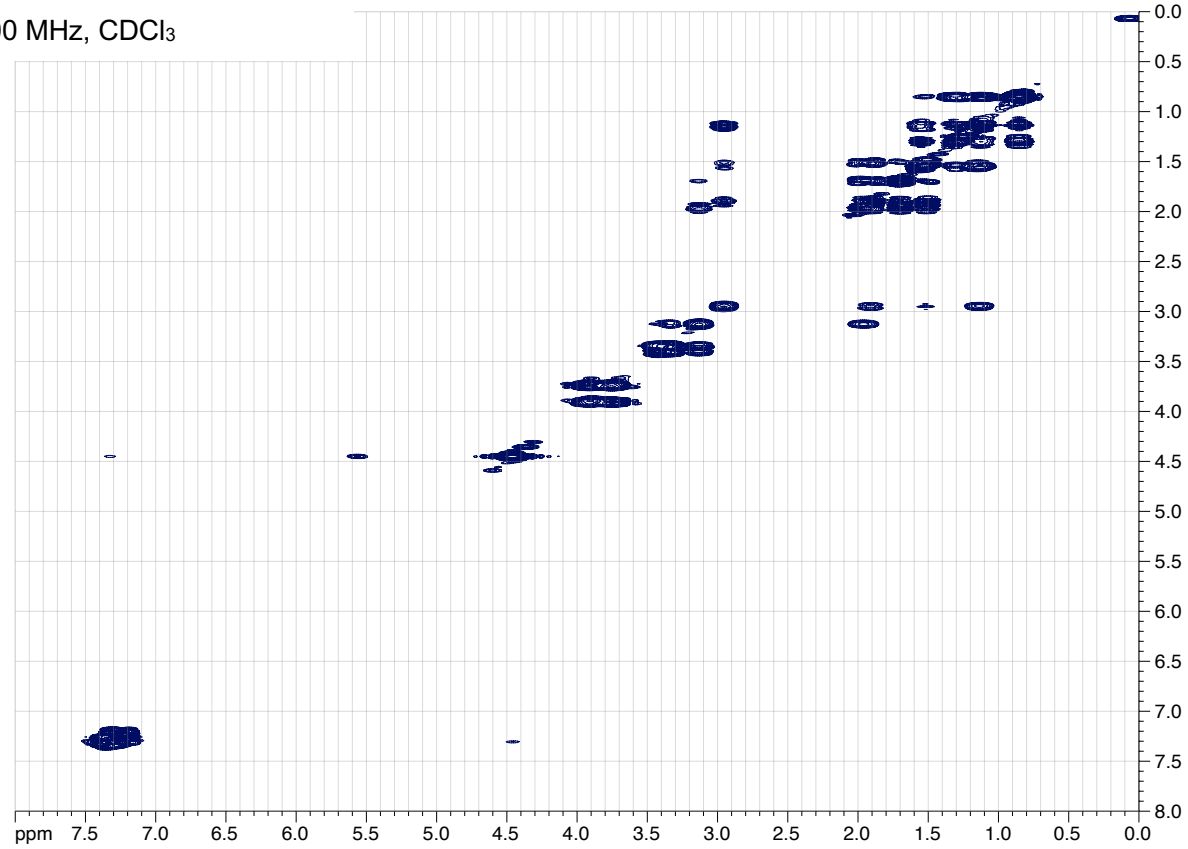


S21

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

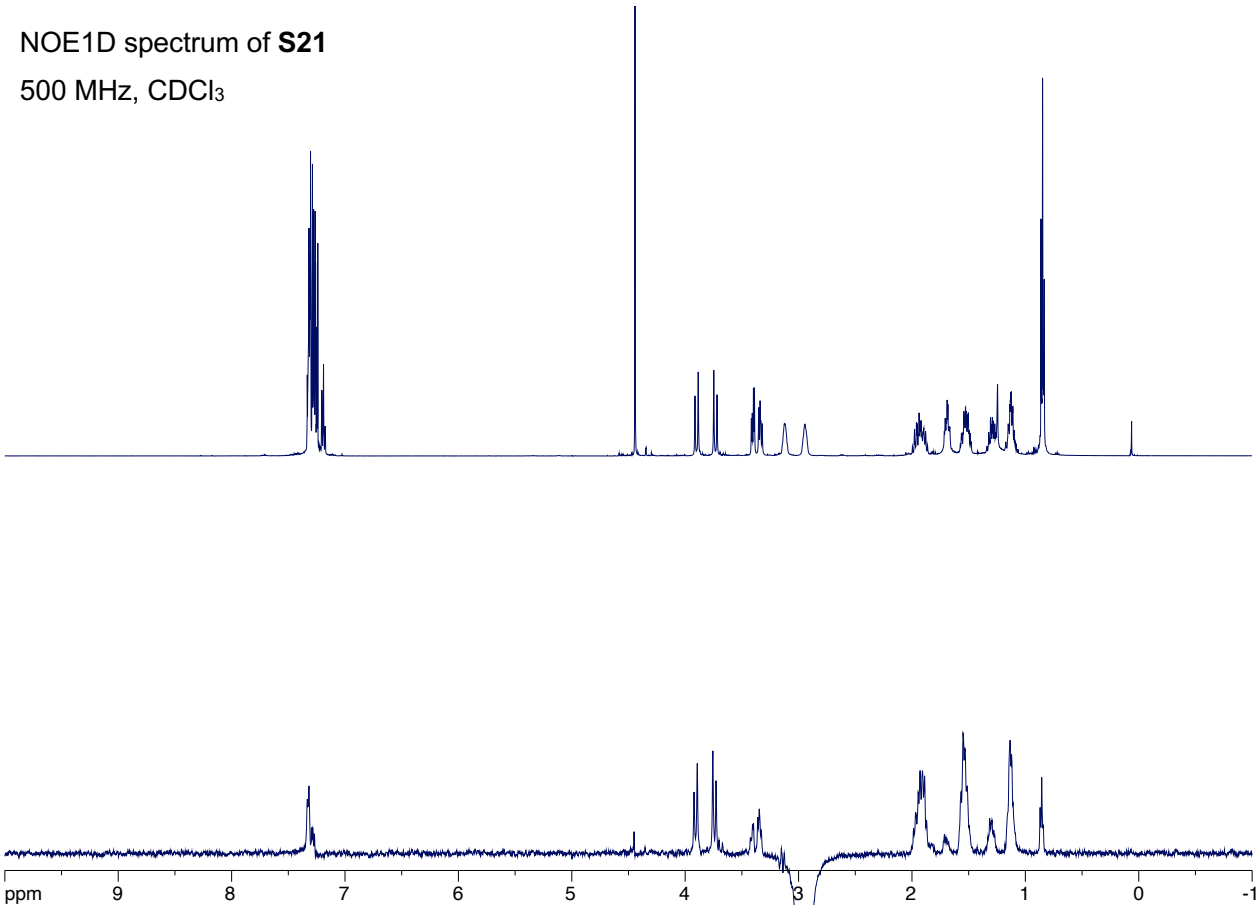
^{1}H-^{1}H COSY spectrum of **S21**

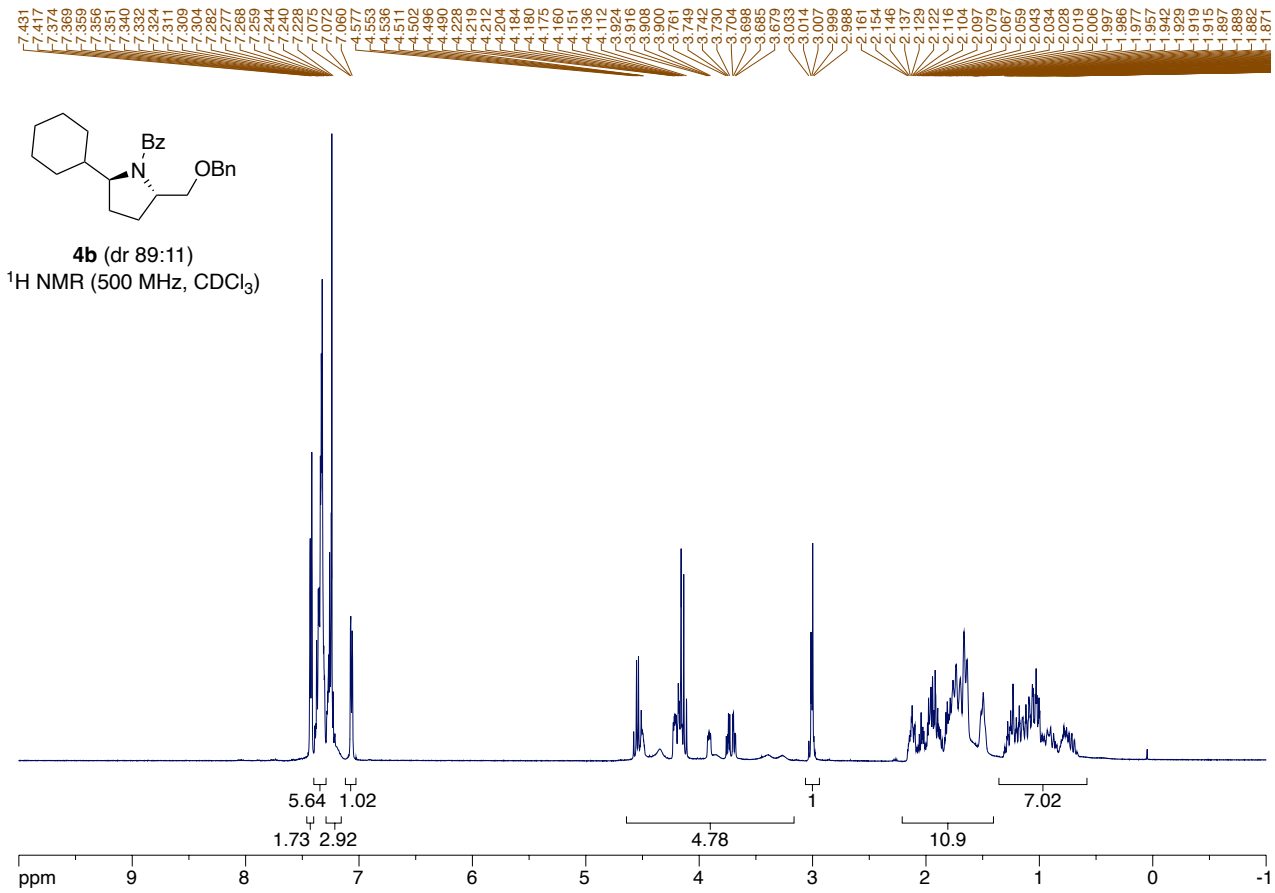
500 MHz, $CDCl_3$



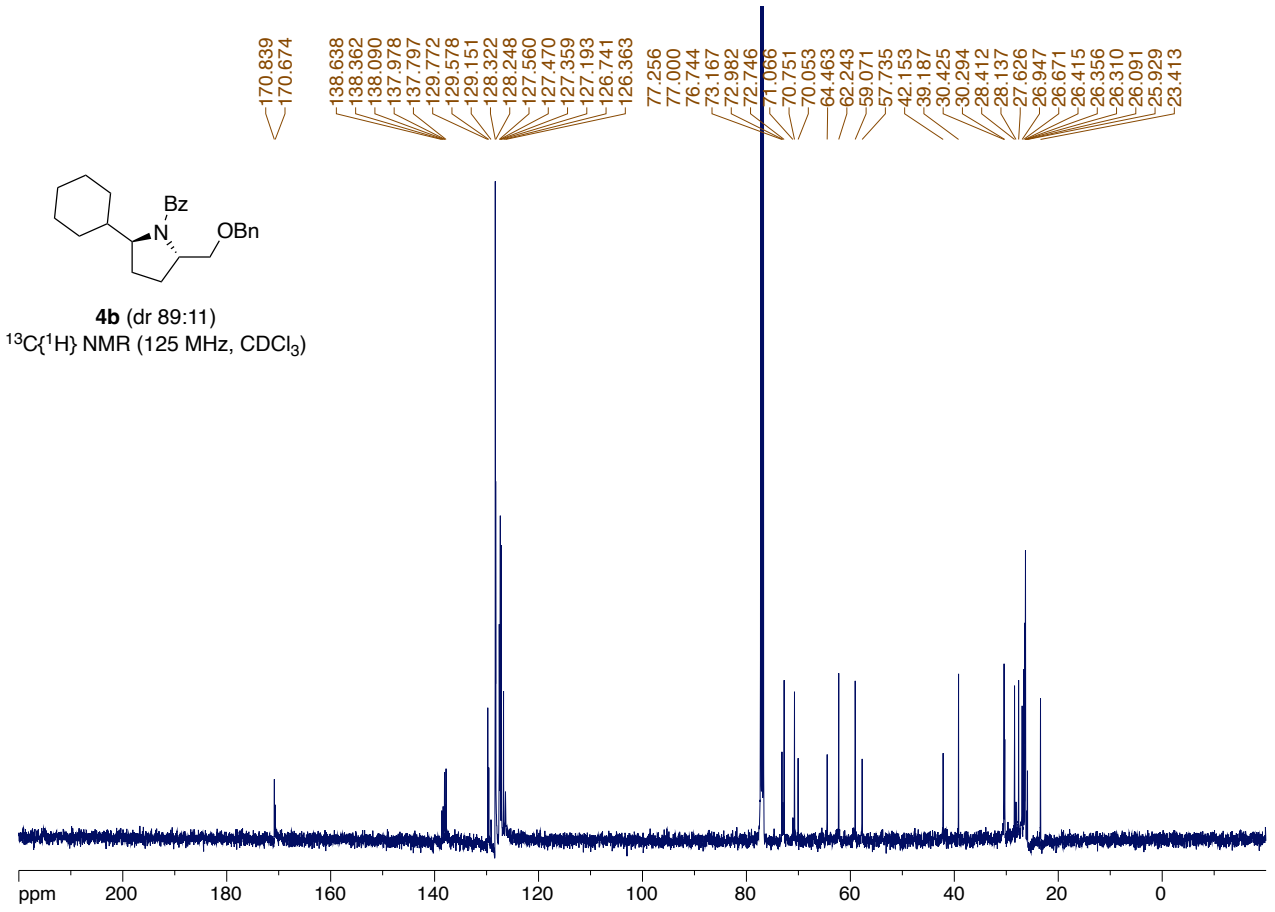
NOE1D spectrum of **S21**

500 MHz, $CDCl_3$

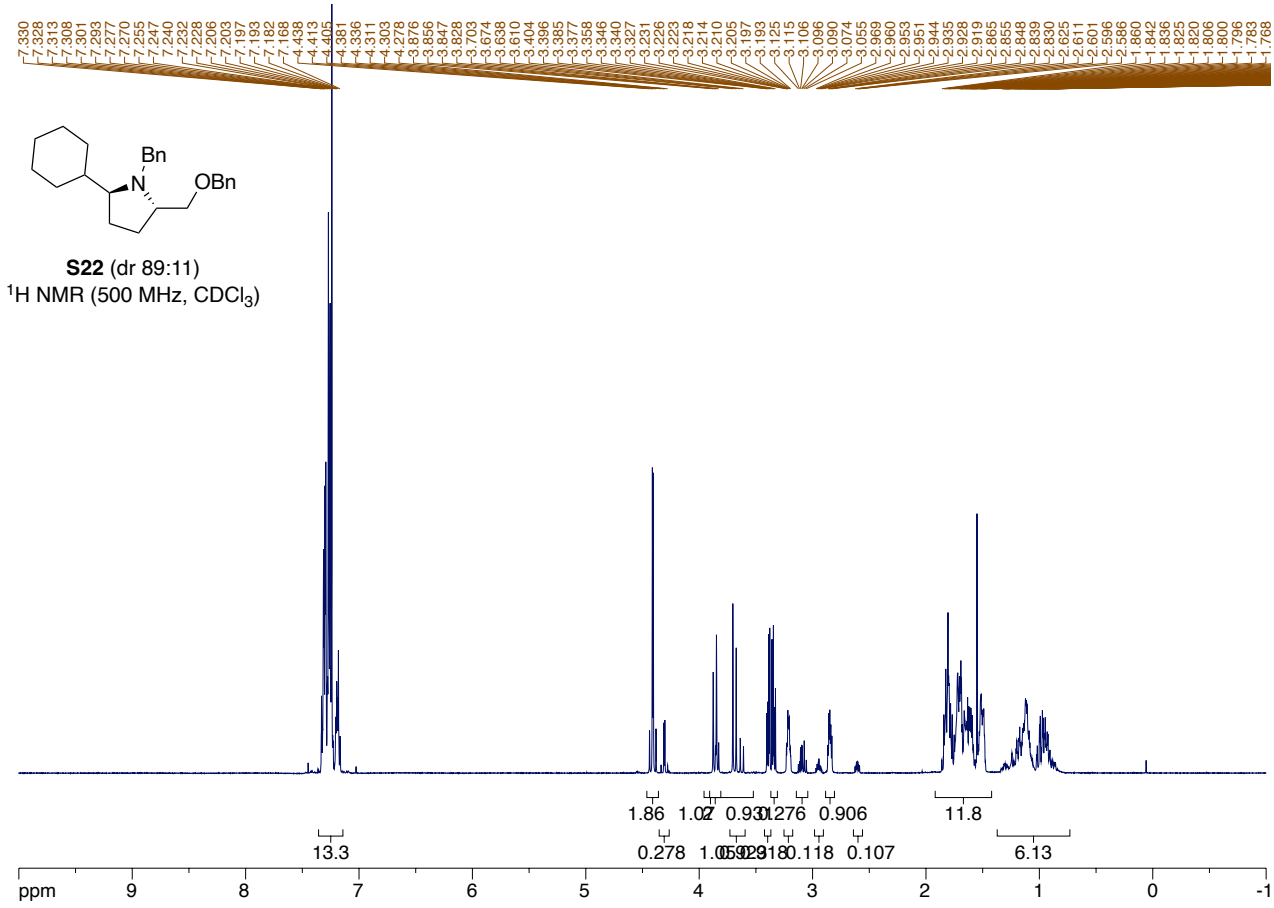




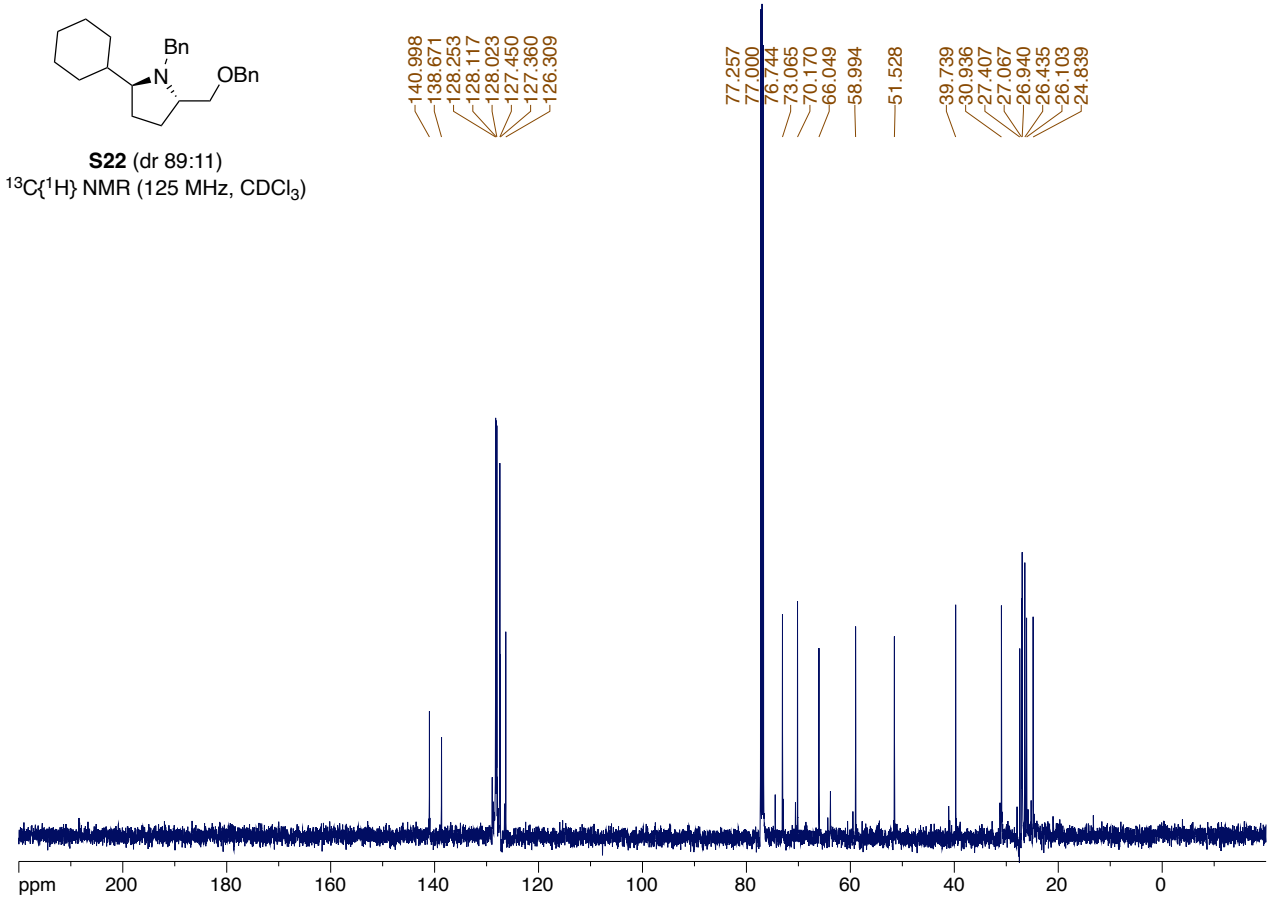
4b (dr 89:11)
^{1}H NMR (500 MHz, $CDCl_3$)



4b (dr 89:11)
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



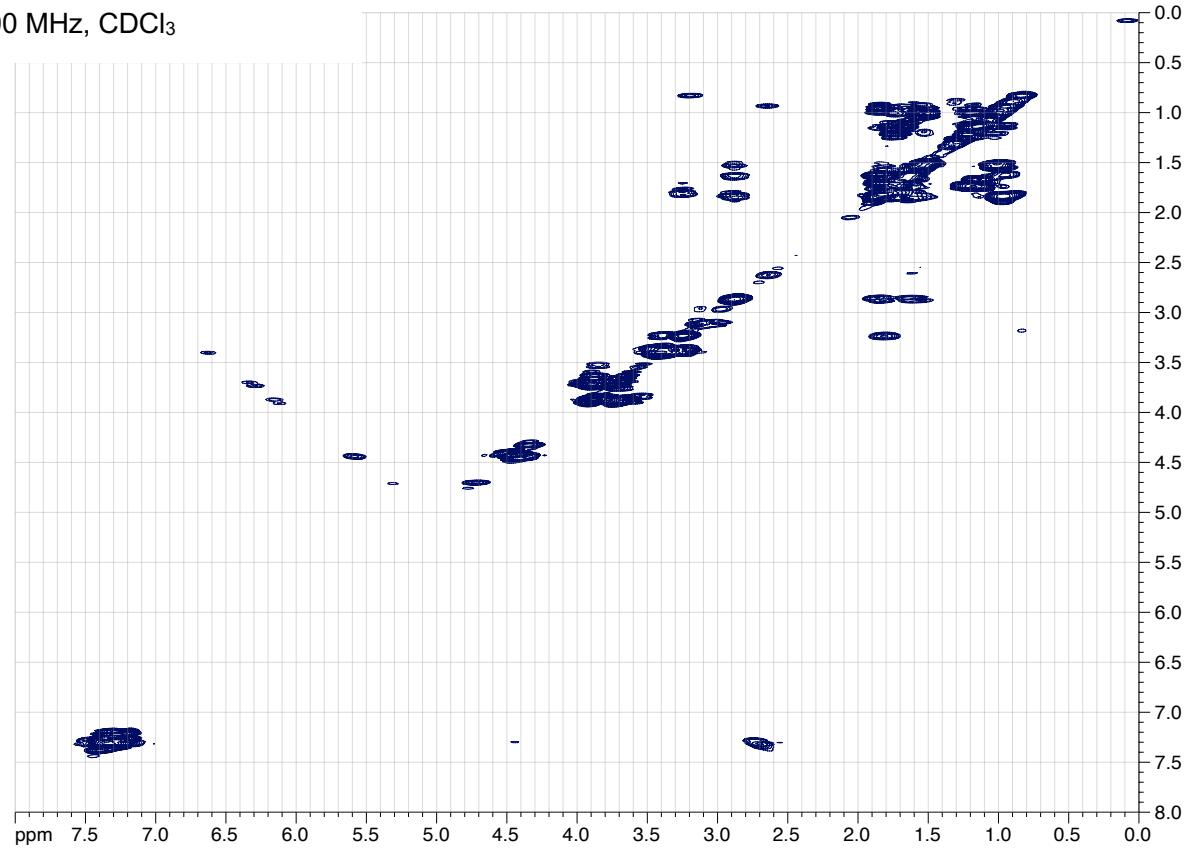
S22 (dr 89:11)
^{1}H NMR (500 MHz, $CDCl_3$)



S22 (dr 89:11)
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

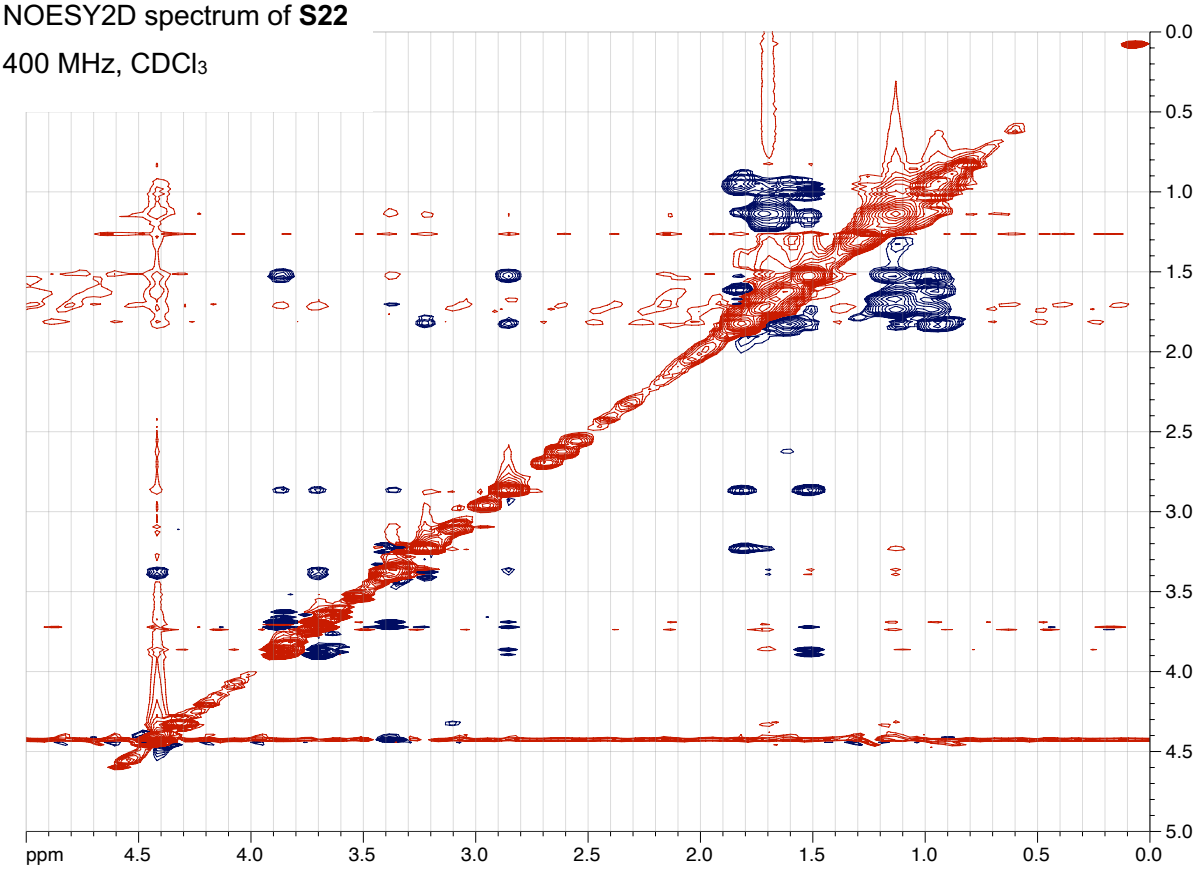
^{1}H-^{1}H COSY spectrum of **S22**

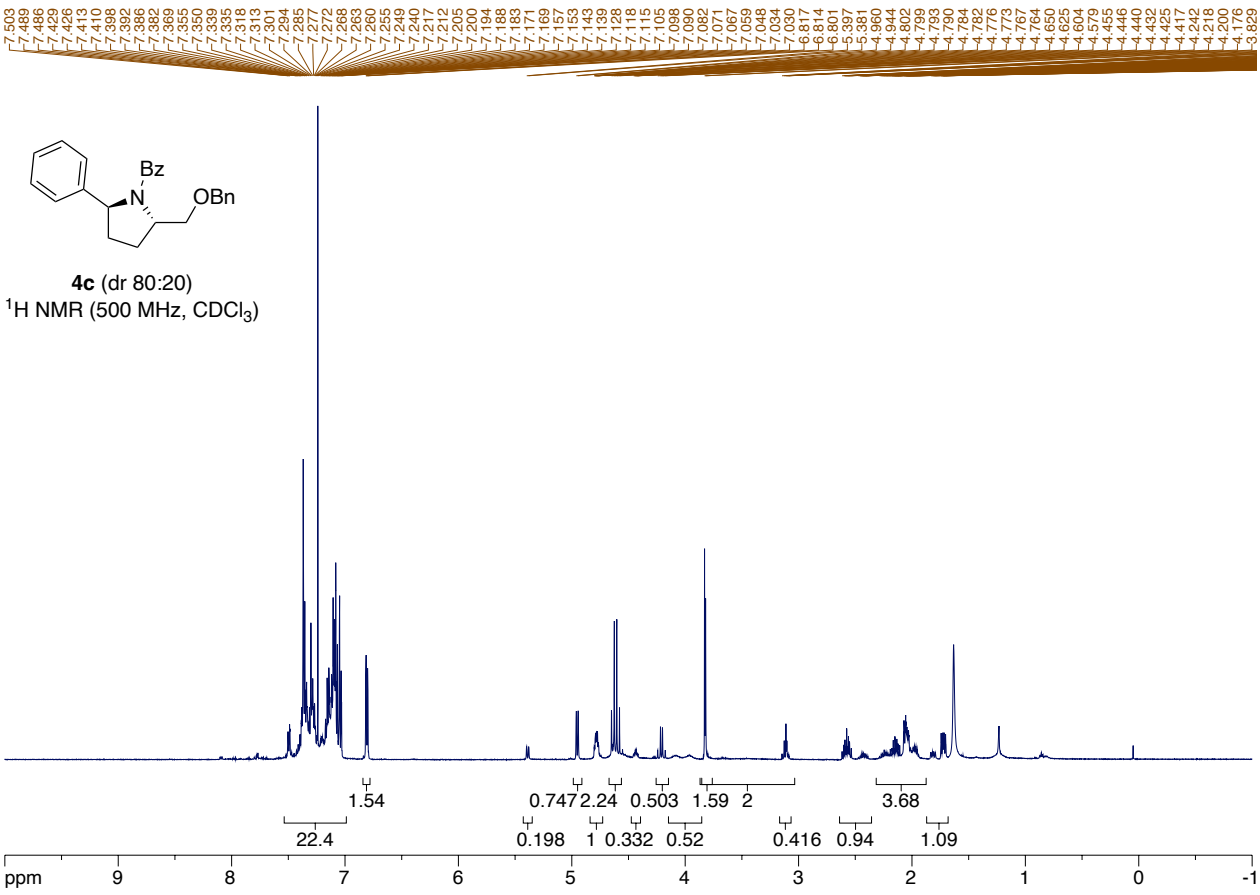
500 MHz, $CDCl_3$

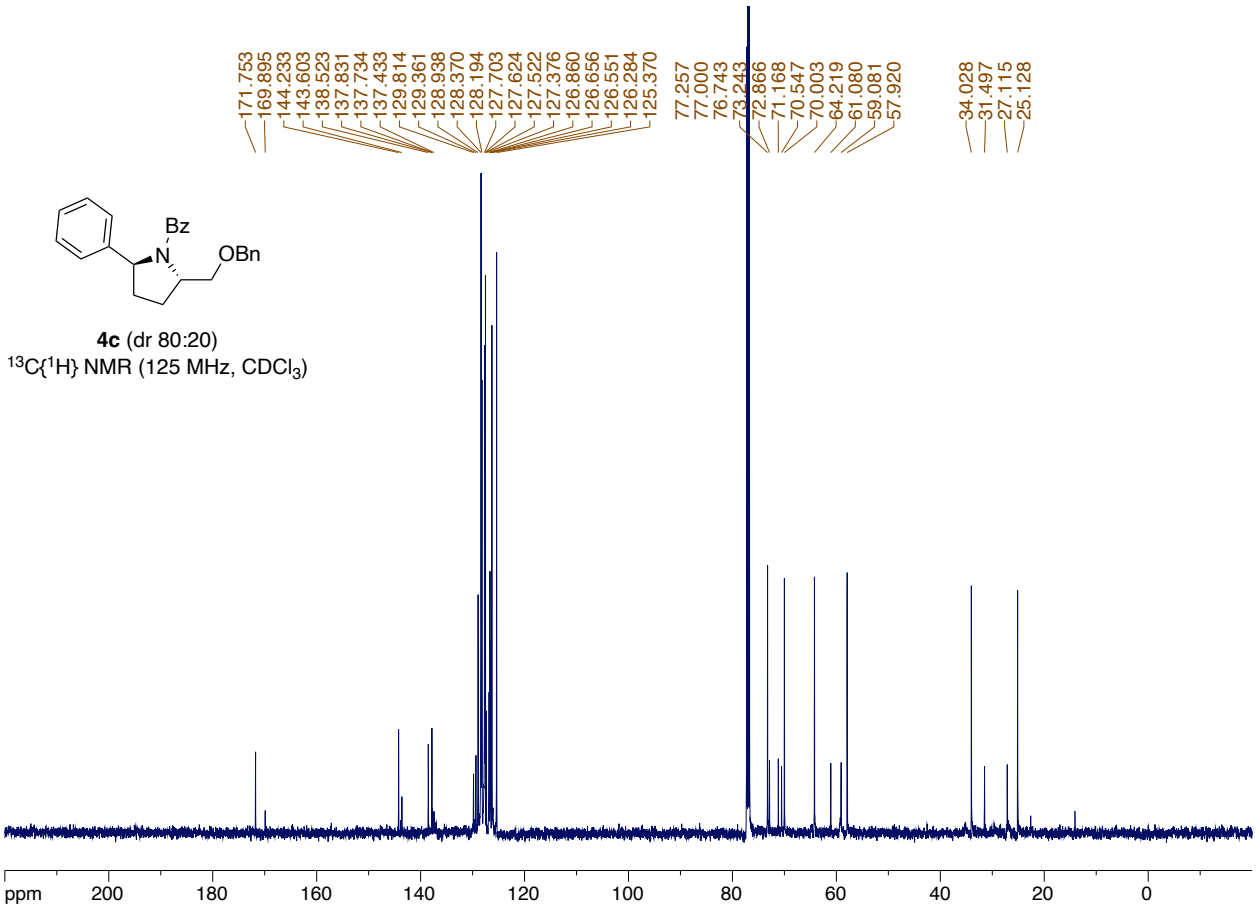


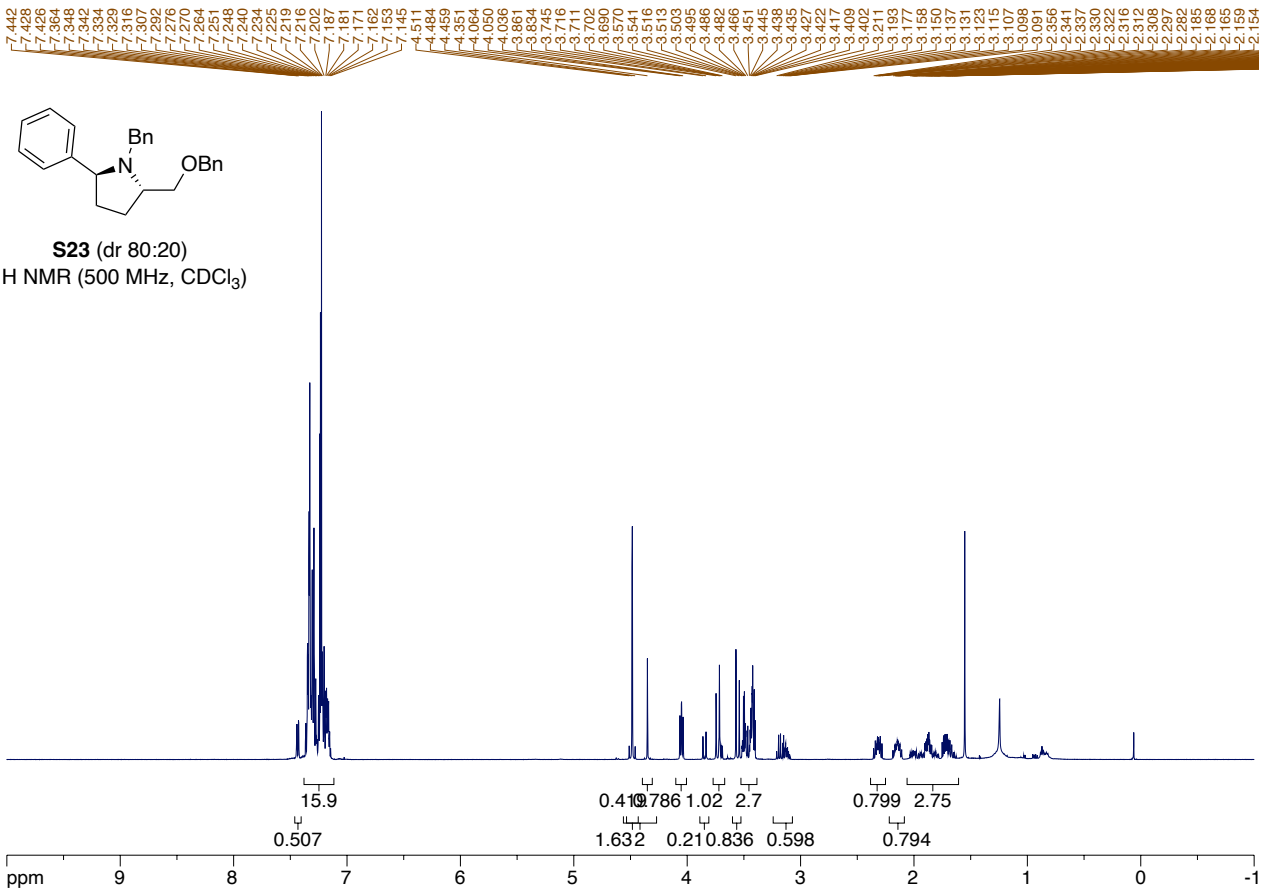
NOESY2D spectrum of **S22**

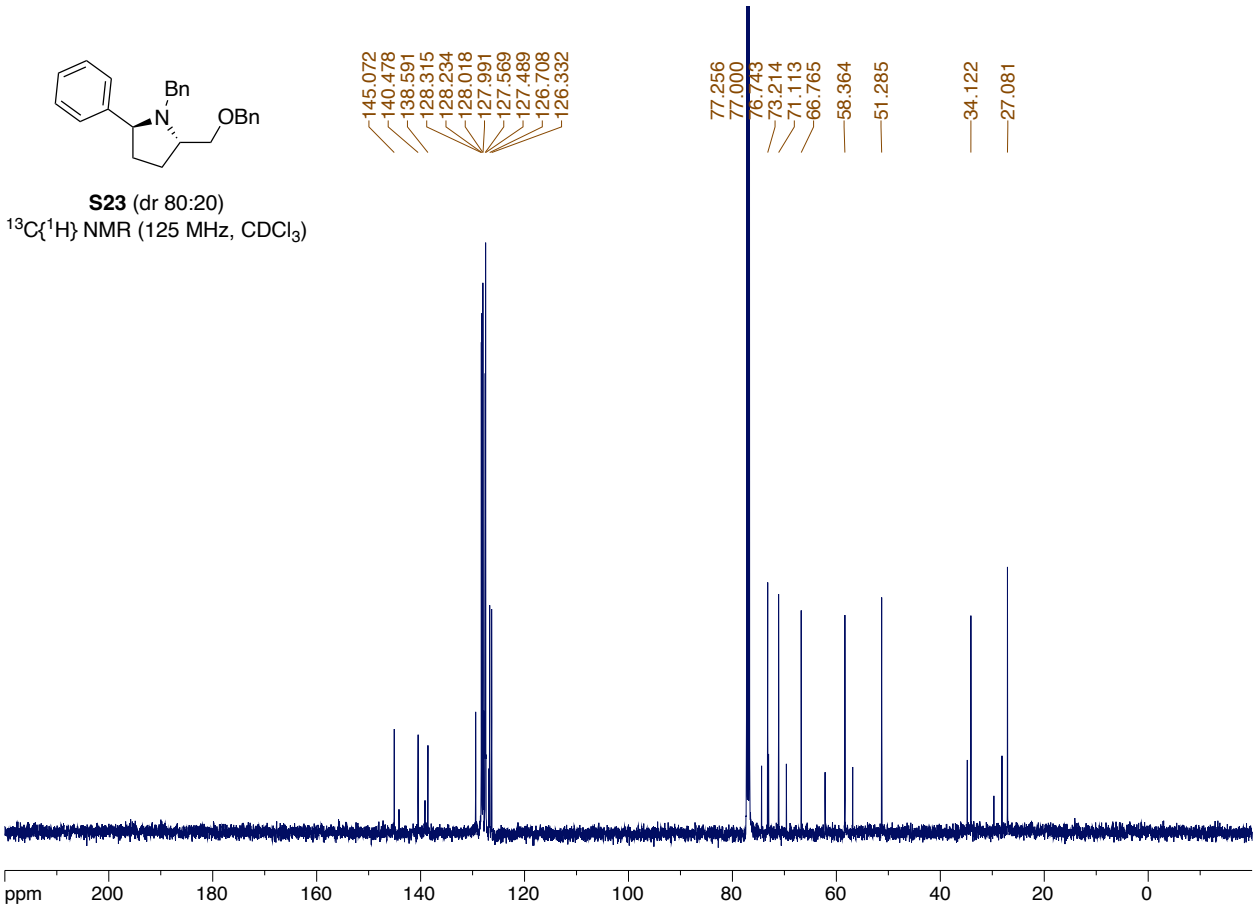
400 MHz, $CDCl_3$




Bz
N
OBn
4c (dr 80:20)
1H NMR (500 MHz, CDCl3)
1.54
0.747
2.24
0.503
1.59
2
3.68
22.4
0.198
1
0.332
0.52
0.416
0.94
1.09
ppm

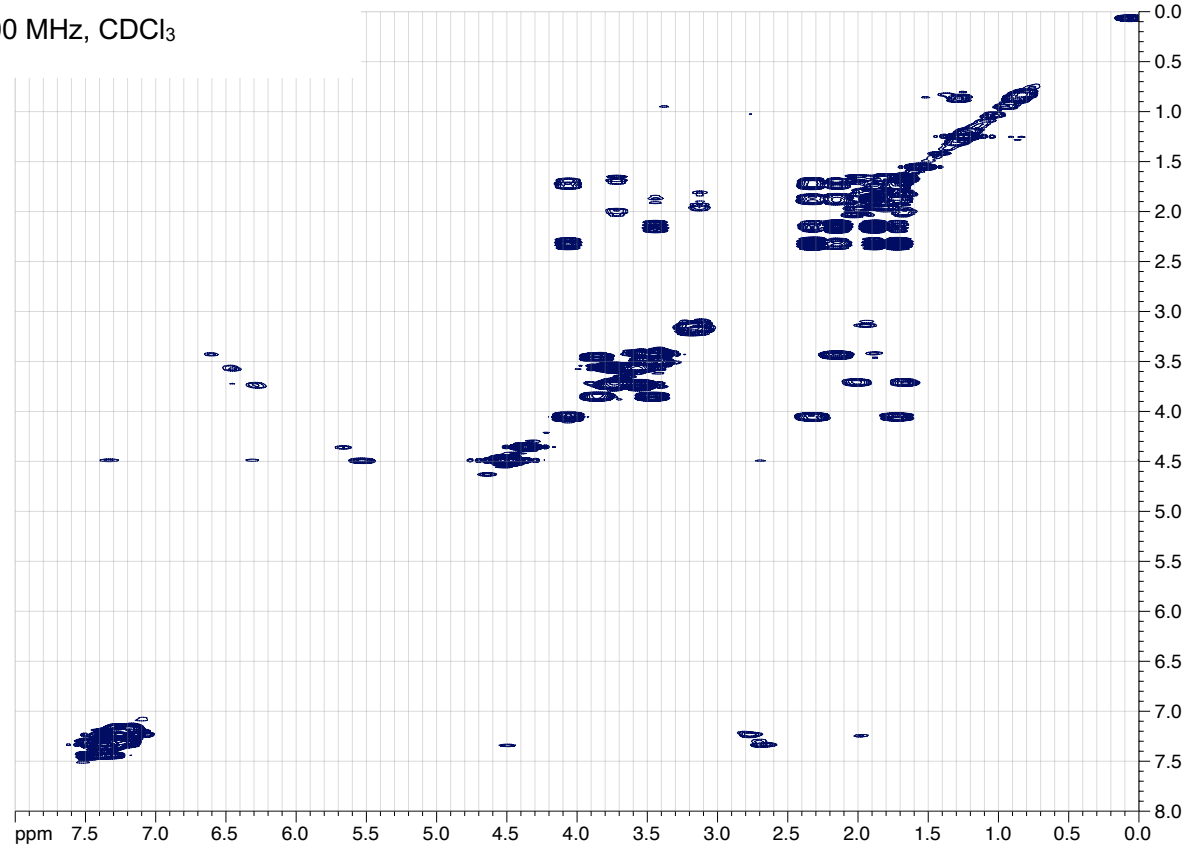

Bz
N
OBn
4c (dr 80:20)
13C{1H} NMR (125 MHz, CDCl3)
ppm


Bn
N
OBn
S23 (dr 80:20)
1H NMR (500 MHz, CDCl3)
15.9
0.507
1.632
0.210.836
0.598
0.799
2.75
0.794
ppm


Bn
N
OBn
S23 (dr 80:20)
13C{1H} NMR (125 MHz, CDCl3)
145.072
140.478
138.591
128.315
128.234
128.018
127.991
127.569
127.489
126.708
126.332
77.256
77.000
76.743
73.214
71.113
66.765
58.364
51.285
34.122
27.081
ppm

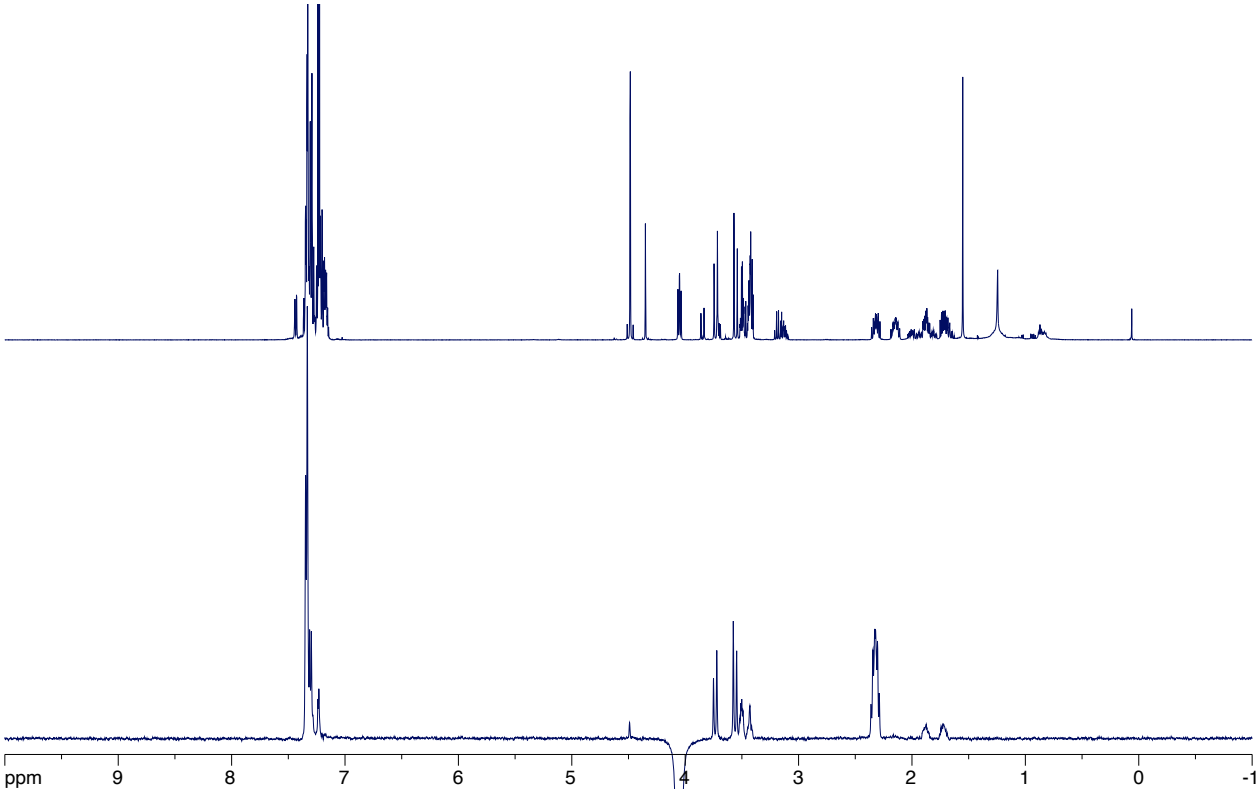
^{1}H-^{1}H COSY spectrum of **S23**

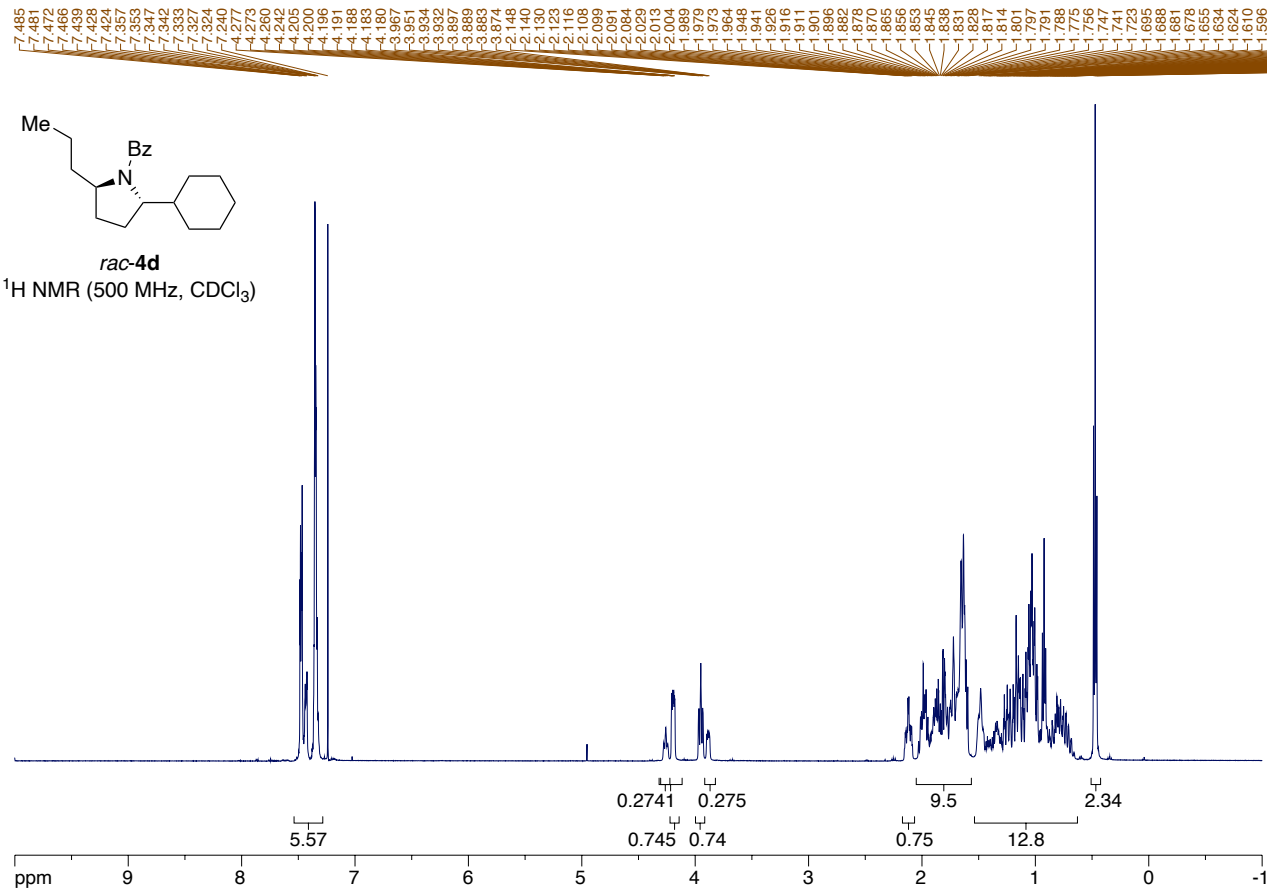
500 MHz, $CDCl_3$

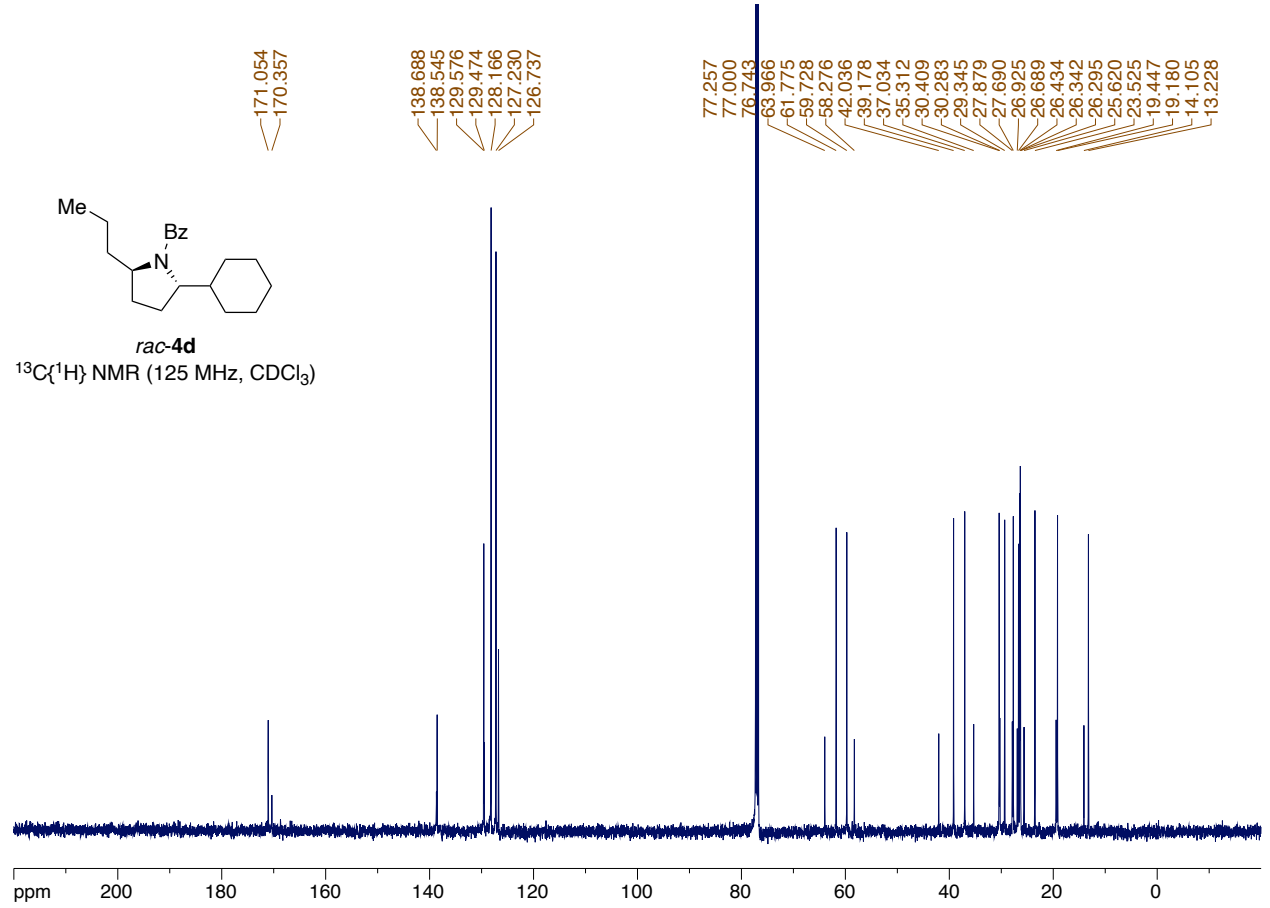


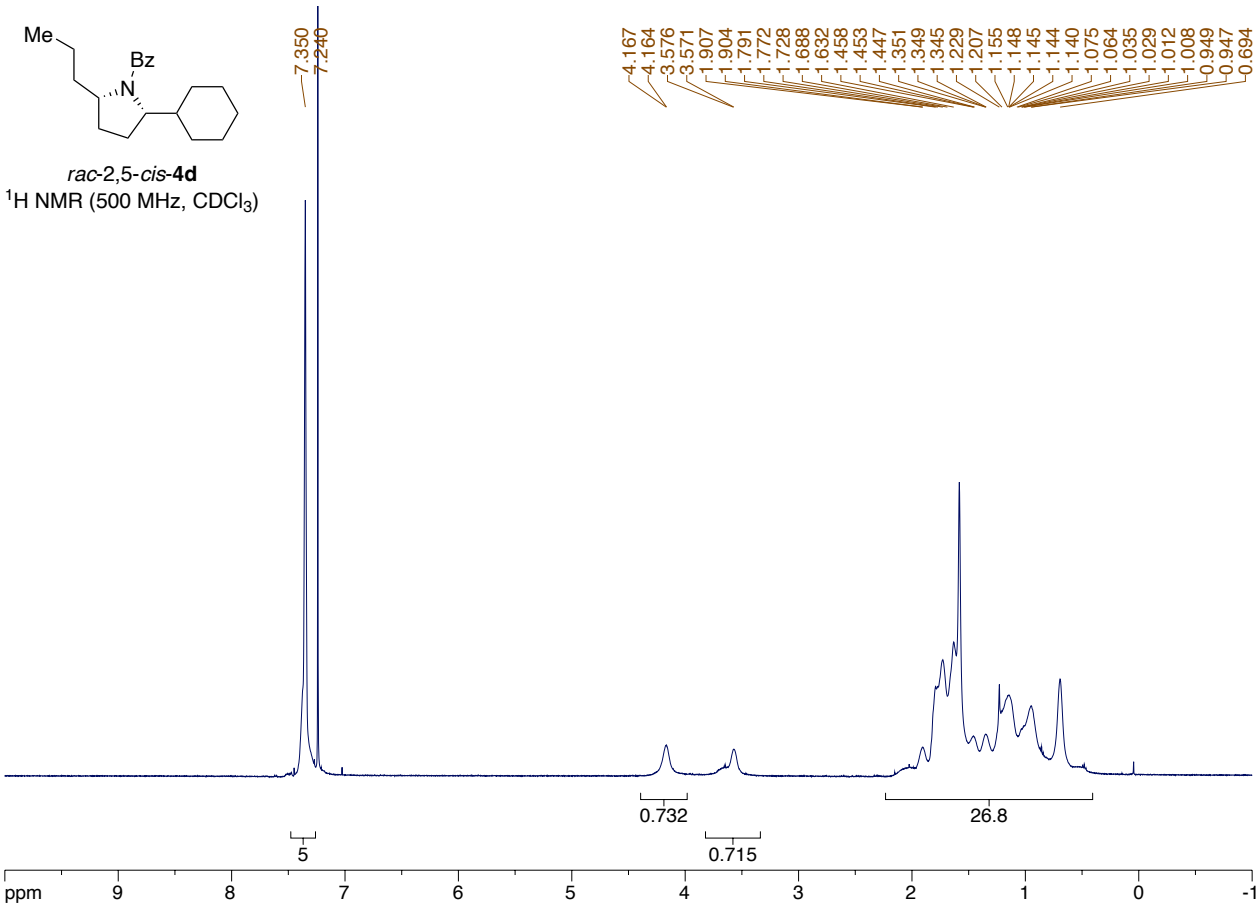
NOE1D spectrum of **S23**

500 MHz, $CDCl_3$

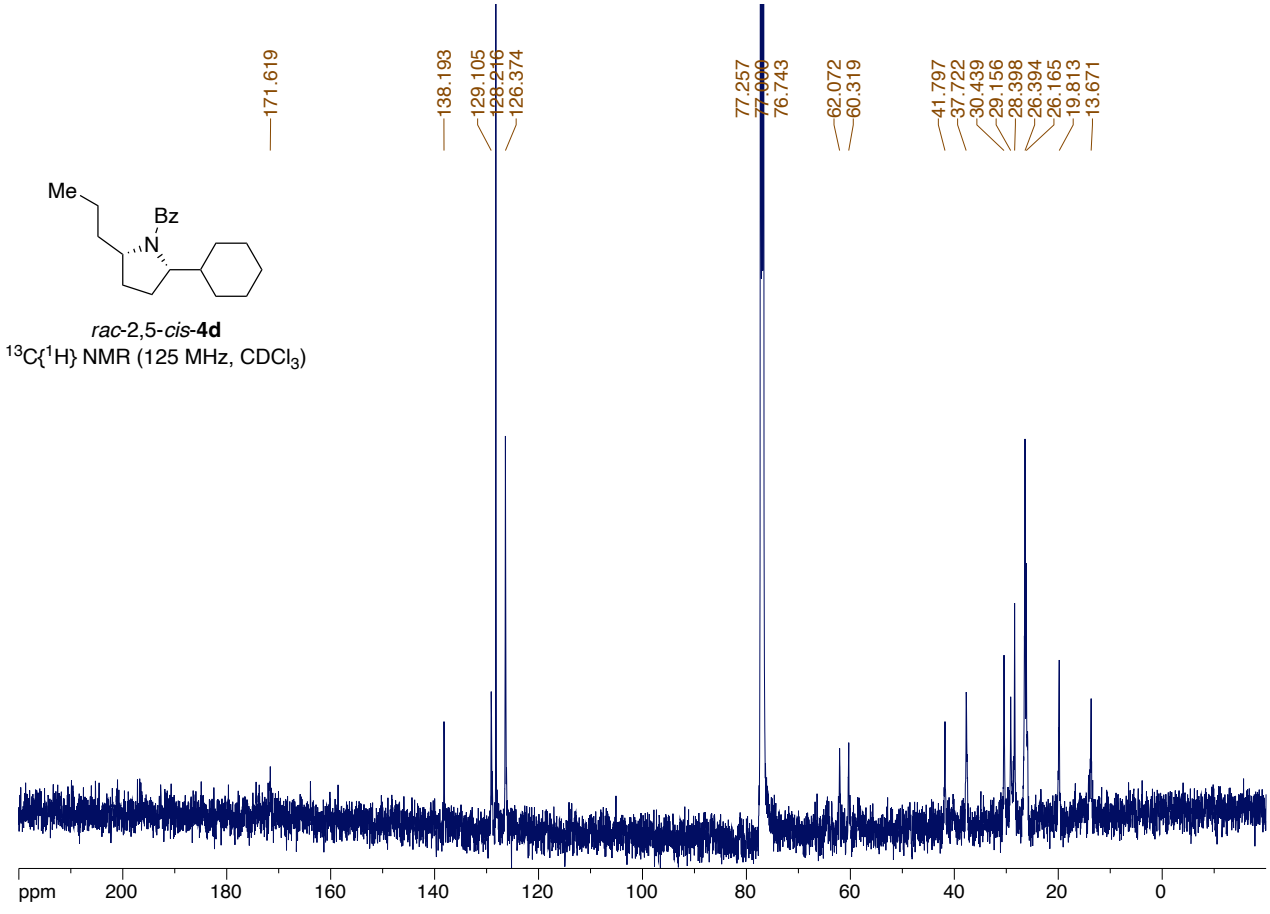



Me
Bz
N
rac-4d
1H NMR (500 MHz, CDCl3)
0.2741
0.275
9.5
2.34
5.57
0.745
0.74
0.75
12.8
ppm

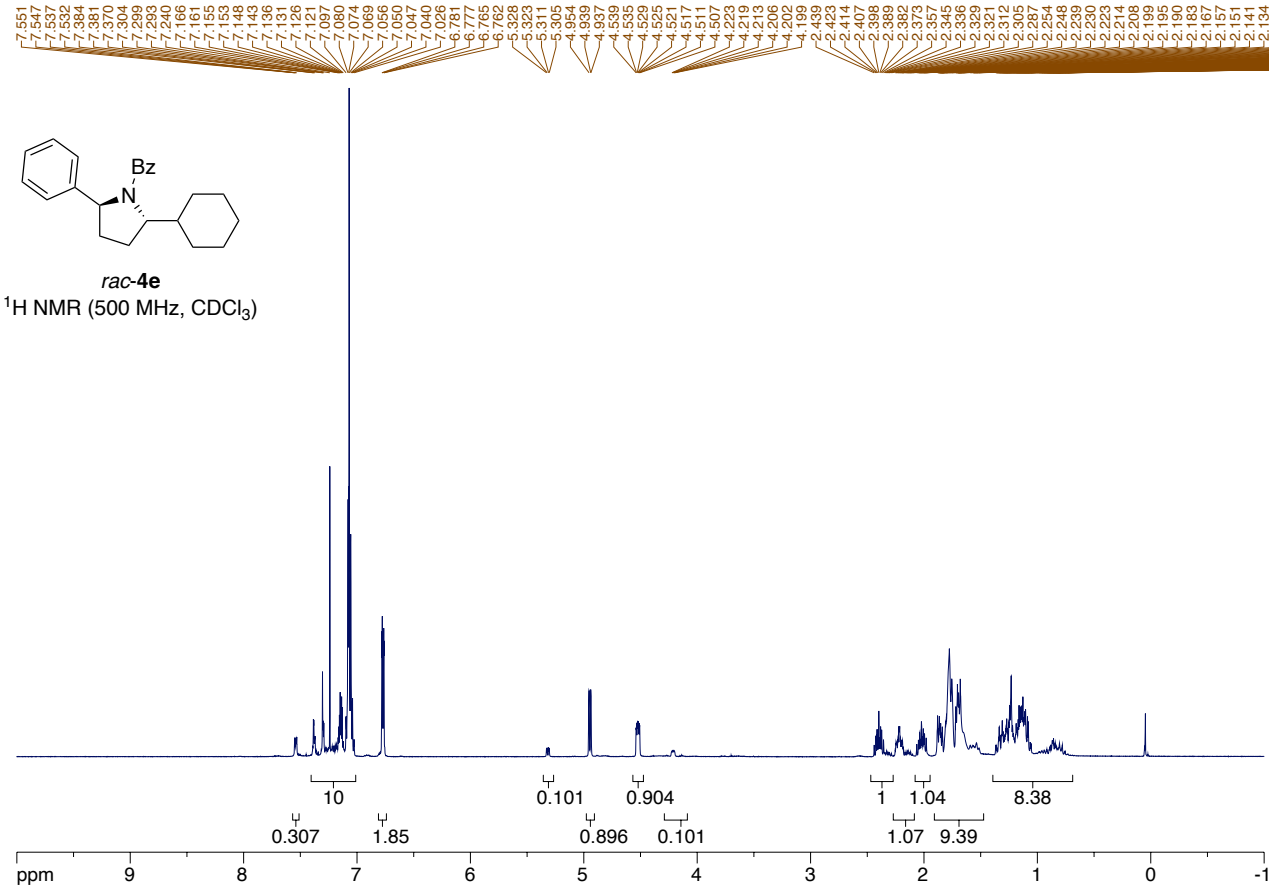

Me
Bz
N
rac-4d
13C{1H} NMR (125 MHz, CDCl3)
ppm



rac-2,5-*cis*-**4d**
^{1}H NMR (500 MHz, $CDCl_3$)

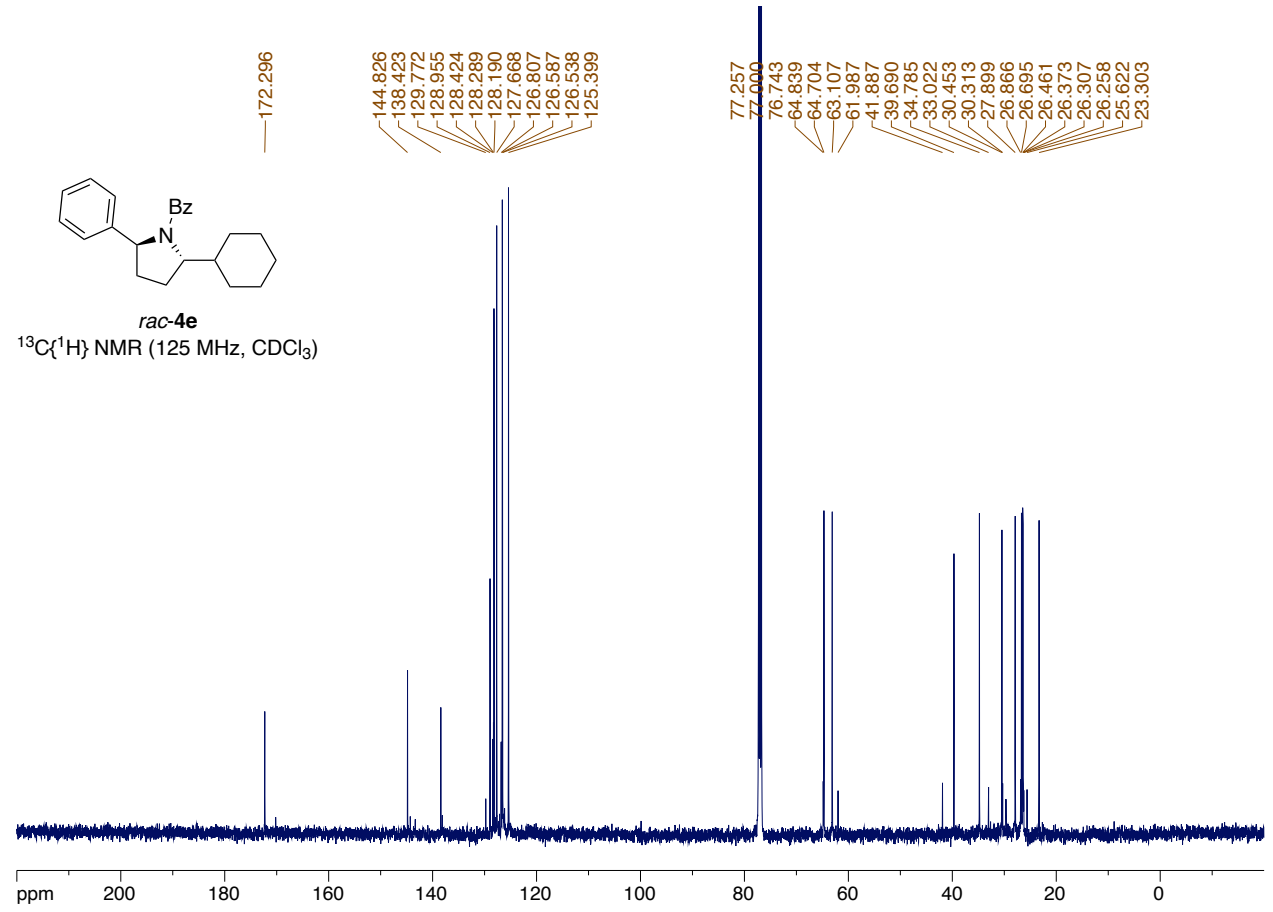


rac-2,5-*cis*-**4d**
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



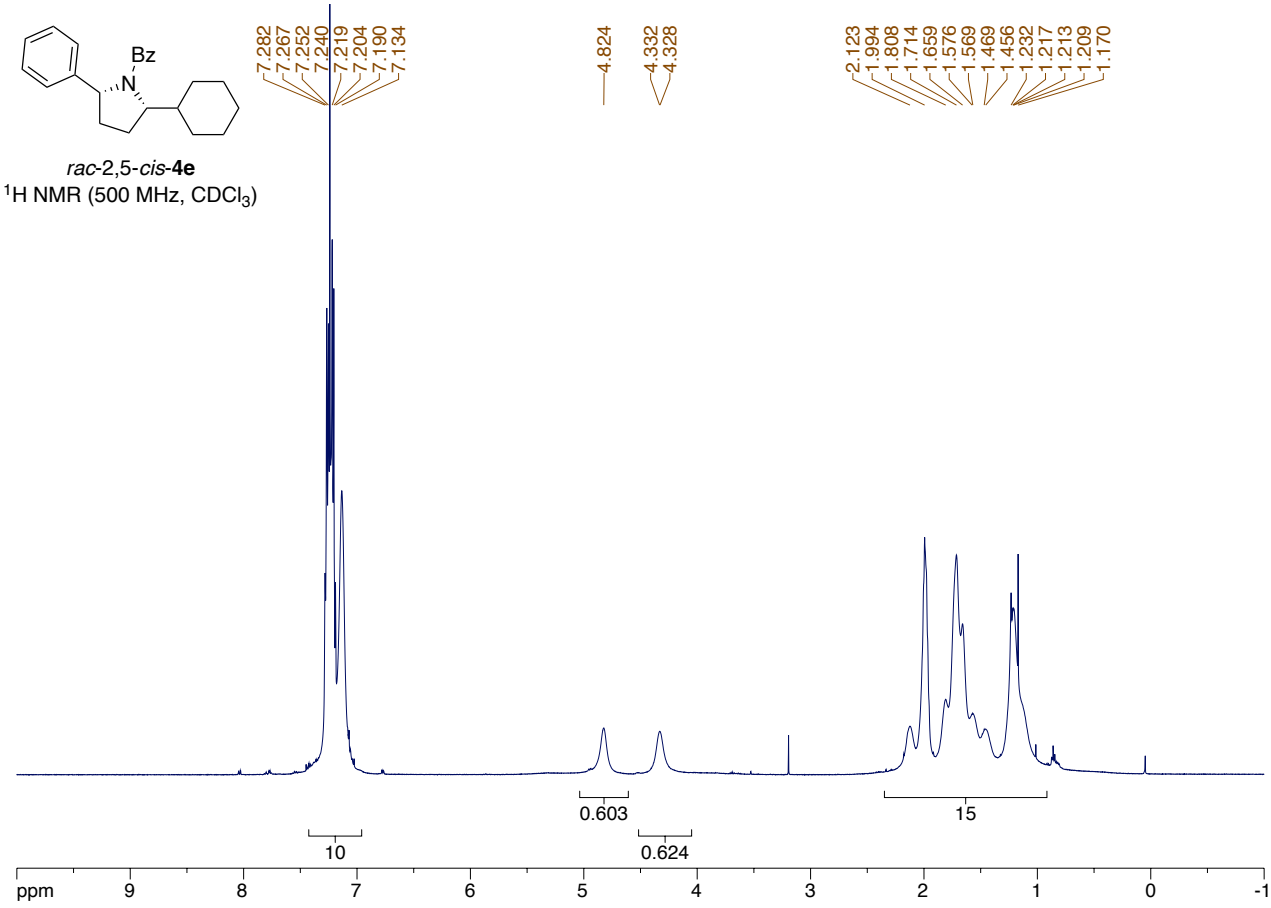
rac-**4e**

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

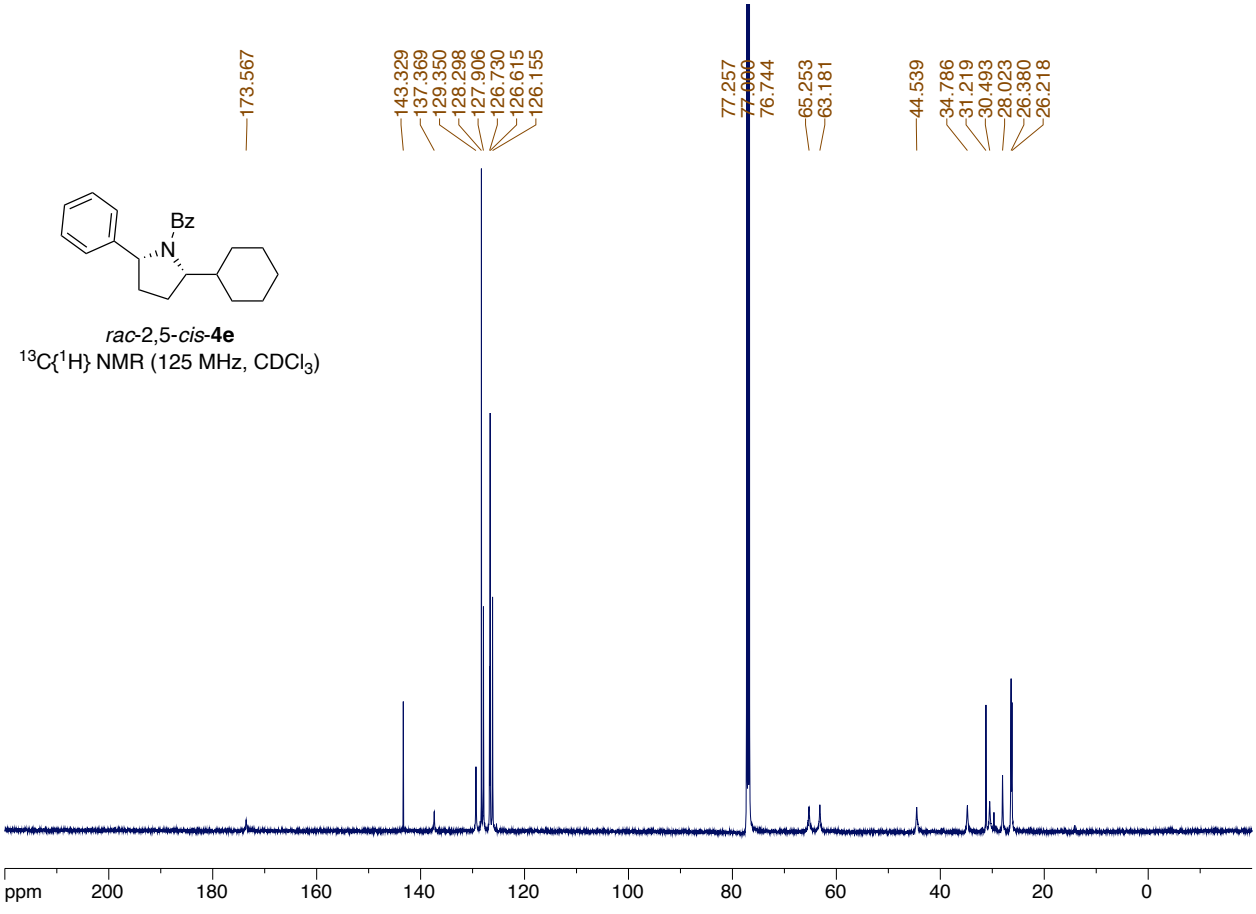


rac-**4e**

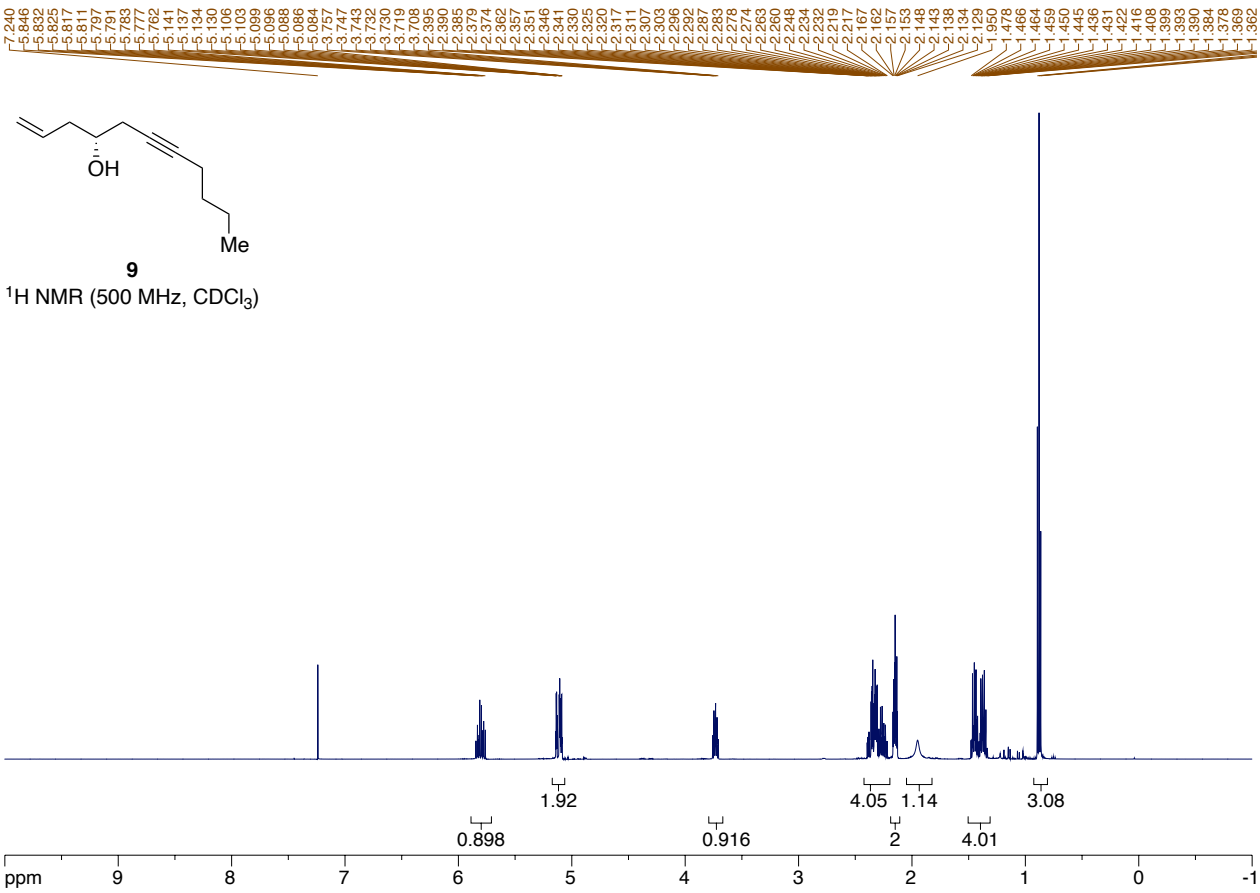
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

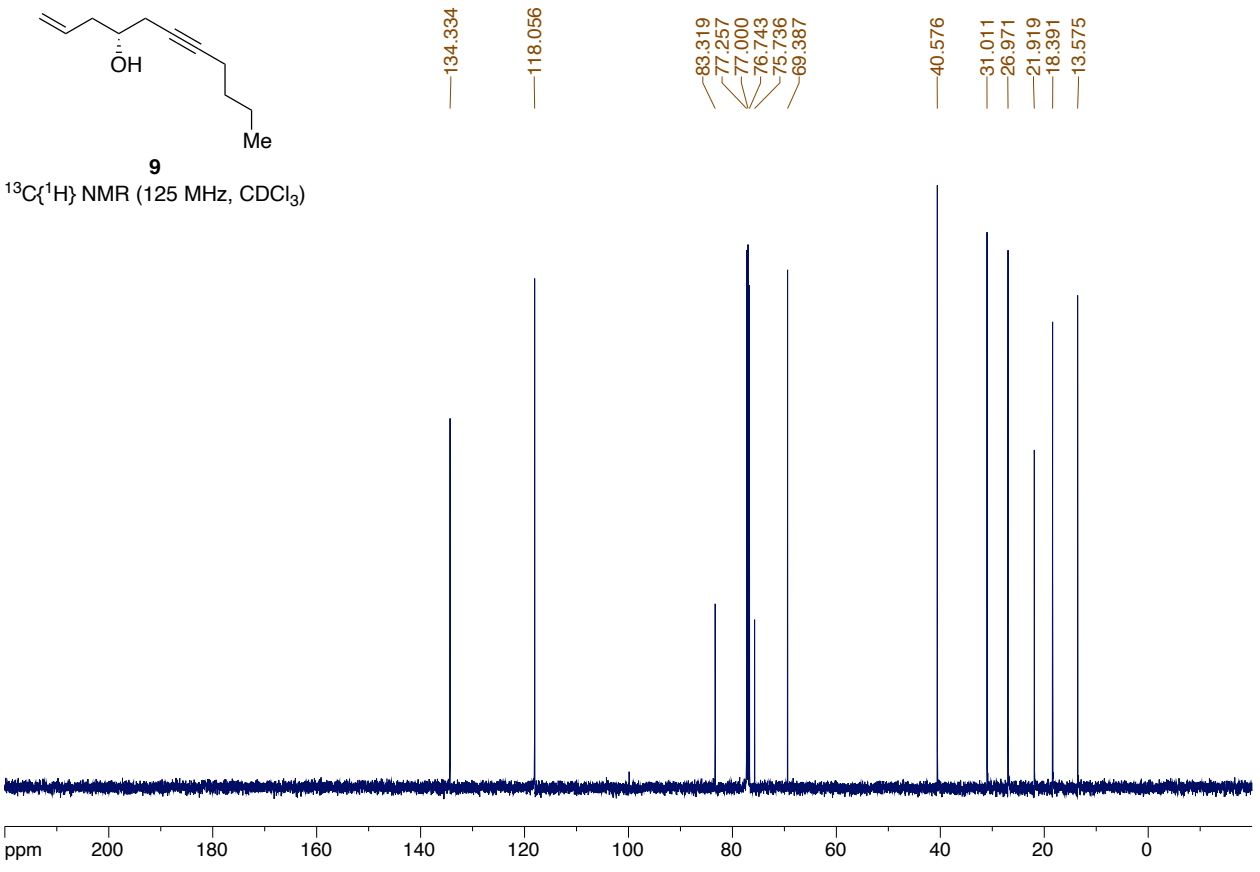


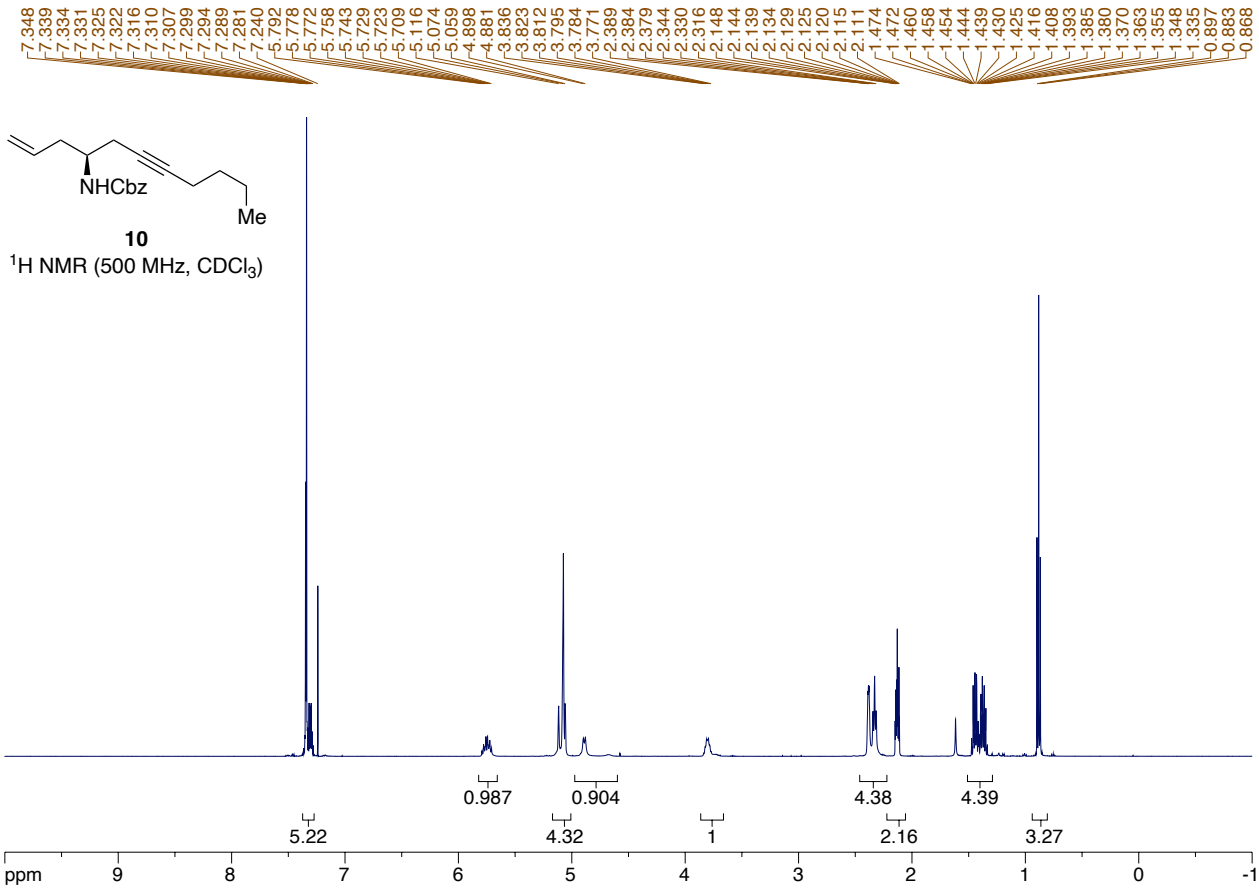
rac-2,5-*cis*-**4e**
^{1}H NMR (500 MHz, $CDCl_3$)

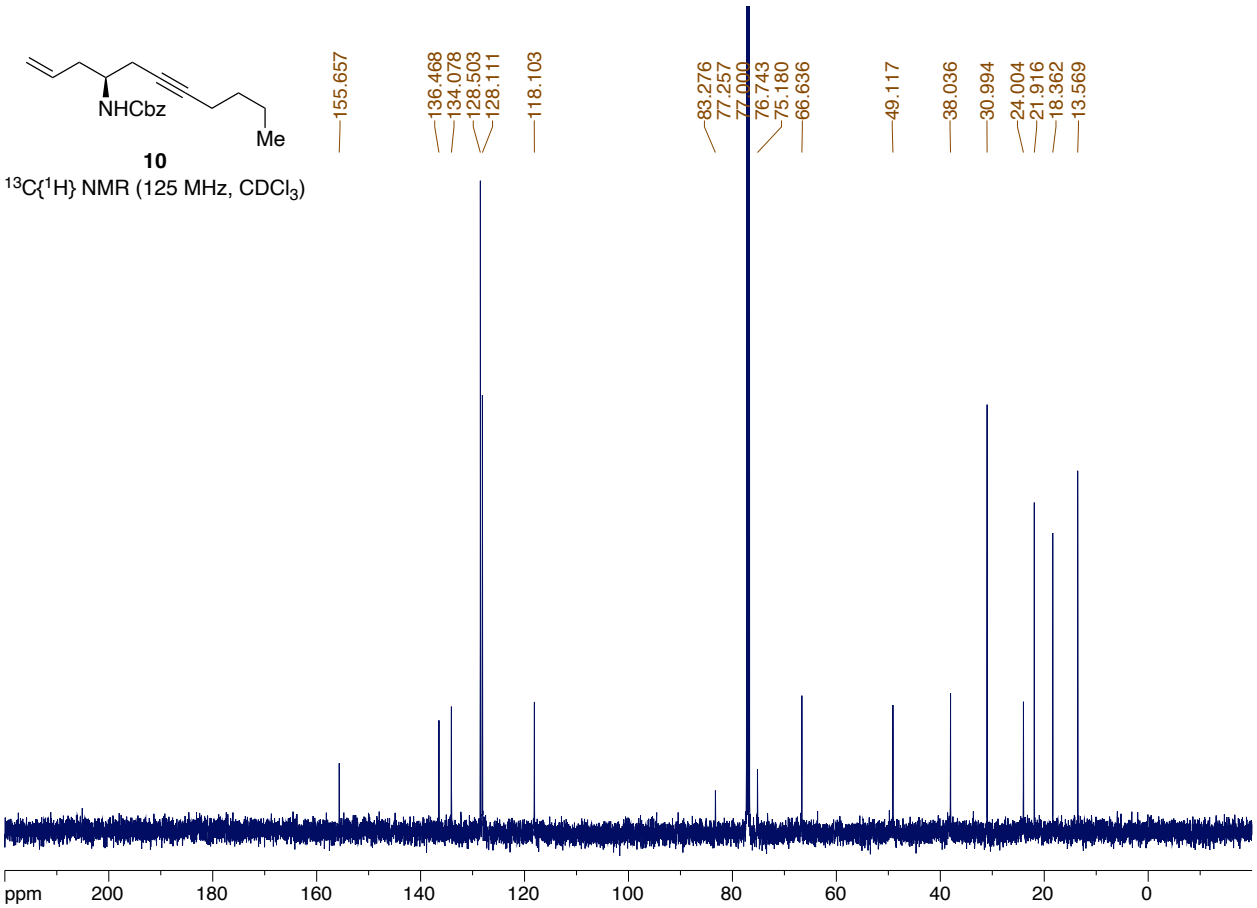


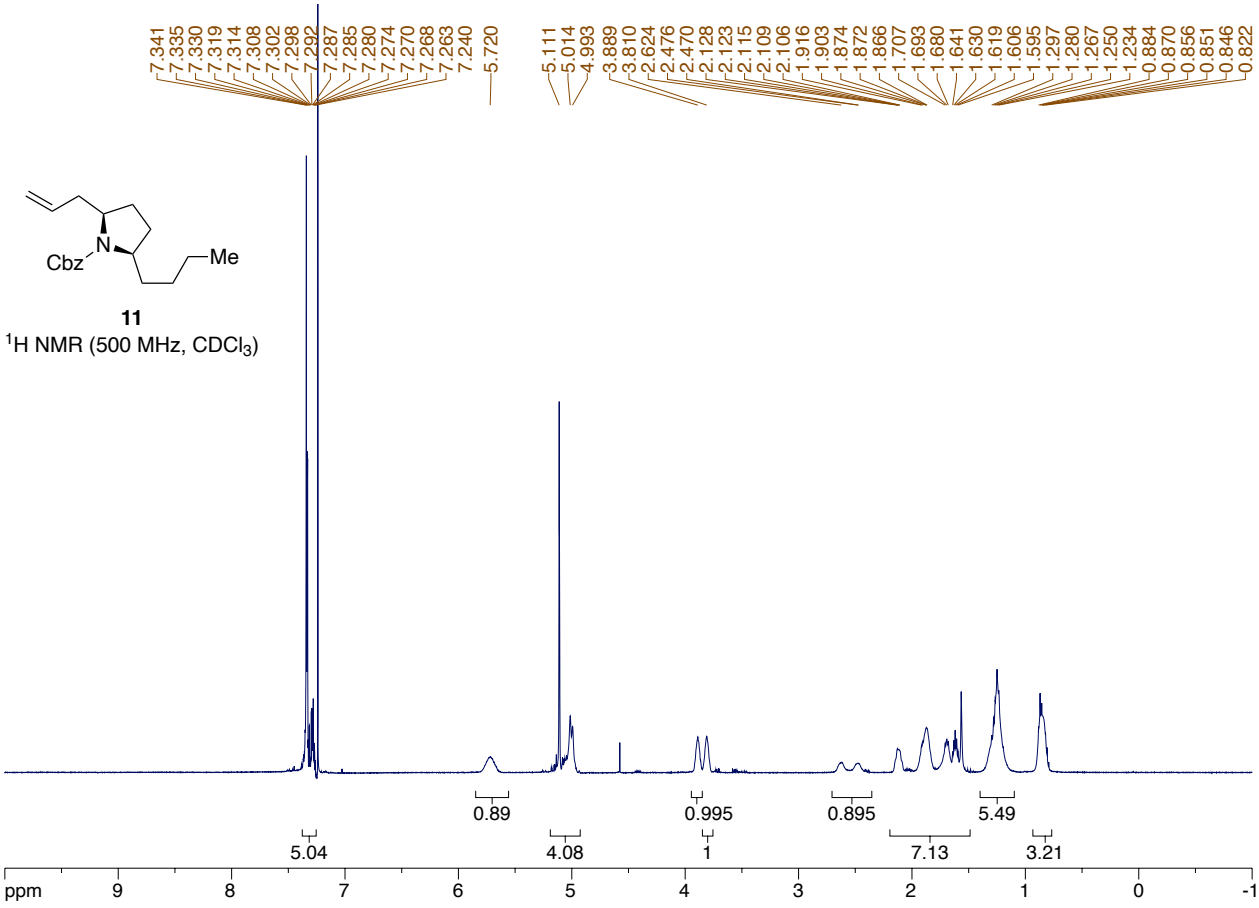
rac-2,5-*cis*-**4e**
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)


7.240
5.846
5.832
5.825
5.817
5.811
5.797
5.791
5.783
5.777
5.762
5.141
5.137
5.134
5.130
5.106
5.103
5.099
5.096
5.088
5.086
5.084
3.757
3.747
3.743
3.732
3.730
3.719
3.708
2.395
2.390
2.385
2.379
2.374
2.362
2.357
2.351
2.346
2.341
2.330
2.325
2.320
2.317
2.311
2.307
2.303
2.296
2.292
2.287
2.283
2.278
2.274
2.263
2.260
2.248
2.234
2.232
2.219
2.217
2.167
2.162
2.157
2.153
2.148
2.143
2.138
2.134
2.129
1.950
1.478
1.466
1.464
1.459
1.450
1.445
1.436
1.431
1.422
1.416
1.408
1.399
1.393
1.390
1.384
1.378
1.369
1.362
OH
Me
9
1H NMR (500 MHz, CDCl3)
1.92
4.05
1.14
3.08
0.898
0.916
2
4.01
ppm
9
8
7
6
5
4
3
2
1
0
-1


134.334
118.056
83.319
77.257
77.000
76.743
75.736
69.387
40.576
31.011
26.971
21.919
18.391
13.575
OH
Me
9
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0

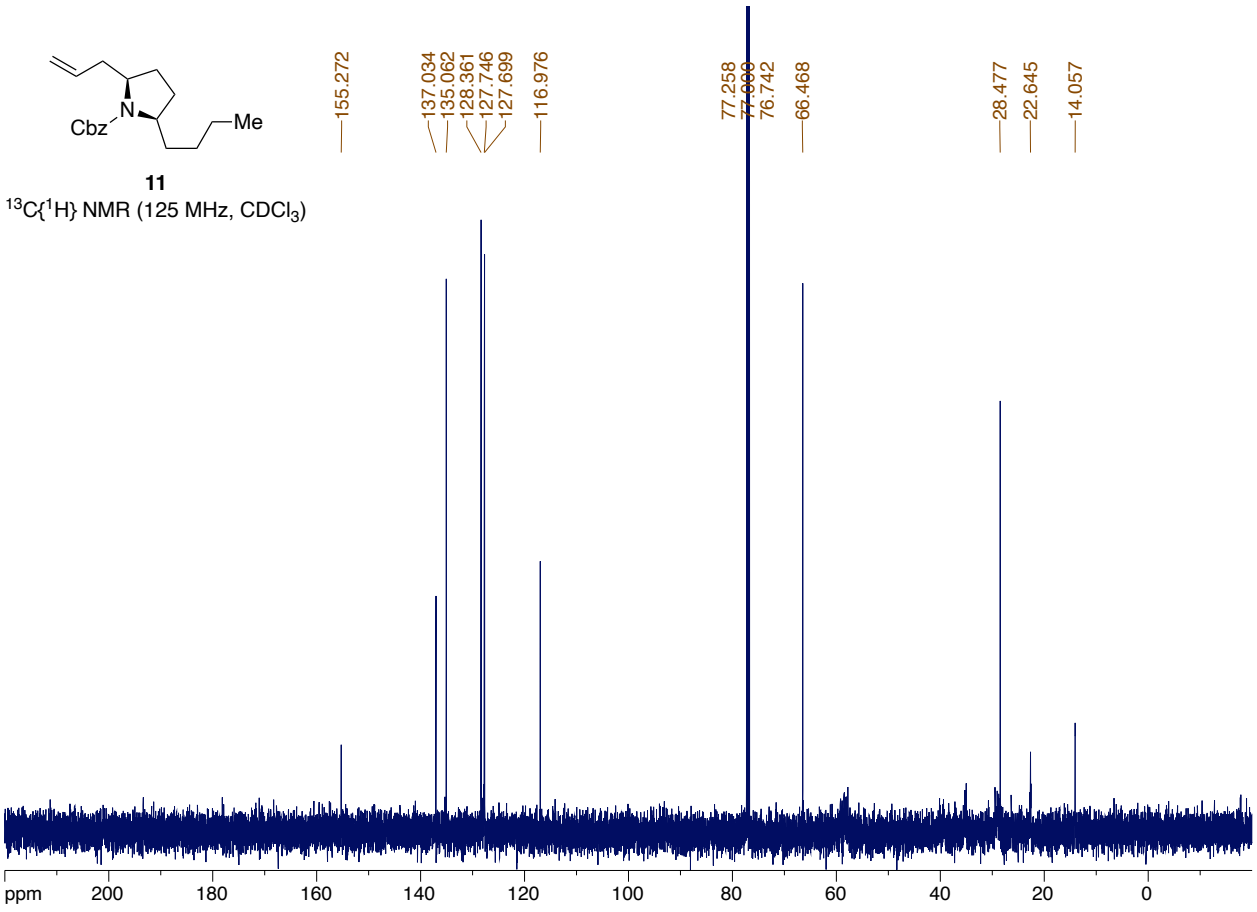

7.348
7.339
7.334
7.331
7.325
7.322
7.316
7.310
7.307
7.299
7.294
7.289
7.281
7.240
5.792
5.778
5.772
5.758
5.743
5.729
5.723
5.709
5.116
5.074
5.059
4.898
4.881
3.836
3.823
3.812
3.795
3.784
3.771
2.389
2.384
2.379
2.344
2.330
2.316
2.148
2.144
2.139
2.134
2.129
2.125
2.120
2.115
2.111
1.474
1.472
1.460
1.458
1.454
1.444
1.439
1.430
1.425
1.416
1.408
1.393
1.385
1.380
1.370
1.363
1.355
1.348
1.335
0.897
0.883
0.868
NHCbz
Me
10
1H NMR (500 MHz, CDCl3)
0.987
0.904
4.38
4.39
5.22
4.32
1
2.16
3.27
ppm
9
8
7
6
5
4
3
2
1
0
-1


NHCbz
Me
10
13C{1H} NMR (125 MHz, CDCl3)
155.657
136.468
134.078
128.503
128.111
118.103
83.276
77.257
77.000
76.743
75.180
66.636
49.117
38.036
30.994
24.004
21.916
18.362
13.569
ppm
200
180
160
140
120
100
80
60
40
20
0



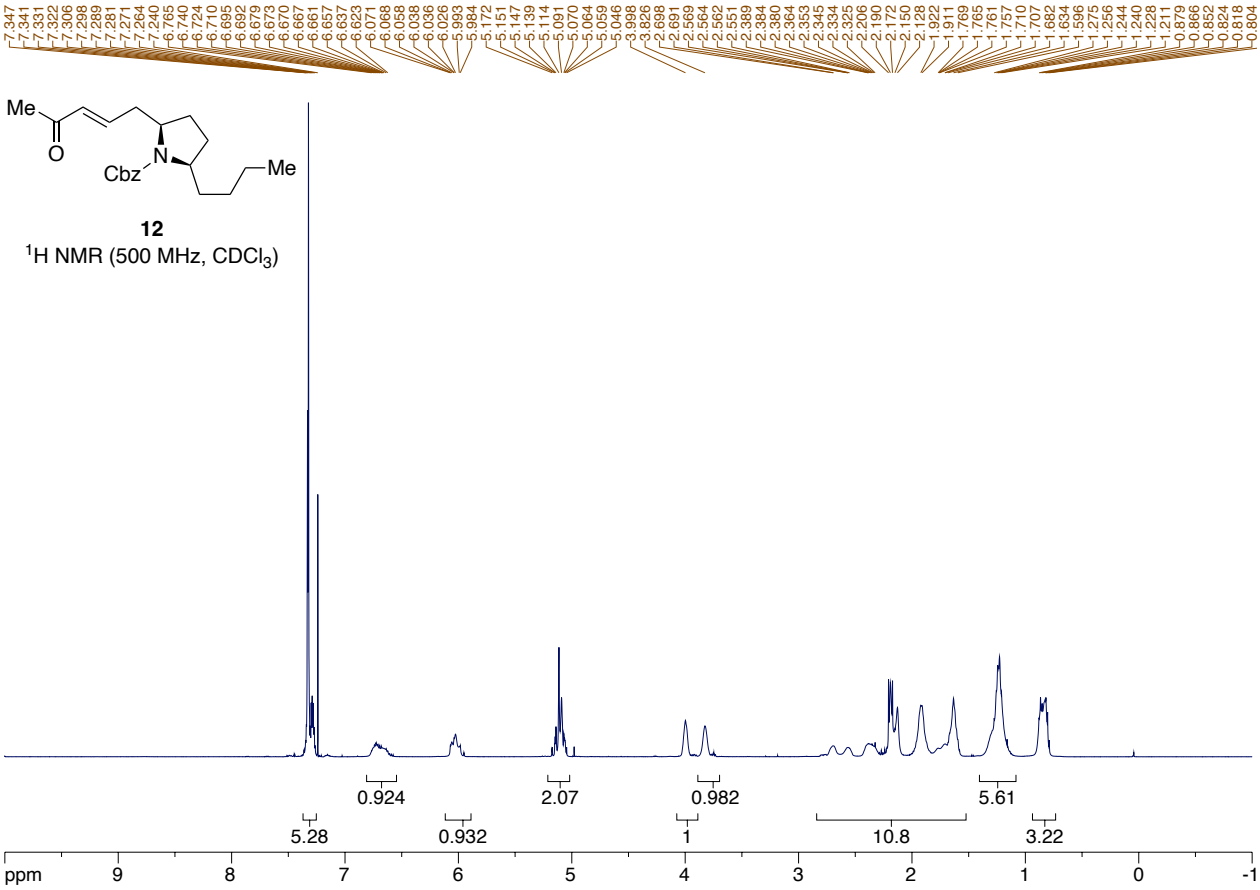
11

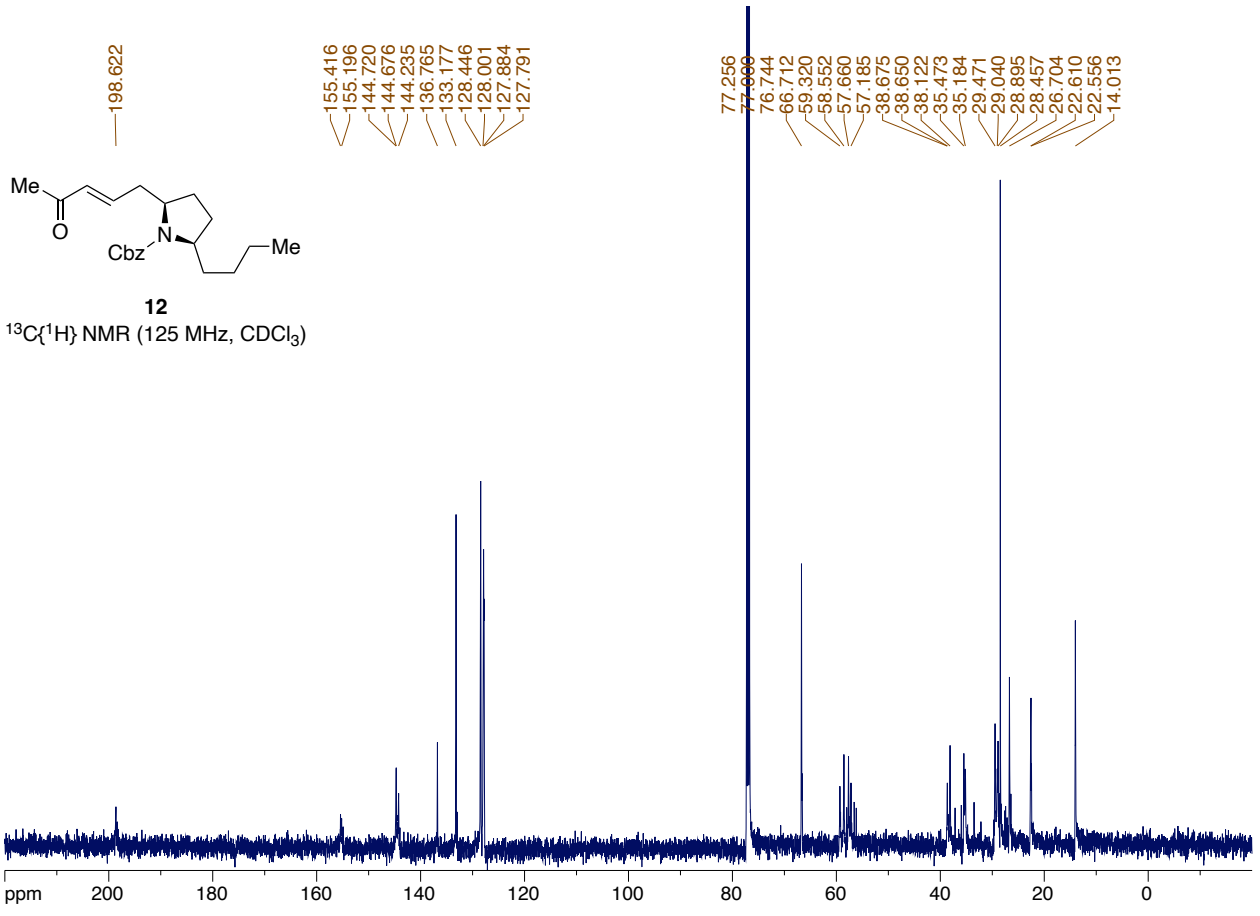
^{1}H NMR (500 MHz, $CDCl_3$)

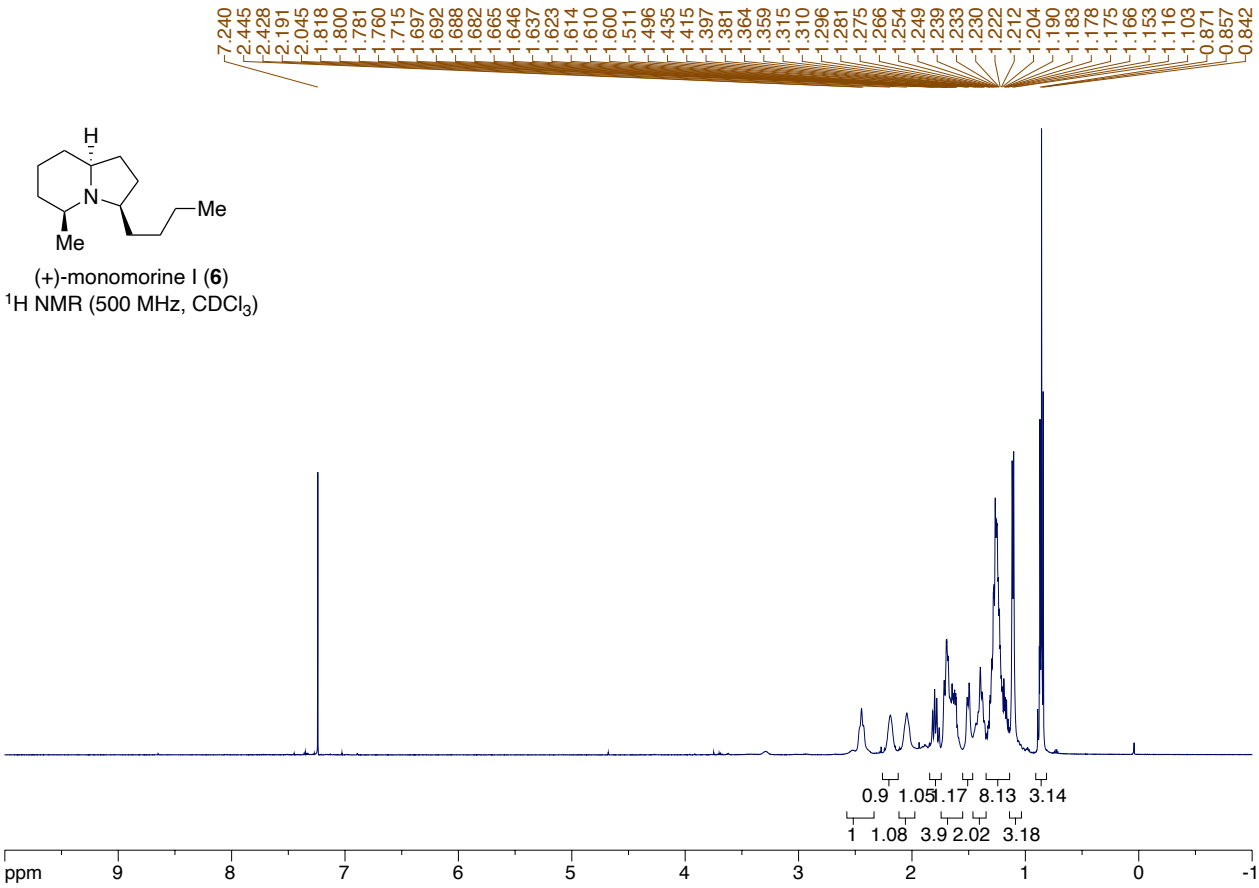


11

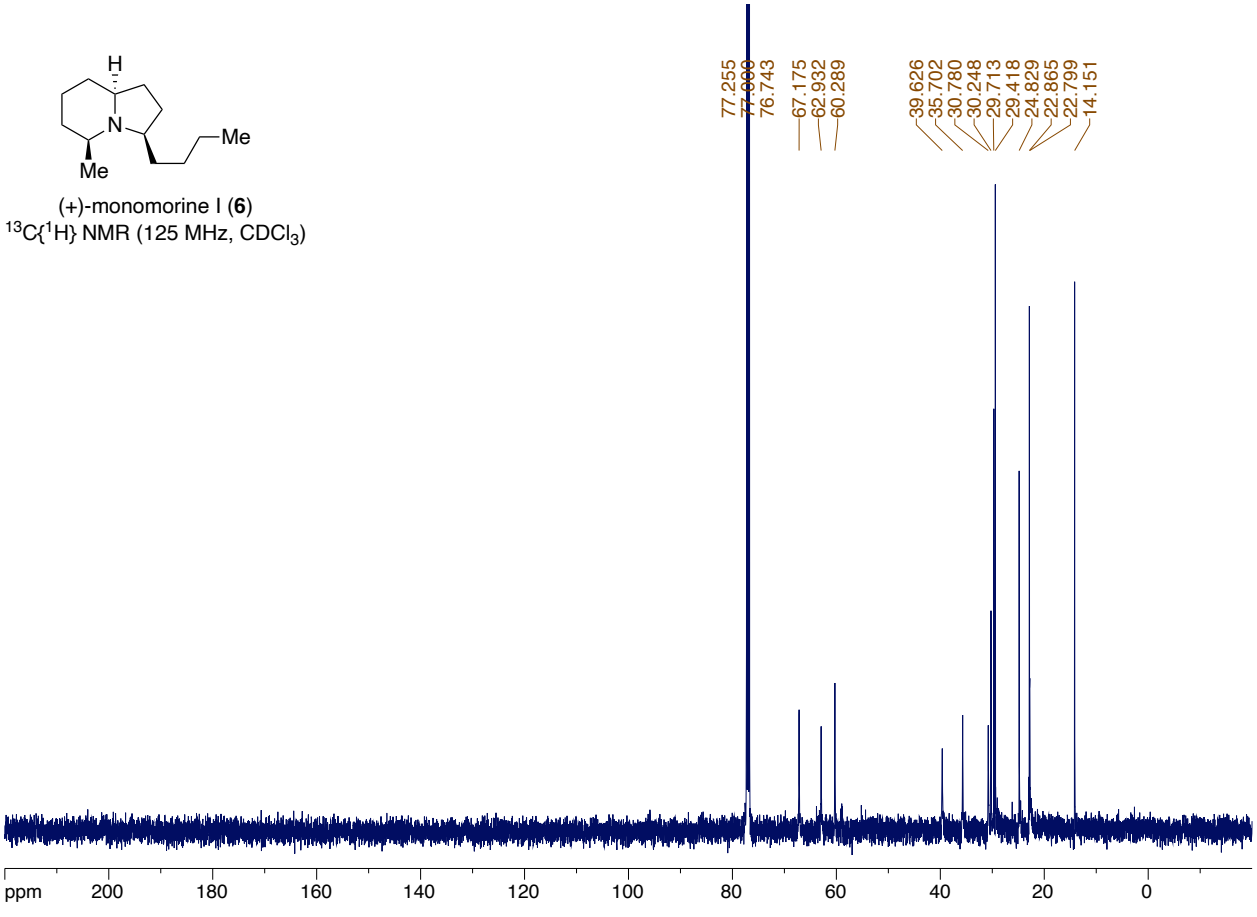
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)


Me
O
N
Cbz
Me
12
1H NMR (500 MHz, CDCl3)
0.924
2.07
0.982
5.61
5.28
0.932
1
10.8
3.22
ppm

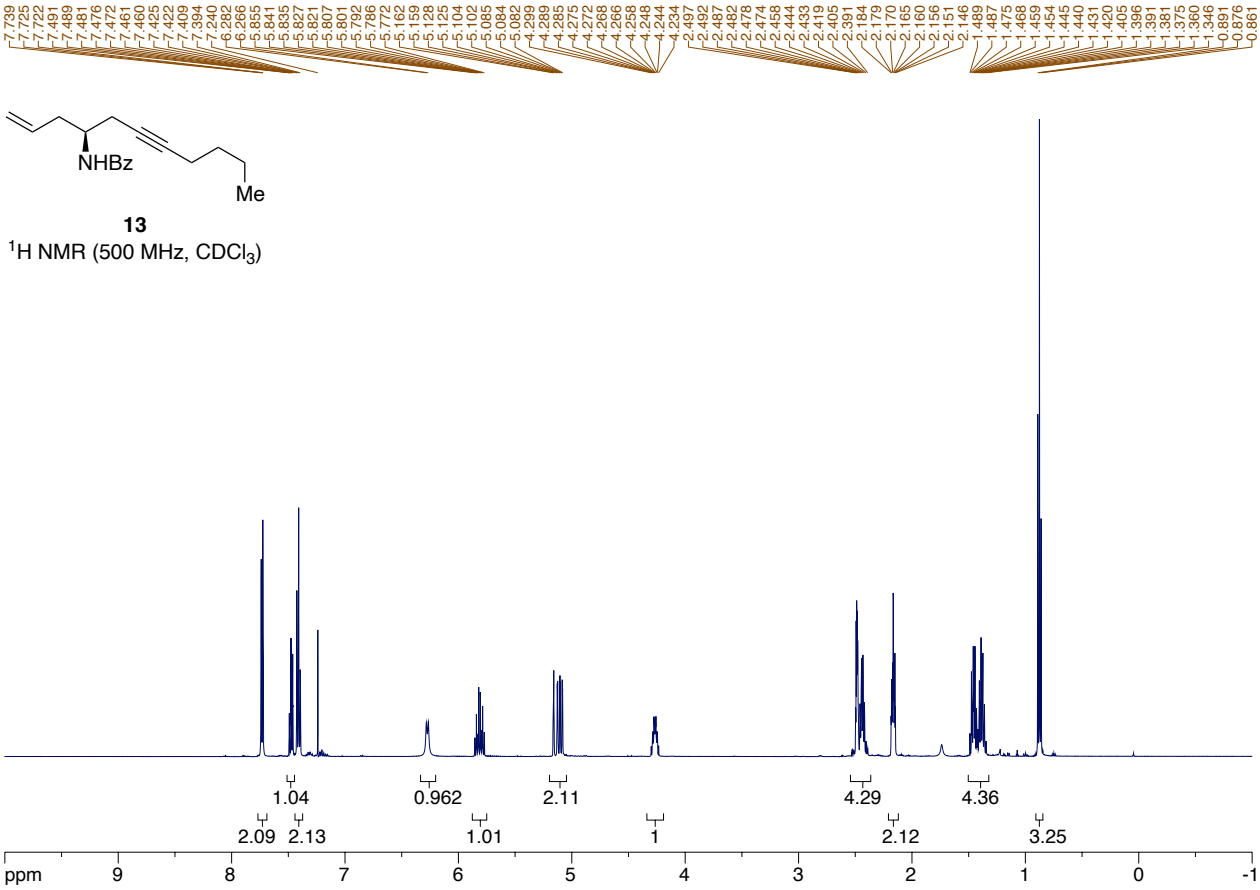

Me
O
N
Cbz
Me
12
13C{1H} NMR (125 MHz, CDCl3)
ppm

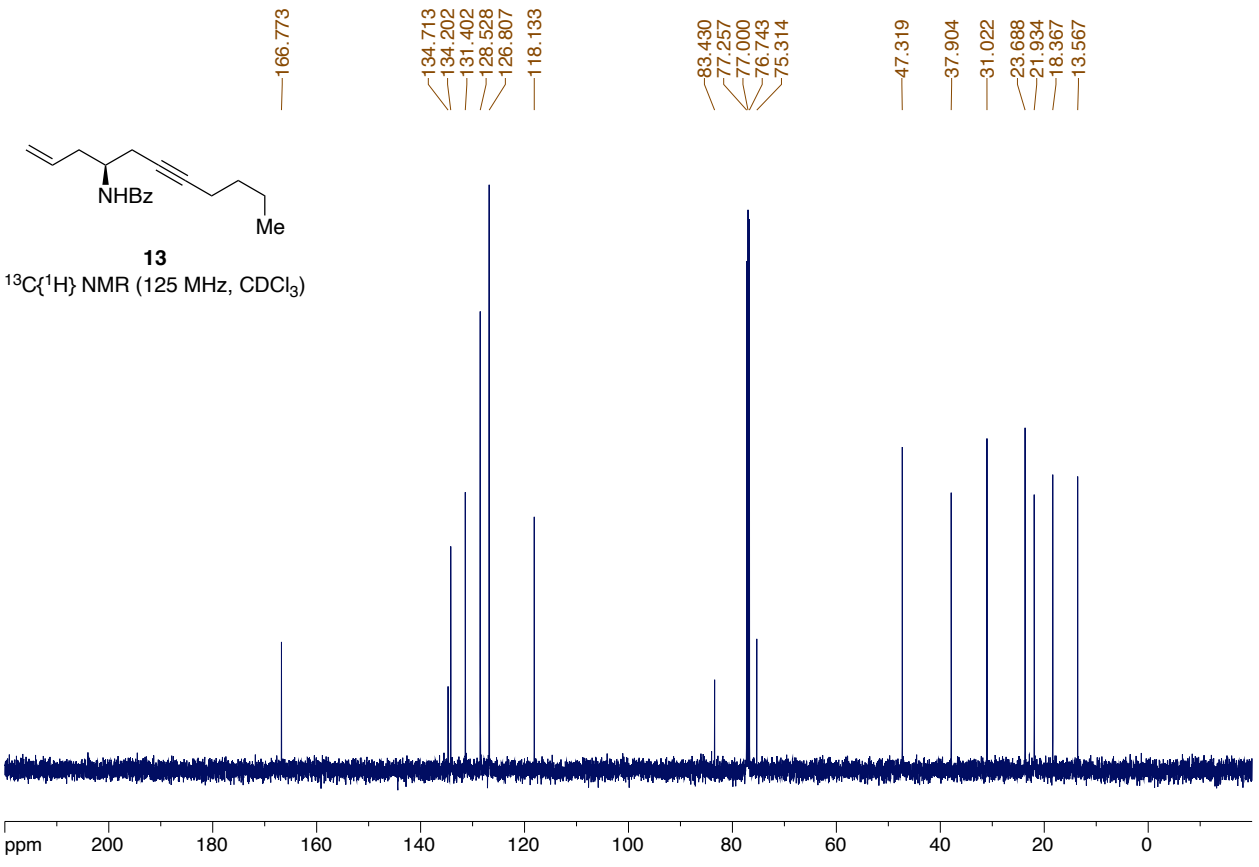


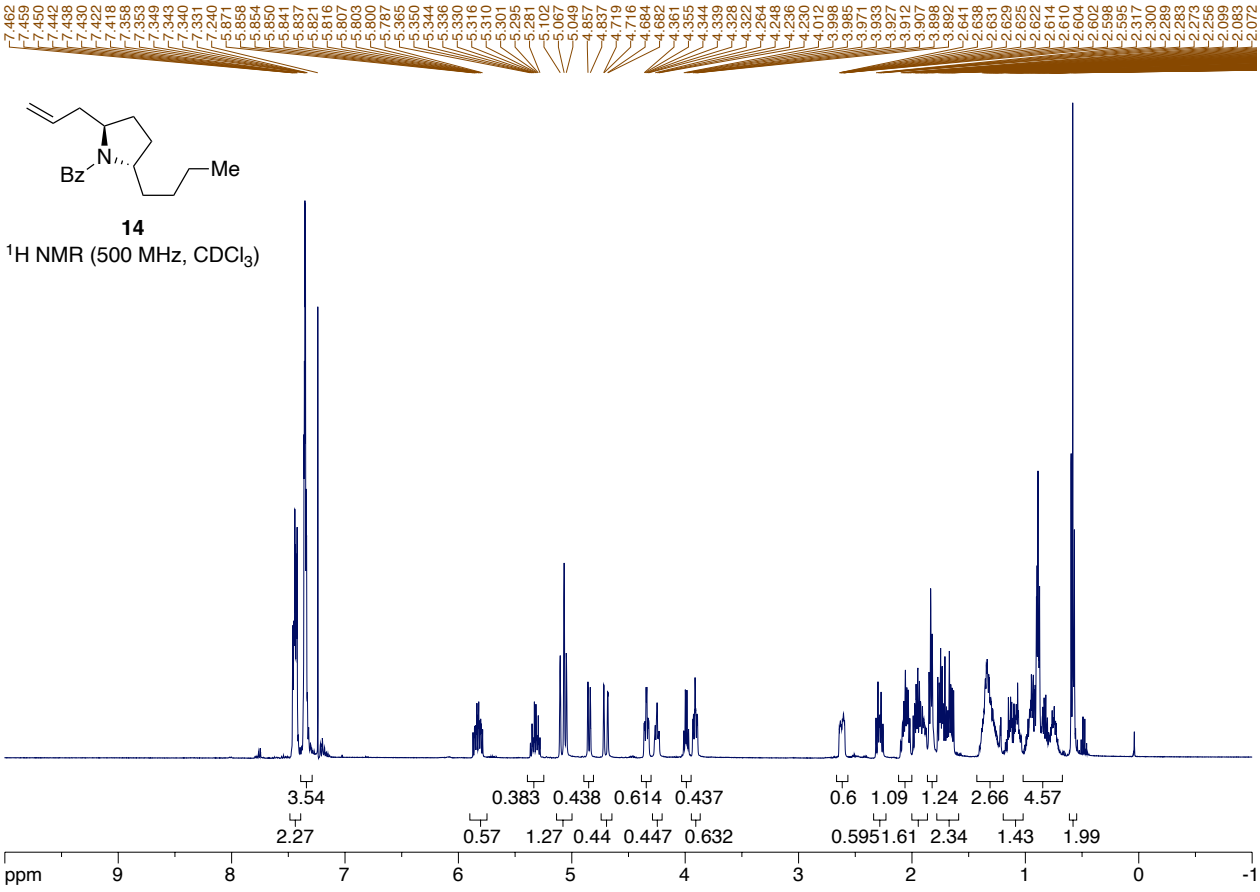
(+)-monomorine I (**6**)
^{1}H NMR (500 MHz, $CDCl_3$)

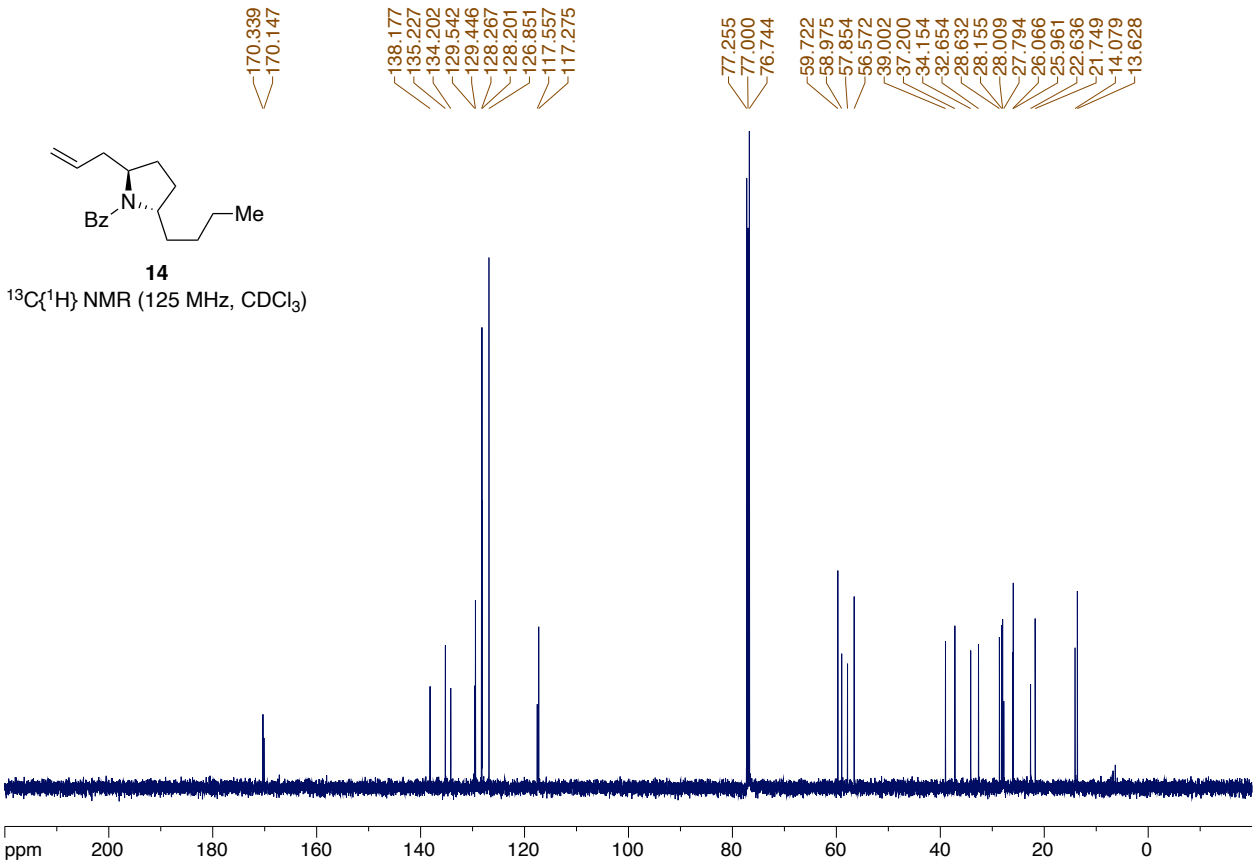


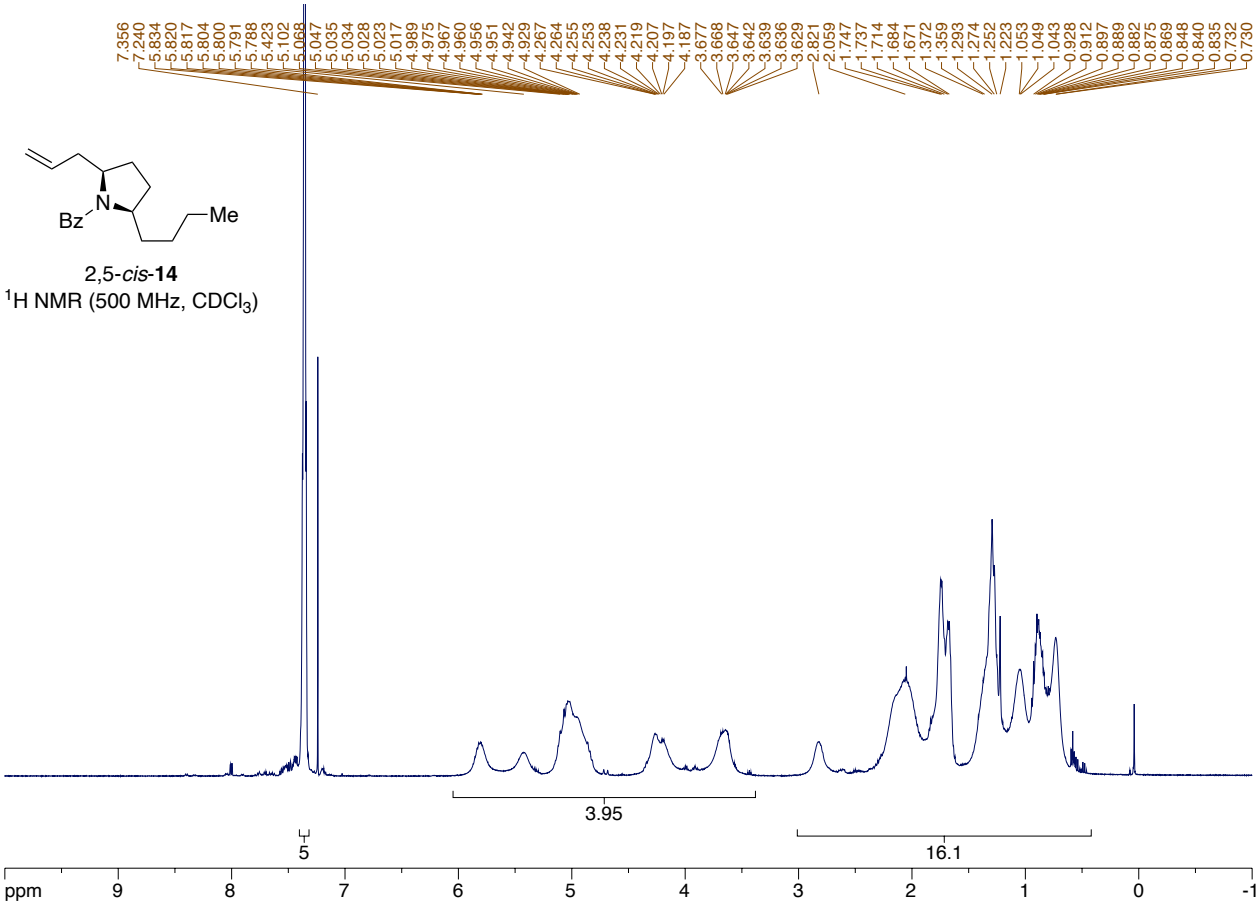
(+)-monomorine I (**6**)
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)


7.739
7.725
7.722
7.491
7.489
7.481
7.476
7.472
7.461
7.460
7.425
7.422
7.409
7.394
7.240
6.282
6.266
5.855
5.841
5.835
5.827
5.821
5.807
5.801
5.792
5.786
5.772
5.162
5.159
5.128
5.125
5.104
5.102
5.085
5.084
5.082
4.299
4.289
4.285
4.275
4.272
4.268
4.266
4.258
4.248
4.244
4.234
2.497
2.492
2.487
2.482
2.478
2.474
2.458
2.444
2.433
2.419
2.405
2.391
2.184
2.179
2.170
2.165
2.160
2.156
2.151
2.146
1.489
1.487
1.475
1.468
1.459
1.454
1.445
1.440
1.431
1.420
1.405
1.396
1.391
1.381
1.375
1.360
1.346
0.891
0.876
0.861
NHBz
Me
13
1H NMR (500 MHz, CDCl3)
1.04
0.962
2.11
4.29
4.36
2.09
2.13
1.01
1
2.12
3.25
ppm
9
8
7
6
5
4
3
2
1
0
-1

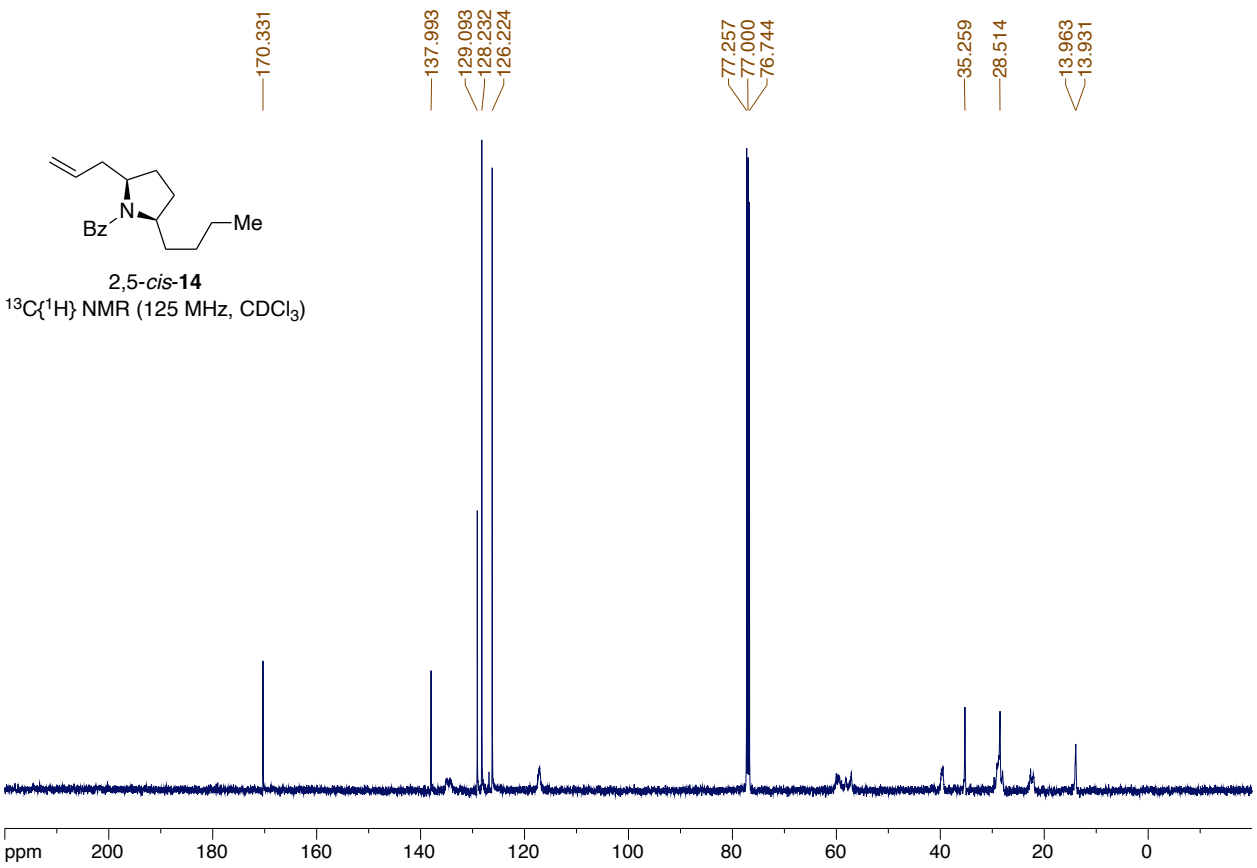

166.773
134.713
134.202
131.402
128.528
126.807
118.133
83.430
77.257
77.000
76.743
75.314
47.319
37.904
31.022
23.688
21.934
18.367
13.567
NHBz
Me
13
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0


7.462
7.459
7.450
7.442
7.438
7.430
7.422
7.418
7.358
7.353
7.349
7.343
7.340
7.331
7.240
5.871
5.858
5.854
5.850
5.841
5.837
5.821
5.816
5.807
5.803
5.800
5.787
5.365
5.350
5.344
5.336
5.330
5.316
5.310
5.301
5.295
5.281
5.102
5.067
5.049
4.857
4.837
4.719
4.716
4.684
4.682
4.361
4.355
4.344
4.339
4.328
4.322
4.264
4.248
4.236
4.230
4.012
3.998
3.985
3.971
3.933
3.927
3.912
3.907
3.898
3.892
2.641
2.638
2.631
2.629
2.625
2.622
2.614
2.610
2.604
2.602
2.598
2.595
2.317
2.300
2.289
2.283
2.273
2.256
2.099
2.083
2.072
Bz
N
Me
14
1H NMR (500 MHz, CDCl3)
3.54
2.27
0.383
0.438
0.614
0.437
0.57
1.27
0.44
0.447
0.632
0.6
1.09
1.24
2.66
4.57
0.595
1.61
2.34
1.43
1.99
ppm
9
8
7
6
5
4
3
2
1
0
-1

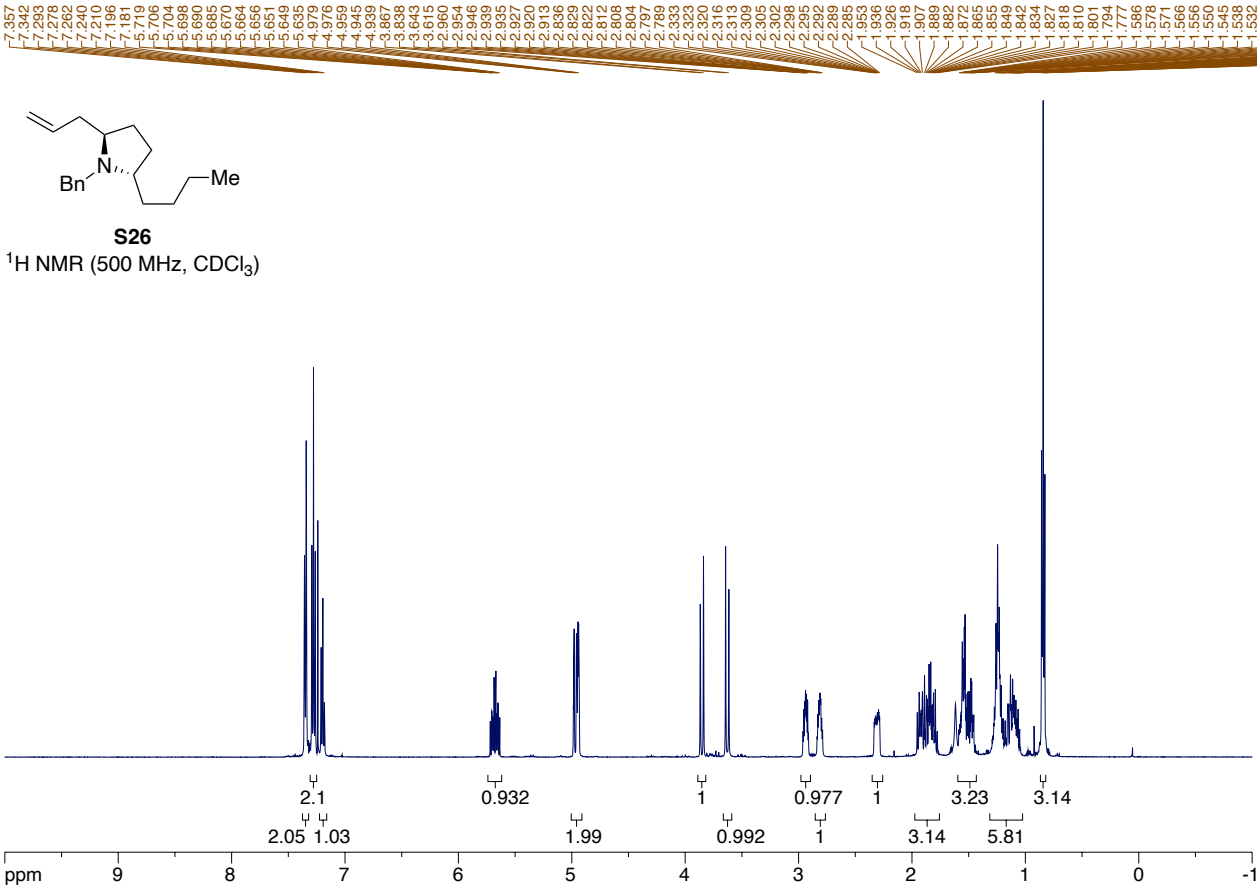

170.339
170.147
138.177
135.227
134.202
129.542
129.446
128.267
128.201
126.851
117.557
117.275
77.255
77.000
76.744
59.722
58.975
57.854
56.572
39.002
37.200
34.154
32.654
28.632
28.155
28.009
27.794
26.066
25.961
22.636
21.749
14.079
13.628
Bz
N
Me
14
13C{1H} NMR (125 MHz, CDCl3)
ppm
200
180
160
140
120
100
80
60
40
20
0



2,5-*cis*-**14**
^{1}H NMR (500 MHz, $CDCl_3$)

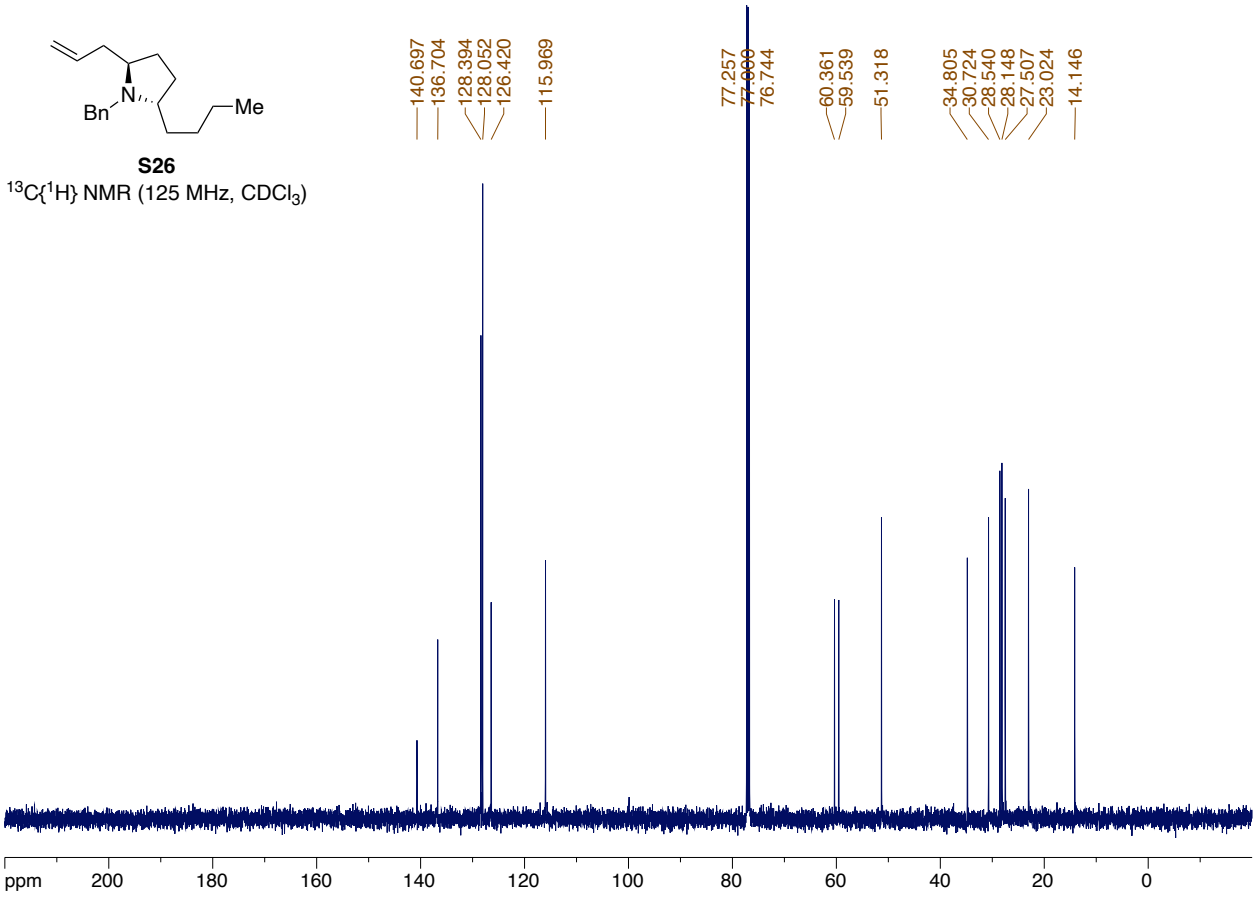


2,5-*cis*-**14**
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



S26

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

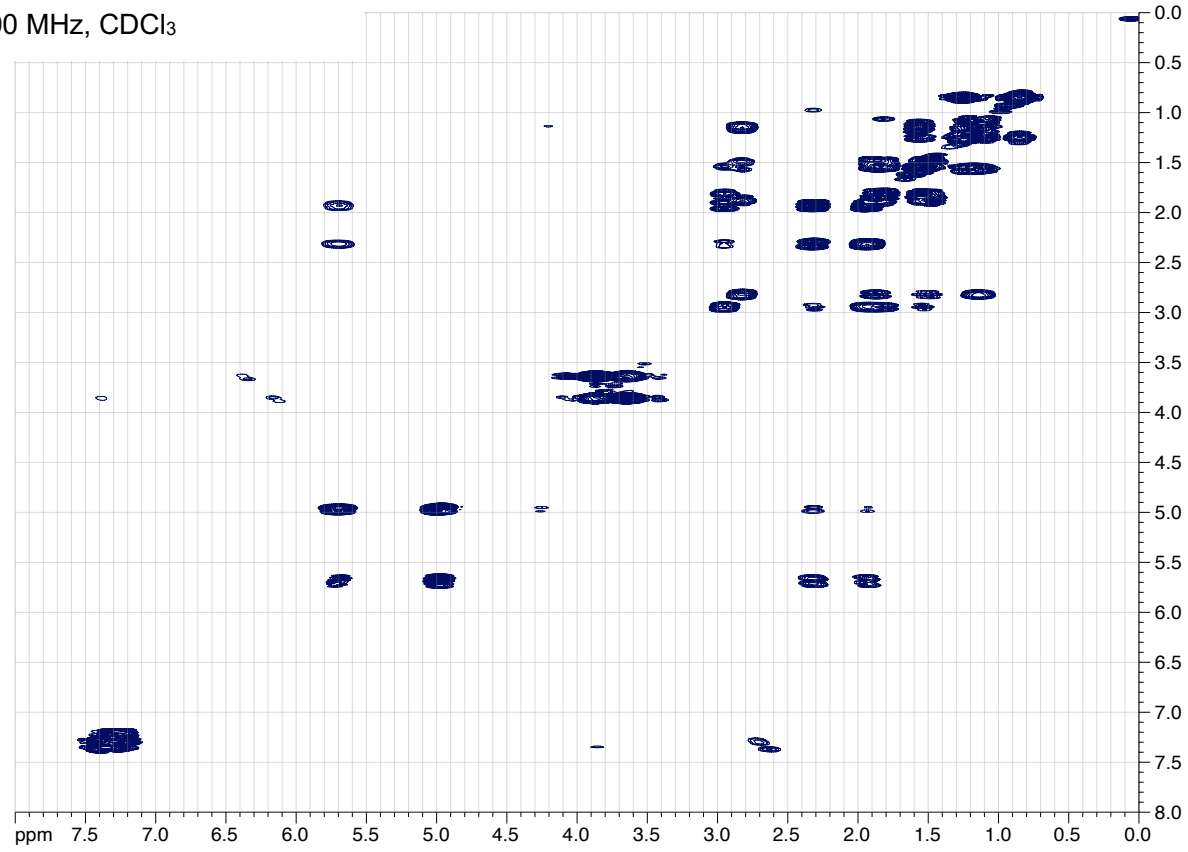


S26

^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)

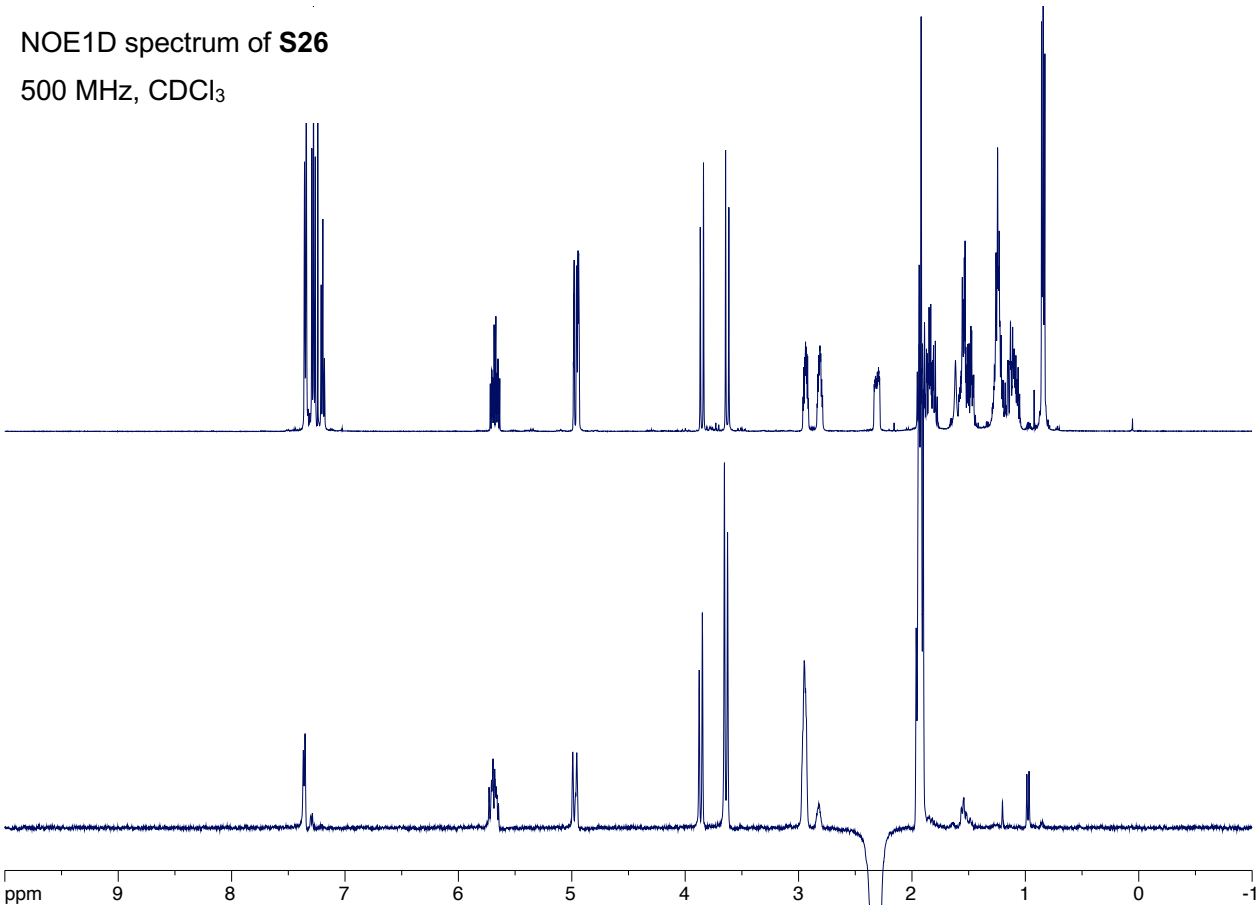
^{1}H-^{1}H COSY spectrum of **S26**

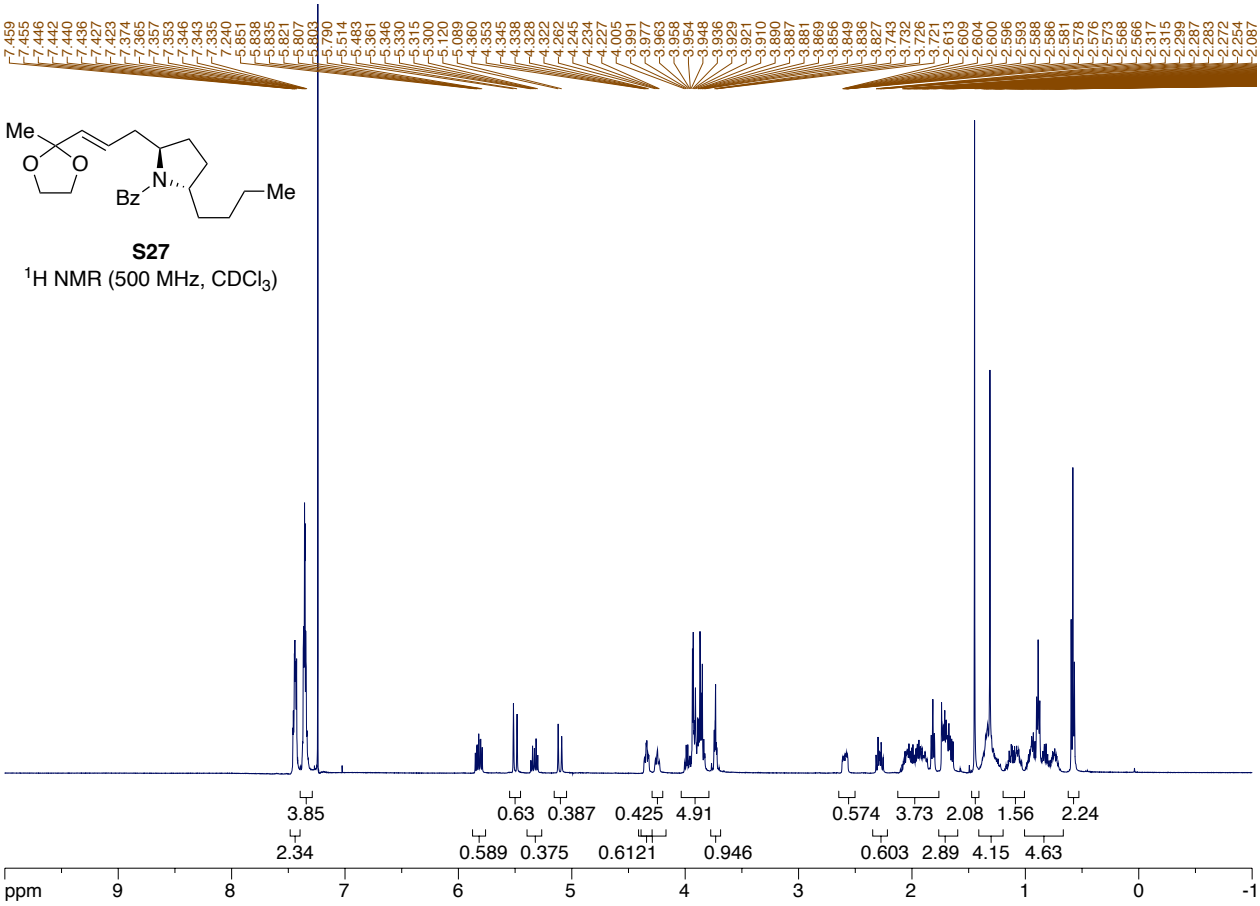
500 MHz, $CDCl_3$



NOE1D spectrum of **S26**

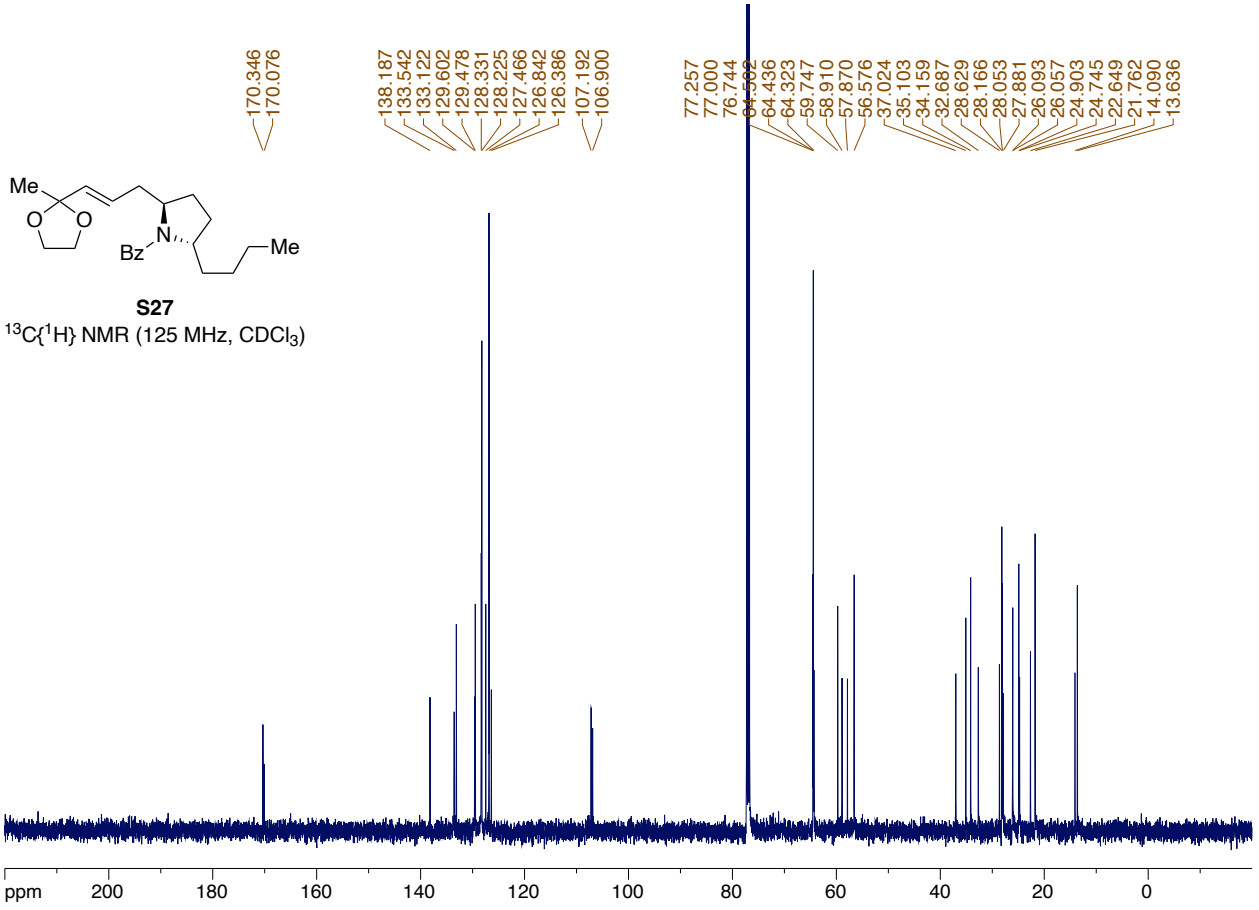
500 MHz, $CDCl_3$





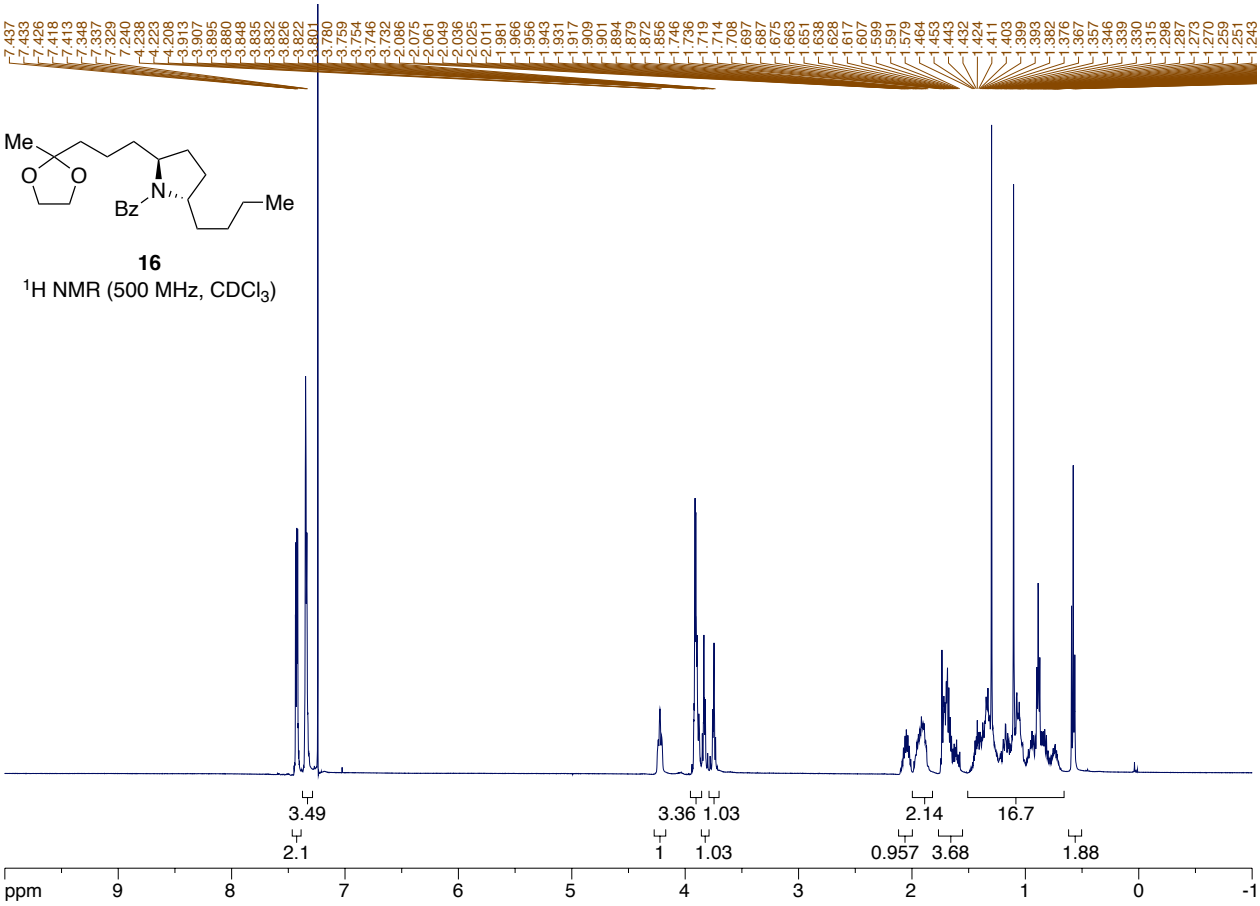
S27

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



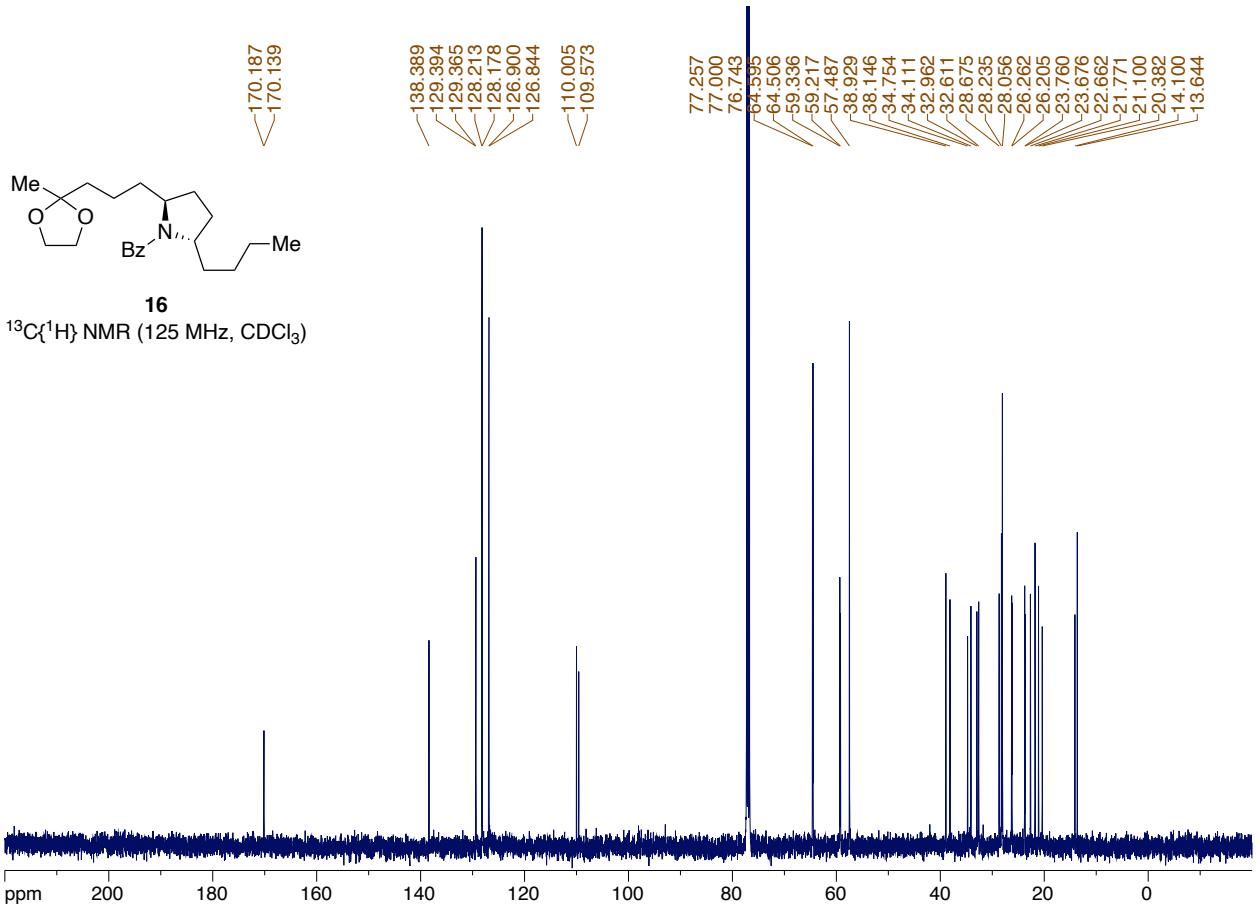
S27

$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)



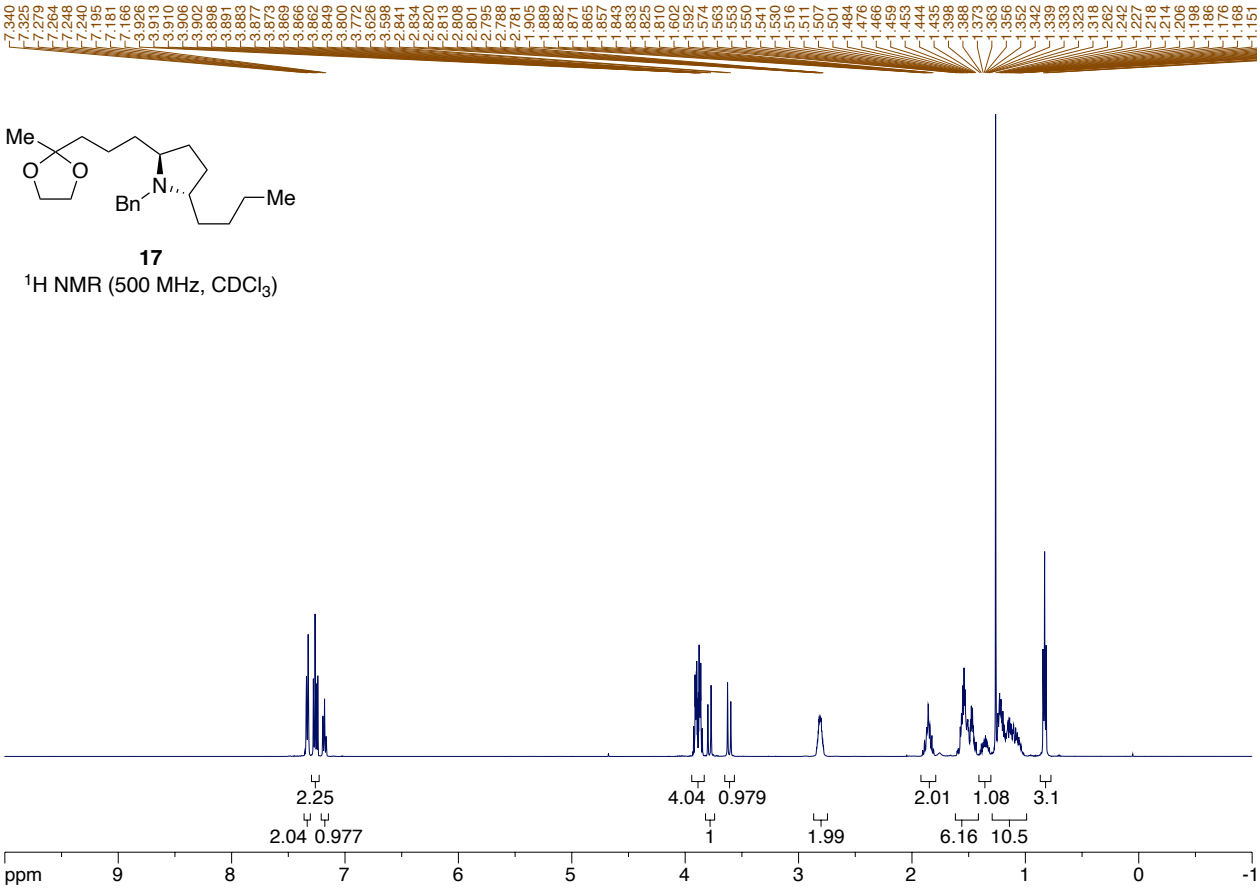
16

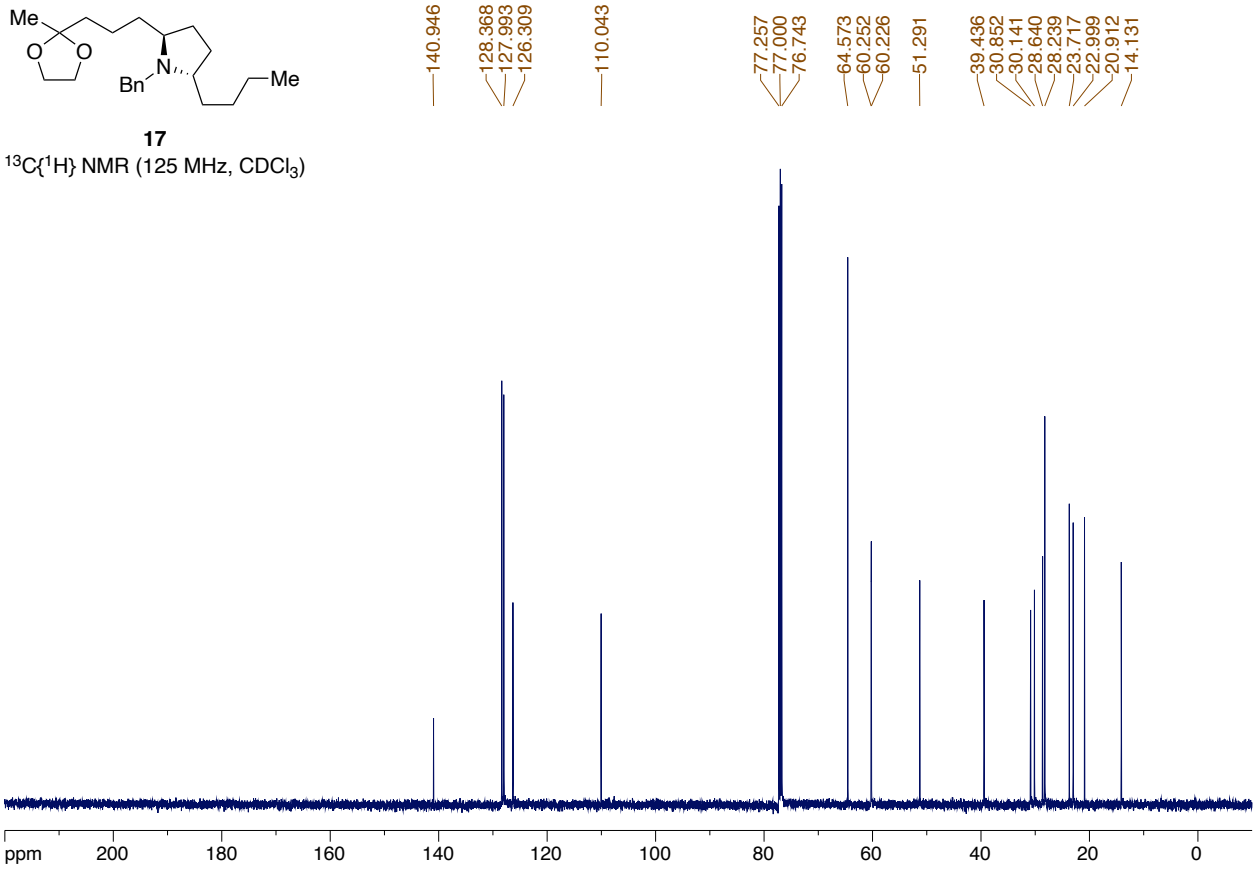
^{1}H NMR (500 MHz, $CDCl_3$)

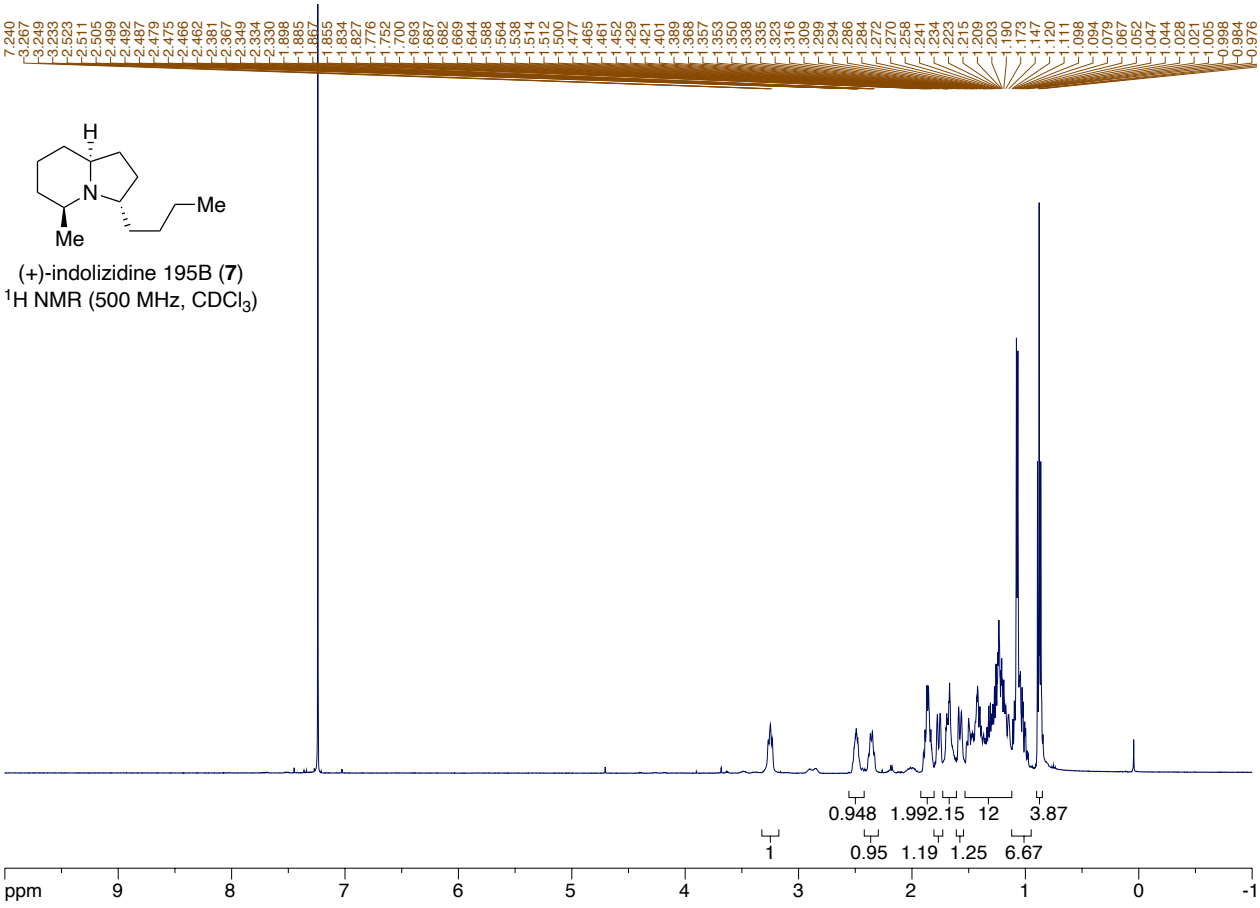


16

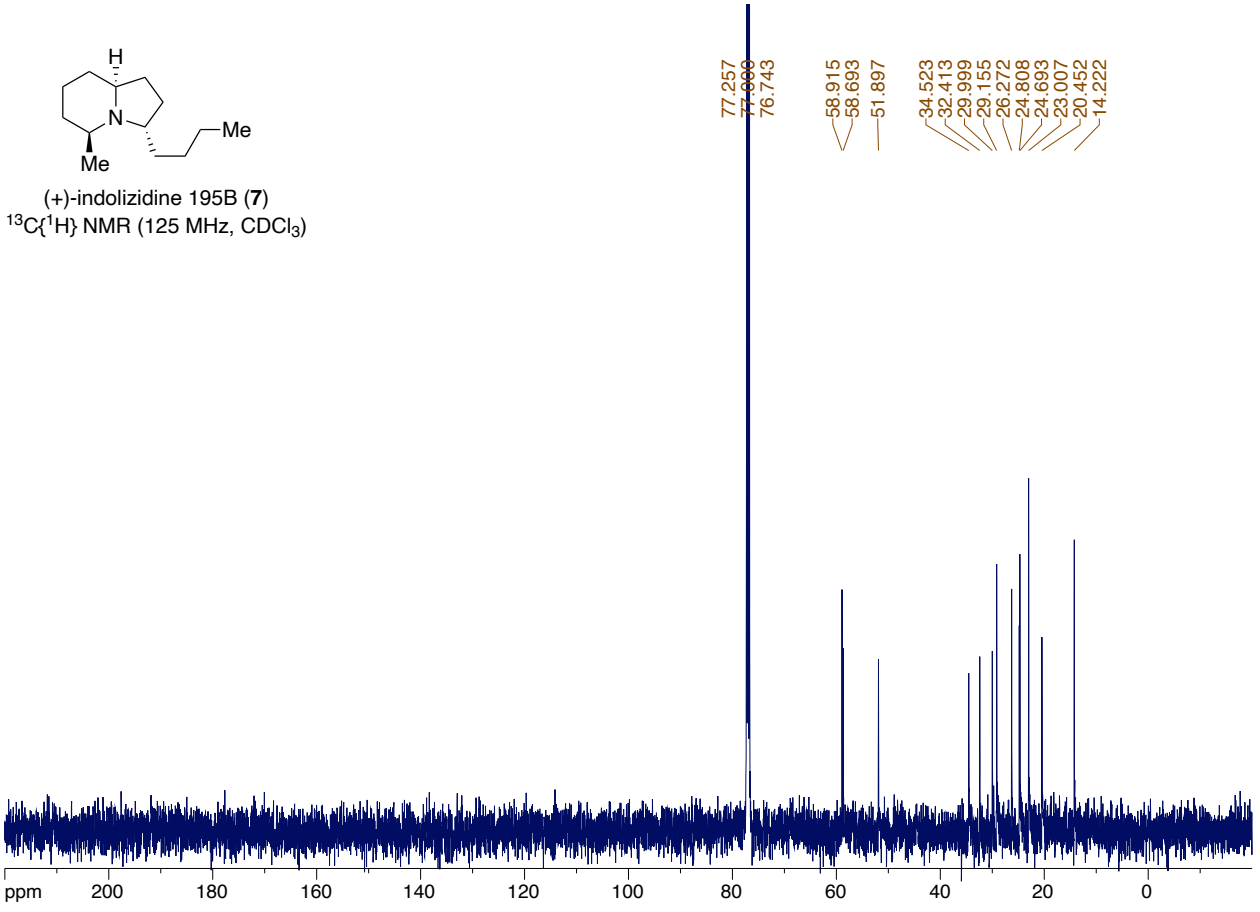
$^{13}C\{^{1}H\}$ NMR (125 MHz, $CDCl_3$)


Me
O
O
N
Bn
Me
17
1H NMR (500 MHz, CDCl3)
2.25
2.04
0.977
4.04
0.979
1
1.99
2.01
1.08
3.1
6.16
10.5
ppm


Me
O
O
N
Bn
Me
17
13C{1H} NMR (125 MHz, CDCl3)
140.946
128.368
127.993
126.309
110.043
77.257
77.000
76.743
64.573
60.252
60.226
51.291
39.436
30.852
30.141
28.640
28.239
23.717
22.999
20.912
14.131
ppm



(+)-indolizidine 195B (**7**)
^{1}H NMR (500 MHz, $CDCl_3$)



(+)-indolizidine 195B (**7**)
^{13}C{^{1}H} NMR (125 MHz, $CDCl_3$)