Enantioselective nickel-catalyzed arylative and alkenylative intramolecular 1,2-allylations of tethered allene–ketones

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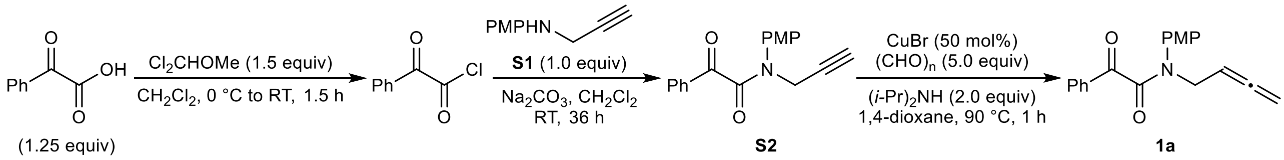
Contents

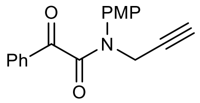
General Information

All air-sensitive reactions were carried out under an inert atmosphere using oven-dried apparatus. 2,2,2-Trifluoroethanol (TFE) was purchased from Alfa Aesar and used as received. MeCN was dried and purified by passage through activated alumina columns using a solvent purification system. All commercially available reagents were used as received unless otherwise stated. Petroleum ether refers to Sigma-Aldrich product 24587 (petroleum ether boiling point 40–60 °C). Thin layer chromatography (TLC) was performed on Merck DF Alufoilien 60F254 0.2 mm precoated plates. Compounds were visualized by exposure to UV light or by dipping the plates into solutions of potassium permanganate or vanillin followed by gentle heating. Column chromatography was carried out using silica gel (Fisher Scientific 60 Å particle size 35-70 micron or Fluorochem 60 Å particle size 40-63 micron). Melting points were recorded on a Gallenkamp melting point apparatus and are uncorrected. The solvent of recrystallization is reported in parentheses. Infrared (IR) spectra were recorded on a Bruker platinum ALPHA FTIR spectrometer on the neat compound using the attenuated total refraction technique. NMR spectra were acquired on Bruker Ascend 400 or Ascend 500 spectrometers. ^{1}H and ^{13}C NMR spectra were referenced to external tetramethylsilane via the residual protonated solvent (^{1}H) or the solvent itself (^{13}C). ^{19}F NMR spectra were referenced through the solvent lock (^{2}H) signal according to the IUPAC-recommended secondary referencing method following Bruker protocols. All chemical shifts are reported in parts per million (ppm). For $CDCl_3$, the shifts are referenced to 7.26 ppm for ^{1}H NMR spectroscopy and 77.16 ppm for ^{13}C NMR spectroscopy. Abbreviations used in the description of resonances are: s (singlet), d (doublet), t (triplet), q (quartet), quin (quintet), sept (septet), br (broad) and m (multiplet) Coupling constants (*J*) are quoted to the nearest 0.1 Hz. ^{13}C NMR assignments were made using the DEPT sequence with secondary pulses at 90° and 135°. High-resolution mass spectra were recorded using electrospray ionization (ESI). X-ray diffraction data were collected at 120 K on an Agilent SuperNova diffractometer using CuKα radiation. Chiral HPLC analysis was performed on an Agilent 1290 series instrument using 4.6 × 250 mm columns. 2-[2-(Diphenylphosphino)ethyl]pyridine was used as an achiral ligand to obtain authentic racemic compounds.

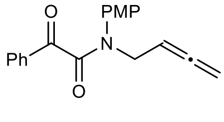
Preparation of Tethered Allene–Ketones

Preparation of Tethered Allene–Ketone 1a



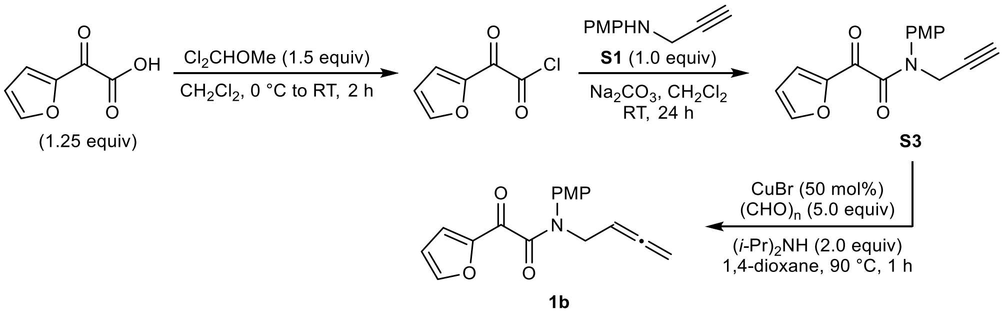


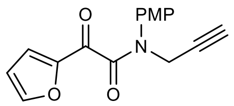
***N*-(4-Methoxyphenyl)-2-oxo-2-phenyl-*N*-(prop-2-yn-1-yl)acetamide (S2).** To a solution of phenylglyoxylic acid (4.69 g, 31.3 mmol) in CH_2Cl_2 (25 mL) at 0 °C under inert atmosphere was added dichloromethyl methyl ether (3.39 mL, 37.5 mmol) dropwise. The mixture was stirred at room temperature for 1.5 h and then diluted with CH_2Cl_2 (80 mL). Na_2CO_3 (26.3 g, 250 mmol) was added, followed by a solution of propargylamine **S1**[1] (4.03 g, 25.0 mmol) in CH_2Cl_2 (20 mL). The mixture was stirred at room temperature for 36 h, quenched with H_2O (100 mL), and extracted with CH_2Cl_2 (2 × 50 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (30% EtOAc/petroleum ether) gave *alkyne* **S2** (6.99 g, 95%) as a white solid. R_f = 0.36 (30% EtOAc/petroleum ether); m.p. 83–85 °C (Et_2O); IR 3309, 3275, 2975, 2840, 1651 (C=O), 1508, 1434, 1255, 1240, 1216, 1167, 1020, 944, 837, 713, 619, 582, 540 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.85–7.82 (2H, m, Ar**H**), 7.60–7.55 (1H, m, Ar**H**), 7.46–7.41 (2H, m, Ar**H**), 7.17–7.13 (2H, m, Ar**H**), 6.76–6.72 (2H, m, Ar**H**), 4.63 (2H, d, *J* = 2.5 Hz, NC**H**$_2$), 3.73 (3H, s, OC**H**$_3$), 2.31 (1H, t, *J* = 2.5 Hz, ≡C**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 190.5 (C), 166.9 (C), 159.7 (C), 134.5 (CH), 133.5 (C), 131.4 (C), 129.9 (2 × CH), 129.5 (2 × CH), 128.9 (2 × CH), 114.7 (CH), 78.1 (C), 73.2 (CH), 55.5 (CH_3), 38.2 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{18}H_{16}NO_3]^+$ $[M + H]^+$: 294.1125, found: 294.1132.



***N*-(Buta-2,3-dien-1-yl)-*N*-(4-methoxyphenyl)-2-oxo-2-phenylacetamide (1a).** To a solution of alkyne **S2** (5.86 g, 20.0 mmol) in 1,4-dioxane (100 mL) at room temperature under inert atmosphere was added paraformaldehyde (3.00 g, 100 mmol), CuBr (1.43 g, 10.0 mmol), and diisopropylamine (5.61 mL, 40.0 mmol). The reaction was heated at 90 °C for 1 h, cooled to room temperature, filtered through a pad of celite using EtOAc as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **1a** (2.82 g, 46%) as a 10:1 mixture of rotamers as a pale yellow solid. R_f = 0.42 (30% EtOAc/petroleum ether); m.p. 50–53 °C (EtOAc); IR 2958, 2926, 1960 (C=C=C), 1656 (C=O), 1592, 1509, 1450, 1427, 1297, 1242, 1211, 1169, 1025, 945, 838, 814, 756, 732, 717, 688, 656, 550, 445 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 7.87–7.84 (2H, m, Ar**H**), 7.59–7.55 (1H, m, Ar**H**), 7.46–7.41 (2H, m, Ar**H**), 7.08–7.04 (2H, m, Ar**H**), 6.74–6.70 (2H, m, Ar**H**), 5.32 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.81 (2H, dt, *J* = 6.6, 2.7 Hz, =C**H**$_2$), 4.45 (2H, dt, *J* = 6.6, 2.7 Hz, NC**H**$_2$), 3.72 (3H, s, OC**H**$_3$); *minor rotamer*: δ 8.07–8.05 (2H, m, Ar**H**), 7.69–7.64 (1H, m, Ar**H**), 7.54–7.52 (2H, m, Ar**H**), 7.33–7.30 (2H, m, Ar**H**), 7.00–6.96 (2H, m, Ar**H**), 5.14 (1H, quin, *J* = 6.5 Hz, NCH_2C**H**), 4.59 (2H, dt, *J* = 6.6, 2.7 Hz, =C**H**$_2$), 4.20 (2H, dt, *J* = 6.5, 2.7 Hz, NC**H**$_2$CH), 3.84 (3H, s, OC**H**$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 209.8 (C), 191.0 (C), 167.1 (C), 159.4 (C), 134.3 (CH), 133.6 (C), 132.1 (C), 129.8 (2 × CH), 129.5 (2 × CH), 128.9 (2 × CH), 114.6 (2 × CH), 85.9 (CH), 77.0 (CH_2), 55.5 (CH_3), 47.9 (CH_2); *observable signals of minor rotamer*: δ 130.1 (2 × CH), 129.1 (2 × CH), 128.3 (2 × CH), 114.8 (CH); HRMS (ESI) Exact mass calculated for $[C_{19}H_{18}NO_3]^+$ $[M+H]^+$: 308.1281, found: 308.1278.

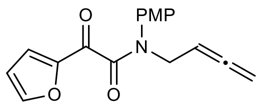
Preparation of Tethered Allene–Ketone 1b





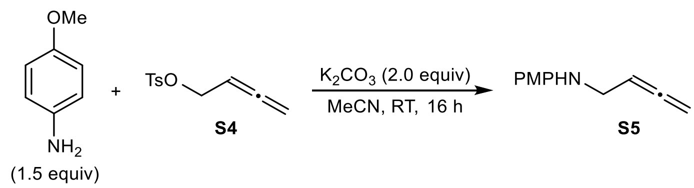
2-(Furan-2-yl)-*N*-(4-methoxyphenyl)-2-oxo-*N*-(prop-2-yn-1-yl)acetamide (S3). To a solution of α-oxo-2-furanacetic acid (1.09 g, 7.76 mmol) in CH_2Cl_2 (15 mL) at 0 °C under inert atmosphere was added dichloromethyl methyl ether (0.84 mL, 9.31 mmol) dropwise. The mixture was stirred at room temperature for 2 h and then diluted with CH_2Cl_2 (5 mL). Na_2CO_3 (6.58 g, 62.1 mmol) was added, followed by a solution of propargylamine **S1**[1] (1.00 g, 6.21 mmol) in CH_2Cl_2 (5 mL). The mixture was stirred at room temperature for 24 h, quenched with H_2O (20 mL), and extracted with CH_2Cl_2 (2 × 20 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (30% EtOAc/petroleum ether) gave *alkyne* **S3** (1.74 g, 99%) as a pale yellow solid. R_f = 0.29 (30% EtOAc/petroleum ether); m.p. 55–59 °C (Et_2O); IR 3283, 3125, 2835, 1640 (C=O), 1509, 1459, 1390, 1214, 1164, 1023, 928, 881, 801, 768, 724, 617, 585, 540, 408 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.63 (1H, dd, *J* = 1.7, 0.8 Hz, Ar**H**), 7.27–7.26 (1H, m, Ar**H**), 7.21–7.17 (2H, m, Ar**H**), 6.81–6.77 (2H, m, Ar**H**), 6.54 (1H, dd, *J* = 3.6, 1.7 Hz, Ar**H**), 4.58 (2H, d, *J* = 2.5 Hz, NC**H**$_2$), 3.75 (3H, s, OC**H**$_3$), 2.28 (1H, t, *J* = 2.5 Hz, ≡C**H**); ^{13}C NMR (101 MHz, $CDCl_3$)

δ 165.4 (C), 159.8 (C), 150.3 (C), 148.4 (2 × CH), 131.4 (C), 129.6 (2 × CH), 121.4 (C), 114.7 (2 ×2 CH), 112.9 (CH), 77.9 (C), 73.2 (CH), 55.5 (CH_3), 38.4 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{16}H_{13}NNaO_4]^+$ $[M+Na]^+$: 306.0737, found: 306.0740.



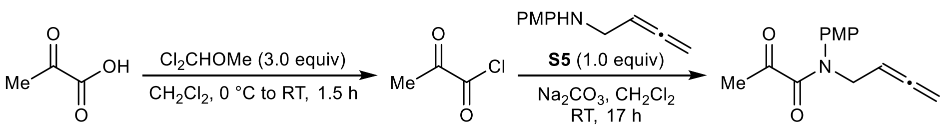
***N*-(Buta-2,3-dien-1-yl)-2-(furan-2-yl)-N-(4-methoxyphenyl)-2-oxoacetamide (1b).** To a solution of alkyne **S3** (708 mg, 2.50 mmol) in 1,4-dioxane (12.5 mL) at room temperature under inert atmosphere was added paraformaldehyde (375 mg, 12.5 mmol), CuBr (287 mg, 2.00 mmol), and diisopropylamine (0.70 mL, 5.0 mmol). The reaction was heated at 90 °C for 1 h, cooled to room temperature, filtered through a pad of celite using EtOAc as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (40% EtOAc/petroleum ether) gave *allene* **1b** (293 mg, 39%) as a 10:1 mixture of rotamers as a pale yellow solid. R_f = 0.41 (40% EtOAc/petroleum ether); m.p. 79–81 °C (Et_2O); IR 3116, 1967 (C=C=C), 1650 (C=O), 1557, 1456, 1436, 1388, 1248, 1165, 1023, 960, 839, 805, 751, 670, 622, 592, 548, 437 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 7.61 (1H, dd, *J* = 1.6, 0.7 Hz, Ar**H**), 7.28–7.25 (1H, m, Ar**H**), 7.12–7.08 (2H, m, Ar**H**), 6.79–6.75 (2H, m, Ar**H**), 6.53 (1H, dd, *J* = 3.6, 1.7 Hz, Ar**H**), 5.28 (1H, quin, *J* = 6.7 Hz, CH_2C**H**=), 4.78 (2H, dt, *J* = 6.6, 2.6 Hz, =C**H**$_2$), 4.40 (2H, dt, *J* = 6.6, 2.6 Hz, NC**H**$_2$), 3.75 (3H, s, OC**H**$_3$); *minor rotamer*: δ 7.75 (1H, dd, *J* = 1.7, 0.7 Hz, Ar**H**), 7.43 (1H, dd, *J* = 3.6, 0.8 Hz, Ar**H**), 7.28–7.27 (2H, m, Ar**H**), 6.98–6.94 (2H, m, Ar**H**), 6.63 (1H, dd, *J* = 3.6, 1.6 Hz, ArC**H**), 5.20 (1H, quin, *J* = 6.5 Hz, CH_2C**H**=), 4.66 (2H, dt, *J* = 6.6, 2.7 Hz, =C**H**$_2$), 4.29 (2H, dt, *J* = 6.4, 2.7 Hz, NC**H**$_2$), 3.83 (3H, s, OC**H**$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 209.8 (C), 178.3 (C), 165.7 (C), 159.5 (C), 150.5 (C), 148.2 (CH), 132.2 (C), 129.6 (2 × CH), 121.1 (CH), 114.7 (2 × CH), 112.8 (CH), 85.7 (CH), 76.9 (CH_2), 55.5 (CH_3), 48.1 (CH_2); *observable signals of minor rotamer*: δ 148.9 (CH), 128.1 (CH), 114.7 (CH), 113.1 (CH), 110.1 (CH), 87.2 (CH), 55.6 (CH_3), 50.4 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{17}H_{16}NO_4]^+$ $[M+H]^+$: 298.1074, found: 298.1077.

***N*-(Buta-2,3-dien-1-yl)-4-methoxyaniline (S5)**



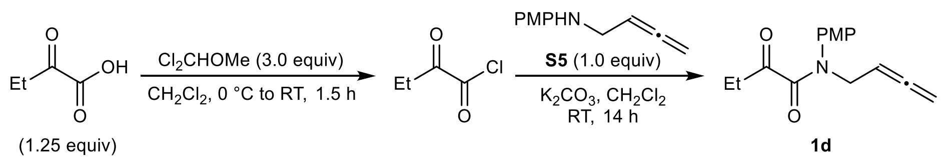
To a solution of *p*-anisidine (3.14 g, 25.5 mmol) in MeCN (68 mL) at room temperature under inert atmosphere was added allylic tosylate **S4**[2] (3.82 g, 17.0 mmol) and K_2CO_3 (4.70 g, 34.0 mmol), and the mixture was stirred at room temperature for 16 h. The mixture was partitioned between Et_2O (50 mL) and saturated aqueous $NaHCO_3$ solution (50 mL), and the organic layer was separated and washed with saturated aqueous $NaHCO_3$ solution (2 × 30 mL), dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **S5** (1.50 g, 50%) as a pale yellow oil. R_f = 0.48 (20% EtOAc/petroleum ether); IR 3387 (NH), 2831, 1954, 1617, 1509, 1463, 1407, 1294, 1232, 1178, 1116, 1034, 847, 817, 517 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 6.83–6.78 (2H, m, Ar**H**), 6.64–6.60 (2H, m, Ar**H**), 5.33–5.25 (1H, m, NCH_2C**H**), 4.83 (2H, dt, *J* = 6.6, 3.3 Hz, =C**H**$_2$), 3.76 (3H, s, OC**H**$_3$), 3.73 (2H, dt, *J* = 6.2, 3.2 Hz, NC**H**$_2$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 208.3 (C), 152.4 (C), 142.0 (C), 114.9 (2 × CH), 114.7 (2 × CH), 88.9 (CH), 77.0 (CH_2), 55.9 (CH_3), 43.3 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{11}H_{14}NO]^+$ $[M+H]^+$: 176.1070, found: 176.1071.

N-(Buta-2,3-dien-1-yl)-*N*-(4-methoxyphenyl)-2-oxopropanamide (1c)



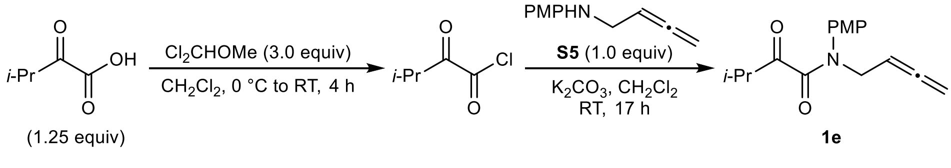
To a solution of pyruvic acid (95.1 mg, 1.08 mmol) in CH_2Cl_2 (1 mL) at 0 °C under inert atmosphere was added dichloromethyl methyl ether (117 μL, 1.30 mmol) dropwise. The mixture was stirred at room temperature for 1.5 h and then diluted with CH_2Cl_2 (3.5 mL). Na_2CO_3 (922 mg, 8.70 mmol) was added, followed by a solution of allenylamine **S5** (152 mg, 0.87 mmol) in CH_2Cl_2 (0.5 mL). The mixture was stirred at room temperature for 17 h, quenched with H_2O (5 mL), and extracted with CH_2Cl_2 (2 × 5 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (40% EtOAc/petroleum ether) gave *allene* **1c** (139 mg, 65%) as a 14:1 mixture of rotamers as a white solid. R_f = 0.42 (40% EtOAc/petroleum ether); m.p. 38–39 °C (Et_2O); IR 3010, 2923, 1955 (C=C=C), 1707, 1641 (C=O), 1509, 1433, 1364, 1302, 1248, 1228, 1164, 1053, 1028, 945, 845, 731, 629, 580, 549, 497, 461, 428 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 7.13–7.09 (2H, m, Ar**H**), 6.89–6.85 (2H, m, Ar**H**), 5.21 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.76 (2H, dt, *J* = 6.6, 2.7 Hz, =C**H**$_2$), 4.30 (2H, dtd, *J* = 6.6, 2.7 Hz, NC**H**$_2$), 3.80 (3H, s, OC**H**$_3$), 2.17 (3H, s, C**H**$_3$C=O); *minor rotamer*: δ 7.19 (2H, d, *J* = 8.9 Hz, Ar**H**), 6.92 (2H, d, *J* = 8.9 Hz, Ar**H**), 5.28–5.26 (1H, m, CH_2C**H**=), 4.82–4.81 (2H, m, =C**H**$_2$), 4.27–4.26 (2H, m, NC**H**$_2$), 3.80 (3H, s, OC**H**$_3$), 2.49 (3H, s, C**H**$_3$C=O); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 209.7 (C), 198.2 (C), 167.3 (C), 159.6 (C), 132.4 (C), 129.2 (2 × CH), 114.8 (2 × CH), 85.7 (CH), 76.9 (CH_2), 55.6 (CH_3), 47.9 (CH_2), 28.0 (CH_3); *observable signals of minor rotamer*: δ 128.0 (2 × CH), 114.6 (2 × CH), 88.0 (CH), 78.0 (CH_2), 49.9 (CH_2), 27.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{14}H_{16}NO_3]^+$ $[M+H]^+$: 246.1125, found: 246.1127.

N-(Buta-2,3-dien-1-yl)-N-(4-methoxyphenyl)-2-oxobutanamide (1d)



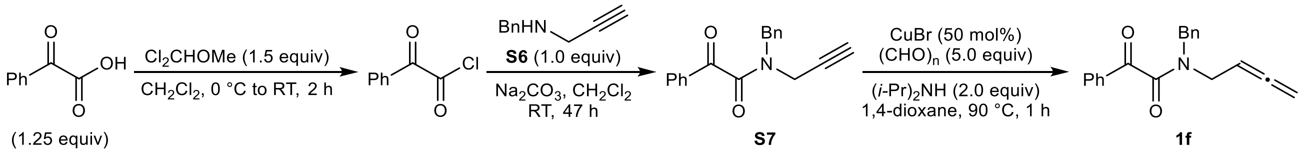
To a solution of 2-ketobutyric acid (383 mg, 3.75 mmol) in CH_2Cl_2 (1.5 mL) at 0 °C under inert atmosphere was added dichloromethyl methyl ether (0.41 mL, 4.5 mmol) dropwise. The mixture was stirred for 5 h at room temperature and then diluted with CH_2Cl_2 (8 mL). K_2CO_3 (2.07 g, 15.0 mmol) was added followed by a solution of allenylamine **S5** (263 mg, 1.50 mmol) in CH_2Cl_2 (0.5 mL). The mixture was stirred at room temperature for 14 h, quenched with H_2O (50 mL), and extracted with CH_2Cl_2 (2 × 50 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **1d** (332 mg, 85%) as a 14:1 mixture of rotamers as a pale yellow amorphous solid. R_f = 0.30 (20% EtOAc/petroleum ether); IR 2981, 1955 (C=C=C), 1714, 1645 (C=O), 1509, 1441, 1404, 1295, 1248, 1217, 1171, 1116, 1028, 835, 725, 613, 544 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 7.13-7.08 (2H, m, Ar**H**), 6.88-6.84 (2H, m, Ar**H**), 5.21 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.75 (2H, dt, *J* = 6.7, 2.7 Hz, =C**H**$_2$), 4.29 (2H, dt, *J* = 6.6, 2.7 Hz, NC**H**$_2$), 3.80 (3H, s, OC**H**$_3$), 2.52 (2H, q, *J* = 7.3 Hz, CH_3C**H**$_2$), 0.91 (3H, t, *J* = 7.3 Hz, C**H**$_3$$CH_2$); *minor rotamer*: δ 7.19–7.11 (2H, m, Ar**H**), 6.93–6.91 (2H, m, Ar**H**), 5.24–5.20 (1H, m, CH_2C**H**=), 4.79 (2H, dt, *J* = 6.4, 2.8 Hz, =C**H**$_2$), 4.23 (2H, dt, *J* = 6.0, 2.8 Hz, NC**H**$_2$), 3.81 (3H, s, OC**H**$_3$), 2.89 (2H, q, *J* = 7.2 Hz, CH_3C**H**$_2$), 1.18 (3H, t, *J* = 7.2 Hz, C**H**$_3$$CH_2$); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 209.7 (C), 201.6 (C), 167.7 (C), 159.5 (C), 132.4 (C), 129.3 (2 × CH), 114.7 (2 × CH), 85.7 (CH), 76.9 (CH_2), 55.6 (CH_3), 47.9 (CH_2), 33.8 (CH_2), 6.9 (CH_3); *observable signals of minor rotamer*: δ 209.1 (C), 128.1 (2 × CH), 114.6 (2 × CH), 87.7 (CH), 77.8 (CH_2), 55.6 (CH_3), 50.0 (CH_2), 33.4 (CH_2), 7.1 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{15}H_{18}NO_3]^+$ $[M+H]^+$: 260.1281, found: 260.1286.

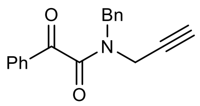
N-(Buta-2,3-dien-1-yl)-N-(4-methoxyphenyl)-3-methyl-2-oxobutanamide (1e)



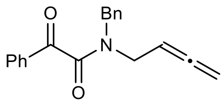
To a solution of 3-methyl-2-oxobutyryl acid (730 mg, 6.29 mmol) in CH_2Cl_2 (6.5 mL) at 0 °C under inert atmosphere was added dichloromethyl methyl ether (0.68 mL, 7.5 mmol) dropwise. The mixture was stirred at room temperature for 4 h and then diluted with CH_2Cl_2 (10 mL). K_2CO_3 (3.46 g, 25.0 mmol) was added followed by a solution of allenylamine **S5** (438 mg, 2.50 mmol) in CH_2Cl_2 (0.5 mL). The mixture was stirred at room temperature for 17 h, quenched with H_2O (10 mL), and extracted with CH_2Cl_2 (2 × 10 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **1e** (205 mg, 30%) as a 14:1 mixture of rotamers as a pale yellow oil. R_f = 0.39 (20% EtOAc/petroleum ether); IR 2971, 1956 (C=C=C), 1712, 1644 (C=O), 1510, 1463, 1441, 1296, 1248, 1217, 1027, 836, 730, 619, 554 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 7.14–7.10 (2H, m, Ar**H**), 6.87–6.83 (2H, m, Ar**H**), 5.22 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.75 (2H, dt, *J* = 6.7, 2.6 Hz, =C**H**$_2$), 4.30 (2H, dt, *J* = 6.7, 2.7 Hz, NC**H**$_2$), 3.80 (3H, s, OC**H**$_3$), 2.78 (1H, sept, *J* = 6.9 Hz, $(CH_3)_2C$**H**), 0.98 (6H, d, *J* = 7.0 Hz, (C**H**$_3$)$_2$CH); *minor rotamer*: δ 7.18–7.16 (2H, m, Ar**H**), 6.94–6.92 (2H, m, Ar**H**), 5.22 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.74–4.72 (2H, m, =C**H**$_2$), 4.19–4.17 (2H, m, NC**H**$_2$), 3.81 (3H, s, OC**H**$_3$), 3.27 (1H, sept, *J* = 7.0 Hz, $(CH_3)_2C$**H**), 1.23 (6H, d, *J* = 7.0 Hz, (C**H**$_3$)$_2$CH); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 209.7 (C), 204.5 (C), 167.4 (C), 159.4 (C), 132.4 (C), 129.7 (2 × CH), 114.5 (2 × CH), 85.8 (CH), 76.9 (CH_2), 55.55 (CH_3), 48.1 (CH_2), 38.1 (CH), 17.3 (2 × CH_3); *observable signals of minor rotamer*: δ 209.4 (C), 128.3 (2 × CH), 114.7 (2 × CH), 87.1 (CH), 77.4 (CH_2), 55.59 (CH_3), 50.0 (CH_2), 37.8 (CH), 17.2 (2 × CH_3); HRMS (ESI) Exact mass calculated for $[C_{16}H_{20}NO_3]^+$ $[M+H]^+$: 274.1438, found: 274.1442.

Preparation of Tethered Allene–Ketone 1f



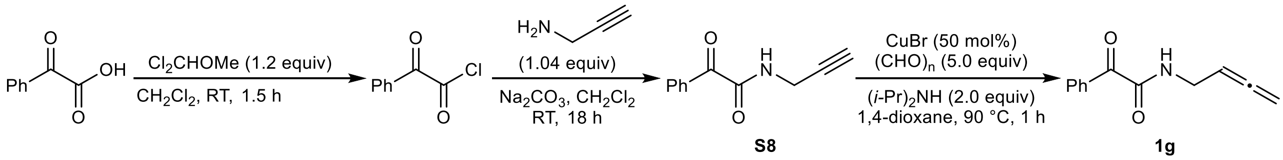


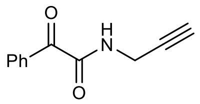
***N*-Benzyl-2-oxo-2-phenyl-*N*-(prop-2-yn-1-yl)acetamide (S7).** To a solution of phenylglyoxylic acid (2.82 g, 18.8 mmol) in CH_2Cl_2 (20 mL) at 0 °C under inert atmosphere was added dichloromethyl methyl ether (2.04 mL, 22.5 mmol) dropwise. The mixture was stirred at room temperature for 1.5 h and then diluted with CH_2Cl_2 (50 mL). Na_2CO_3 (15.9 g, 150 mmol) was added followed by a solution of propargylamine **S6**[3] (2.18 g, 15.0 mmol) in CH_2Cl_2 (5 mL). The reaction mixture was stirred at room temperature for 47 h, quenched with H_2O (30 mL), and extracted with CH_2Cl_2 (2 × 30 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo* to leave *alkyne* **S7** (4.15 g, >99%) as a 1.7:1 mixture of rotamers as a pale yellow oil. R_f = 0.46 (30% EtOAc/petroleum ether); IR 3287, 2978, 1817, 1678, 1643 (C=O), 1440, 1256, 1203, 1175, 947, 722, 696, 660, 596, 460 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 8.00-7.98 (2H, m, Ar**H**), 7.67-7.63 (2H, m, Ar**H**), 7.54-7.49 (3H, m, Ar**H**), 7.34-7.31 (3H, m, Ar**H**), 4.53 (2H, s, C**H**$_2$Ph), 4.24 (2H, d, *J* = 2.5 Hz, C**H**$_2$C≡), 2.35 (1H, t, *J* = 2.5 Hz, ≡C**H**); *minor rotamer*; δ 8.14-8.12 (1H, m, Ar**H**), 8.00-7.98 (2H, m, Ar**H**), 7.54-7.49 (1H, m, Ar**H**), 7.48-7.46 (1H, m, Ar**H**), 7.41-7.37 (4H, m, Ar**H**), 7.34-7.31 (1H, m, Ar**H**), 4.89 (2H, s, C**H**$_2$Ph), 3.91 (2H, d, *J* = 2.5 Hz, C**H**$_2$C≡), 2.27 (1H, t, *J* = 2.5 Hz, ≡C**H**); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 190.8 (C), 166.9 (C), 135.1 (CH), 134.2 (C), 133.1 (C), 130.0 (CH), 129.8 (2 × CH), 129.2 (2 × CH), 128.9 (2 × CH), 128.4 (2 × CH), 77.4 (C), 73.1 (CH), 50.3 (CH_2), 32.2 (CH_2); *minor rotamer*: δ 190.7 (C), 167.0 (C), 135.2 (C), 135.0 (CH), 133.0 (C), 130.7 (CH), 129.1 (2 × CH), 129.0 (CH), 128.9 (CH), 128.7 (2 × CH), 128.5 (CH), 128.2 (CH), 77.0 (C), 74.1 (CH), 46.8 (CH_2), 36.3 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{18}H_{16}NO_2]^+$ $[M+H]^+$: 278.1176, found: 278.1176.



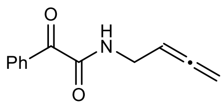
***N*-Benzyl-*N*-(buta-2,3-dien-1-yl)-2-oxo-2-phenylacetamide (1f).** To a solution of alkyne **S7** (693 mg, 2.50 mmol) in 1,4-dioxane (12.5 mL) at room temperature under inert atmosphere was added paraformaldehyde (375 mg, 12.5 mmol), CuBr (287 mg, 2.00 mmol), and diisopropylamine (0.70 mL, 5.0 mmol). The reaction was heated at 90 °C for 1 h, cooled to room temperature, filtered through a pad of celite using EtOAc as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **1f** (348 mg, 48%) as a 1.3:1 mixture of rotamers as a colorless oil. R_f = 0.52 (30% EtOAc/petroleum ether); IR 3063, 2929, 1955 (C=C=C), 1677, 1637 (C=O), 1595, 1446, 1360, 1316, 1259, 1202, 1175, 950, 850, 722, 699, 613, 519, 459 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) *major rotamer*: δ 8.02–7.97 (2H, m, Ar**H**), 7.67–7.62 (2H, m, Ar**H**), 7.53–7.49 (2H, m, Ar**H**), 7.39–7.25 (4H, m, Ar**H**), 5.04 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.77 (2H, s, C**H**$_2$Ph), 4.74 (2H, dt, *J* = 6.6, 2.7 Hz, =C**H**$_2$), 3.74 (2H, dt, *J* = 6.6, 2.7 Hz, C**H**$_2$CH=); *minor rotamer*: δ 8.02-7.97 (2H, m, Ar**H**), 7.53–7.49 (2H, m, Ar**H**), 7.39–7.25 (6H, m, Ar**H**), 5.23 (1H, quin, *J* = 6.5 Hz, CH_2C**H**=), 4.87 (2H, dt, *J* = 6.6, 2.8 Hz, =C**H**$_2$), 4.42 (2H, s, C**H**$_2$Ph), 4.04 (2H, dt, *J* = 6.5, 2.8 Hz, C**H**$_2$CH=); ^{13}C NMR (101 MHz, $CDCl_3$) *major rotamer*: δ 209.6 (C), 191.2 (C), 167.3 (C), 135.0 (C), 134.8 (CH), 133.3 (C), 129.9 (2 × CH), 129.1 (2 × CH), 129.0 (2 × CH), 128.8 (2 × CH), 128.3 (CH), 86.1 (CH), 77.2 (CH_2), 46.9 (CH_2), 45.7 (CH_2); *observable signals of minor rotamer*: δ 209.7 (C), 191.4 (C), 167.2 (C), 136.1 (C), 135.0 (CH), 129.9 (2 × CH), 129.1 (2 × CH), 128.9 (2 × CH), 128.3 (2 × CH), 128.0 (CH), 110.1 (C), 85.6 (CH), 77.4 (CH_2), 50.7 (CH_2), 41.8 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{19}H_{18}NO_2]^+$ $[M+H]^+$: 292.1332, found: 292.1333.

Preparation of Tethered Allene–Ketone 1g



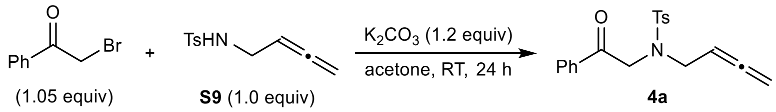


2-Oxo-2-phenyl-N-(prop-2-yn-1-yl)acetamide (S8). To a solution of phenylglyoxylic acid (450 mg, 3.00 mmol) in CH_2Cl_2 (3 mL) under inert atmosphere was added dichloromethyl methyl ether (0.33 mL, 3.60 mmol) dropwise. The mixture was stirred at room temperature for 1.5 h and then diluted with CH_2Cl_2 (6 mL). Na_2CO_3 (2.11 g, 20.0 mmol) was added, followed by a solution of propargylamine (0.20 mL, 3.12 mmol) in CH_2Cl_2 (1 mL). The mixture was stirred at room temperature for 18 h, quenched with H_2O (10 mL), and extracted with CH_2Cl_2 (2 × 10 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (15% EtOAc/petroleum ether) gave *alkyne* **S8** (475 mg, 85%) as a white solid. R_f = 0.23 (15% EtOAc/petroleum ether); m.p. 87–88 °C (Et_2O); IR 3274 (NH), 1678 (C=O), 1643, 1593, 1550, 1216, 1176, 675, 621, 559, 464 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.35 (2H, d, J = 7.6 Hz, Ar**H**), 7.64 (1H, t, J = 7.4 Hz, Ar**H**), 7.49 (2H, t, J = 7.7 Hz, Ar**H**), 7.28 (1H, br s, N**H**), 4.19 (2H, dd, J = 5.4, 2.4 Hz, NC**H**$_2$), 2.30 (1H, t, J = 2.2 Hz, ≡C**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 186.9 (C), 161.3 (C), 134.8 (CH), 133.2 (C), 131.4 (2 × CH), 128.7 (2 × CH), 78.5 (C), 72.5 (CH), 29.4 (CH_2); HRMS (ESI) Exact mass calcd for $[C_{11}H_9NO_2Na]^+$ $[M + Na]^+$: 210.0525, found: 210.0529.



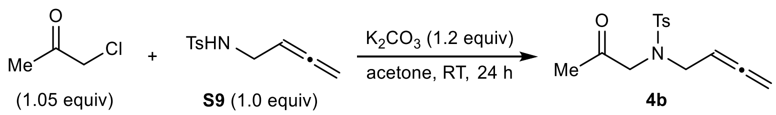
***N*-(Buta-2,3-dien-1-yl)-2-oxo-2-phenylacetamide (1g).** To a solution of alkyne **S8** (407 mg, 2.20 mmol) in 1,4-dioxane (11 mL) at room temperature under inert atmosphere was added paraformaldehyde (327 mg, 10.9 mmol), CuBr (158 mg, 1.10 mmol), and diisopropylamine (0.62 mL, 4.40 mmol). The reaction was heated at 90 °C for 1 h, cooled to room temperature, filtered through a pad of celite using EtOAc as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (30% EtOAc/petroleum ether) gave *allene* **1g** (112 mg, 25%) as a pale yellow amorphous solid. R_f = 0.47 (30% EtOAc/petroleum ether); IR 3375 (NH), 1960, 1655 (C=O), 1514, 1449, 1277, 1201, 1178, 864, 746, 690, 615, 494 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 8.37–8.31 (2H, m, Ar**H**), 7.66–7.59 (1H, m, Ar**H**), 7.48 (2H, t, J = 7.7 Hz, Ar**H**), 7.22 (1H, br s, N**H**), 5.28 (1H, quin, J = 6.4 Hz, CH_2C**H**=), 4.90 (2H, dt, J = 6.5, 3.2 Hz, =C**H**$_2$), 3.99 (2H, app tt, J = 6.0, 3.2 Hz, NC**H**$_2$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 208.4 (C), 187.6 (C), 161.6 (C), 134.6 (CH), 133.4 (C), 131.3 (2 × CH), 128.6 (2 × CH), 87.2 (CH), 78.2 (CH_2), 37.6 (CH_2); HRMS (ESI) Exact mass calcd for $[C_{12}H_{12}NO_2]^+$ $[M+H]^+$: 202.0863, found: 202.0866.

N-(Buta-2,3-dien-1-yl)-4-methyl-N-(2-oxo-2-phenylethyl)benzenesulfonamide (4a)[4]



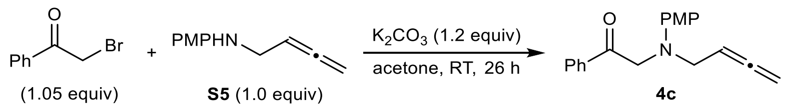
To a solution of sulfonamide **S9**[5] (400 mg, 1.79 mmol) in acetone (10 mL) was added K_2CO_3 (297 mg, 2.15 mmol) followed by 2-bromoacetophenone (374 mg, 1.88 mmol), and the resulting suspension was stirred at room temperature for 24 h. The reaction was quenched with H_2O (10 mL) and the acetone was removed under reduced pressure. The resulting aqueous phase was extracted with EtOAc (3 × 10 mL) and the combined organic layers were washed with brine (10 mL), dried ($MgSO_4$), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/petroleum ether to 20% EtOAc/petroleum ether) gave *allene* **4a** (470 mg, 78%) as a white solid that displayed spectroscopic data consistent with those reported previously.[4] R_f = 0.82 (20% EtOAc/petroleum ether); m.p. 69–72 °C (Et_2O); IR 2961, 1956 (C=C=C), 1733, 1686 (C=O), 1596, 1450, 1321, 1296, 1193, 1173, 991, 847, 685, 538 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.96–7.91 (2H, m, Ar**H**), 7.76 (2H, d, *J* = 8.3 Hz, Ar**H**), 7.62–7.58 (1H, m, Ar**H**), 7.50–7.47 (2H, m, Ar**H**), 7.31 (2H, d, *J* = 8.1 Hz, Ar**H**), 4.99 (1H, quin, *J* = 6.9 Hz, $CH_2C\mathbf{H}$=), 4.77 (2H, s, O=C$C\mathbf{H}_2$), 4.63 (2H, dt, *J* = 6.6, 2.4 Hz, =$C\mathbf{H}_2$), 3.94 (2H, dt, *J* = 7.3, 2.5 Hz, N$C\mathbf{H}_2$CH), 2.43 (3H, s, $C\mathbf{H}_3$); ^{13}C NMR (126 MHz, $CDCl_3$) δ 209.9 (C), 194.0 (C), 143.6 (C), 137.0 (C), 135.2 (C), 133.9 (CH), 129.8 (2 × CH), 129.0 (2 × CH), 128.1 (2 × CH), 127.6 (2 × CH), 85.8 (CH), 76.4 (CH_2), 52.1 (CH_2), 47.4 (CH_2), 21.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{19}H_{20}NO_3S]^+$ $[M+H]^+$: 342.1158, found: 342.1169.

N-(Buta-2,3-dien-1-yl)-4-methyl-N-(2-oxopropyl)benzenesulfonamide (4b)[6]



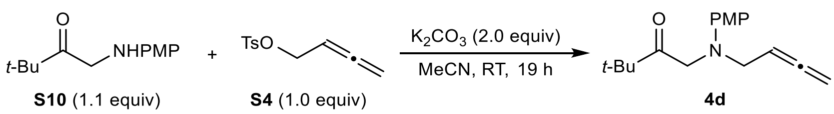
To a solution of sulfonamide **S9**[5] (558 mg, 2.50 mmol) in acetone (10 mL) was added K_2CO_3 (691 mg, 5.00 mmol) followed by chloroacetone (209 µL, 2.63 mmol), and the resulting suspension was stirred at room temperature for 24 h. The reaction was quenched with H_2O (10 mL) and the acetone was removed under reduced pressure. The resulting aqueous phase was extracted with EtOAc (3 × 10 mL) and the combined organic layers were washed with brine (10 mL), dried ($MgSO_4$), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/petroleum ether to 20% EtOAc/petroleum ether) gave *allene* **4b** (542 mg, 78%) as a colorless oil that displayed spectroscopic data consistent with those reported previously.[6] R_f = 0.32 (20% EtOAc/petroleum ether); IR 2924, 2928, 2967, 1955 (C=C=C), 1733 (C=O), 1597, 1416, 1153, 1098, 986, 851, 760, 658, 545, 527 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.70 (2H, d, *J* = 8.3 Hz, Ar**H**), 7.31 (2H, d, *J* = 8.1 Hz, Ar**H**), 4.97 (1H, q, *J* = 7.0 Hz, $CH_2C\mathbf{H}$=), 4.71 (2H, dt, *J* = 6.6, 2.4 Hz, =$C\mathbf{H}_2$), 3.93 (2H, s, O=CC**H**$_2$), 3.83 (2H, dt, *J* = 7.4, 2.4 Hz, NC**H**$_2$CH), 2.43 (3H, s, C**H**$_3$C=O), 2.21 (3H, s, ArC**H**$_3$); ^{13}C NMR (126 MHz, CDCl$_3$) δ 210.1 (C), 204.3 (C), 143.9 (C), 136.3 (C), 129.9 (2 × CH), 127.6 (2 × CH), 85.5 (CH), 76.6 (CH$_2$), 56.0 (CH$_2$), 48.2 (CH$_2$), 27.2 (CH$_3$), 21.7 (CH$_3$); HRMS (ESI) Exact mass calculated for $[C_{14}H_{17}NaNO_3S]^+$ $[M+Na]^+$: 302.0821, found: 302.0822.

2-[Buta-2,3-dien-1-yl(4-methoxyphenyl)amino]-1-phenylethan-1-one (4c)



To a solution of allenylamine **S5** (351 mg, 2.00 mmol) in acetone (10 mL) was added K_2CO_3 (553 mg, 4.00 mmol) followed by bromoacetophenone (478 mg, 2.40 mmol), and the resulting suspension was stirred at room temperature for 26 h. The reaction was quenched with H_2O (10 mL) and the acetone was removed under reduced pressure. The resulting aqueous phase was extracted with EtOAc (3 × 10 mL) and the combined organic layers were washed with brine (10 mL), dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (10% EtOAc/petroleum ether) gave *allene* **4c** (469 mg, 80%) as a colorless oil. R_f = 0.41 (10% EtOAc/petroleum ether); IR 2930, 2827, 1954 (C=C=C), 1693 (C=O), 1515, 1263, 1219, 1177, 1033, 966, 846, 805, 757, 721, 692, 519, 504 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 8.02–8.00 (2H, m, Ar**H**), 7.63–7.58 (1H, m, Ar**H**), 7.51–7.47 (2H, m, Ar**H**), 6.82–6.78 (2H, m, Ar**H**), 6.69–6.65 (2H, m, Ar**H**), 5.24 (1H, quin, *J* = 6.5 Hz, CH$_2$C**H**=), 4.74 (2H, dt, *J* = 6.8, 2.8 Hz, =C**H**$_2$), 4.71 (2H, s, O=CC**H**$_2$), 4.03 (2H, dt, *J* = 6.1, 2.8 Hz, NC**H**$_2$CH), 3.74 (3H, s, OC**H**$_3$); ^{13}C NMR (101 MHz, CDCl$_3$) δ 209.2 (C), 196.9 (C), 152.4 (C), 143.0 (C), 135.7 (C), 133.6 (CH), 128.9 (2 × CH), 128.0 (2 × CH), 115.2 (2 × CH), 114.9 (2 × CH), 87.2 (CH), 76.1 (CH$_2$), 57.7 (CH$_2$), 55.8 (CH$_3$), 51.6 (CH$_2$); HRMS (ESI) Exact mass calculated for $[C_{19}H_{20}NO_2]^+$ $[M+H]^+$: 294.1489, found: 294.1495.

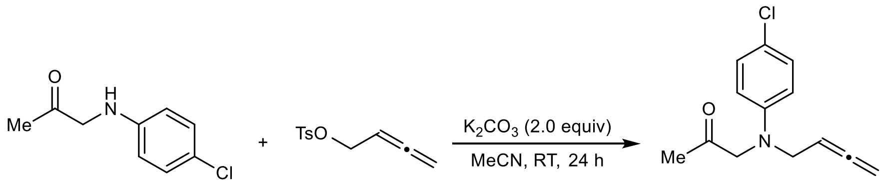
1-[Buta-2,3-dien-1-yl(4-methoxyphenyl)amino]-3,3-dimethylbutan-2-one (4d)



To a solution of aniline **S10**[7] (487 mg, 2.20 mmol) in MeCN (8 mL) was added K_2CO_3 (553 mg, 4.00 mmol) followed by allenyl tosylate **S4**[2] (448 mg, 2.00 mmol), and the resulting suspension was stirred at room temperature for 19 h. The reaction was partitioned between Et_2O (10 mL) and saturated aqueous $NaHCO_3$ solution (10 mL). The aqueous layer was separated and extracted with Et_2O (3 × 10 mL), and the combined organic layers were washed with saturated aqueous $NaHCO_3$ solution (2 × 10 mL), dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **4d** (333 mg, 61%) as a pale yellow oil.

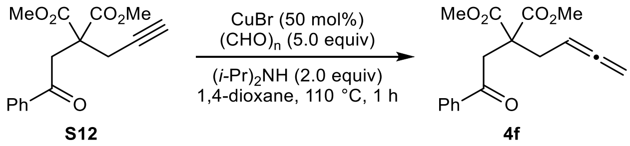
R_f = 0.47 (20% EtOAc/petroleum ether); IR 2968, 1954 (C=C=C), 1716, 1673 (C=O), 1511, 1463, 1364, 1243, 1178, 1032, 835, 812, 730, 549 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 6.79–6.77 (2H, m, Ar**H**), 6.60–6.58 (2H, m, Ar**H**), 5.17 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.73 (2H, dt, *J* = 6.6, 2.8 Hz, =C$\mathbf{H}_2$), 4.27 (2H, s, O=CC$\mathbf{H}_2$), 3.90 (2H, dt, *J* = 6.6, 2.8 Hz, NC$\mathbf{H}_2$CH), 3.73 (3H, s, OC$\mathbf{H}_3$), 1.22 (9H, s, C(C$\mathbf{H}_3$)$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 212.4 (C), 209.2 (C), 152.2 (C), 143.2 (C), 114.9 (2 × CH), 114.8 (2 × CH), 87.4 (CH), 75.9 (CH_2), 55.8 (CH_3), 55.5 (CH_2), 51.2 (CH_2), 43.5 (C), 26.7 (3 × CH_3); HRMS (ESI) Exact mass calculated for $[C_{17}H_{23}NNaO_2]^+$ $[M+Na]^+$: 296.1621, found: 296.1619.

1-[Buta-2,3-dien-1-yl(4-chlorophenyl)amino]propan-2-one (4e)



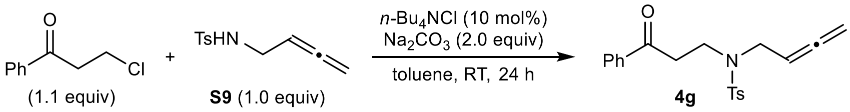
To a solution of aniline **S11**[7] (302 mg, 1.65 mmol) in MeCN (6 mL) was added K_2CO_3 (415 mg, 3.00 mmol) followed by allenyl tosylate **S4**[2] (336 mg, 1.50 mmol), and the resulting suspension was stirred at room temperature for 24 h. The reaction was partitioned between Et_2O (5 mL) and saturated aqueous $NaHCO_3$ solution (5 mL). The aqueous layer was separated and extracted with Et_2O (3 × 5 mL), and the combined organic layers were washed with saturated aqueous $NaHCO_3$ solution (2 × 5 mL), dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (20% EtOAc/petroleum ether) gave *allene* **4e** (234 mg, 66%) as a yellow oil. R_f = 0.36 (20% EtOAc/petroleum ether); IR 2961, 1954 (C=C=C), 1727 (C=O), 1596, 1497, 1352, 1226, 1160, 1097, 961, 847, 808, 655, 508 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.17–7.13 (2H, m, Ar**H**), 6.54–6.50 (2H, m, Ar**H**), 5.17 (1H, quin, *J* = 6.6 Hz, CH_2C**H**=), 4.78 (2H, dt, *J* = 6.6, 2.9 Hz, =C$\mathbf{H}_2$), 4.00-3.98 (4H, m, O=CC$\mathbf{H}_2$ and NC$\mathbf{H}_2$CH), 2.16 (3H, s, C$\mathbf{H}_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 209.2 (C), 207.7 (C), 146.6 (C), 129.2 (2 × CH), 122.6 (C), 113.9 (2 × CH), 86.4 (CH), 76.9 (CH_2), 61.4 (CH_2), 51.1 (CH_2), 27.2 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{13}H_{15}ClNO]^+$ $[M+H]^+$: 236.0837, found: 236.0836.

Dimethyl 2-(buta-2,3-dien-1-yl)-2-(2-oxo-2-phenylethyl)malonate (4f)



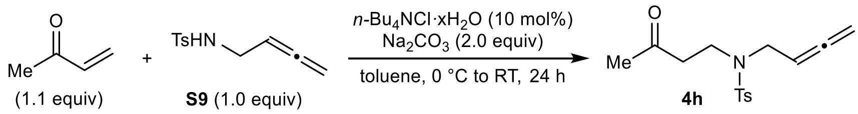
To a stirred solution of alkyne **S12**[8] (1.00 g, 3.50 mmol) in 1,4-dioxane (20 mL) at room temperature under inert atmosphere was added paraformaldehyde (530 mg, 17.7 mmol), CuBr (251 mg, 1.75 mmol), and diisopropylamine (0.98 mL, 12.0 mmol) The reaction was heated at 110 °C for 1 h, cooled to room temperature, diluted with EtOAc, filtered through a pad of silica using EtOAc (200 mL) as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/petroleum ether to 10% EtOAc/petroleum ether) gave *allene* **4f** (200 mg, 18%) as a colorless oil. R_f = 0.31 (10% EtOAc/petroleum ether); IR 2953, 1954 (C=C=C), 1732 (C=O), 1684 (C=O), 1596, 1434, 1356, 1283, 1199, 1068, 1002, 848, 749, 689, 554 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.02–7.91 (2H, m, Ar**H**), 7.61–7.55 (1H, m, Ar**H**), 7.51–7.43 (2H, m, Ar**H**), 4.97 (1H, tt, *J* = 8.1, 6.6 Hz, $CH_2C\mathbf{H}$=), 4.51 (2H, dt, *J* = 6.6, 2.4 Hz, =$C\mathbf{H}_2$), 3.76 (6H, s, 2 × $CO_2C\mathbf{H}_3$), 3.75 (2H, s, O=$CC\mathbf{H}_2$), 2.83 (2H, dt, *J* = 8.1, 2.4 Hz, $C\mathbf{H}_2$C=); ^{13}C NMR (101 MHz, $CDCl_3$) δ 210.2 (C), 196.8 (C), 171.0 (2 × C), 136.7 (C), 133.6 (CH), 128.8 (2 × CH), 128.2 (2 × CH), 84.8 (CH), 74.9 (CH_2), 55.7 (C), 53.0 (2 × CH_3), 41.4 (CH_2), 32.9 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{17}H_{18}NaO_5]^+$ $[M+Na]^+$: 325.1046, found: 325.1051.

***N*-(Buta-2,3-dien-1-yl)-4-methyl-*N*-(3-oxo-3-phenylpropyl)benzenesulfonamide (4g)**



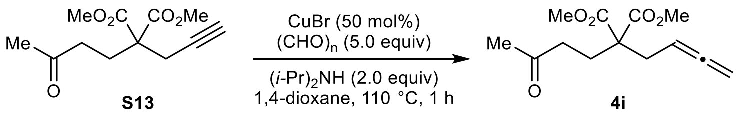
To a suspension of sulfonamide **S9**[5] (446 mg, 2.00 mmol), *n*-Bu_4NCl (59 mg, 0.21 mmol), and Na_2CO_3 (424 mg, 4.00 mmol) in toluene (16 mL) at 0 °C and was added 3-chloropropiophenone (371 mg, 2.20 mmol) portionwise and the mixture was stirred at room temperature for 24 h. The reaction was quenched with saturated aqueous NH_4Cl solution (20 mL) and extracted with EtOAc (3 × 10 mL). The combined organic layers were washed with brine (2 × 10 mL), dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/petroleum ether to 20% EtOAc/petroleum ether) gave *allene* **4g** (618 mg, 87%) as a white solid. R_f = 0.59 (20% EtOAc/petroleum ether); m.p 73–75 °C (Et_2O); IR 2983, 1965 (C=C=C), 1680 (C=O), 1596, 1429, 1321, 1209, 1149, 1092, 995, 936, 861, 838, 808, 740, 685, 538, 509, 426 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.96–7.94 (2H, m, Ar**H**), 7.73–7.70 (2H, m, Ar**H**), 7.61–7.56 (1H, m, Ar**H**), 7.50-7.45 (2H, m, Ar**H**), 7.32–7.28 (2H, m, Ar**H**), 4.97 (1H, quin, *J* = 6.9 Hz, $CH_2C\mathbf{H}$=), 4.70 (2H, dt, *J* = 6.6, 2.5 Hz, =$C\mathbf{H}_2$), 3.90 (2H, dt, *J* = 7.1, 2.5 Hz, $NC\mathbf{H}_2CH$), 3.59–3.56 (2H, m, $CH_2C\mathbf{H}_2N$), 3.41–3.37 (2H, m, O=CC**H**2), 2.42 (3H, s, ArC**H**3); ^{13}C NMR (101 MHz, $CDCl_3$) δ 209.6 (C), 198.5 (C), 143.6 (C), 136.7 (C), 136.6 (C), 133.6 (CH), 129.9 (2 × CH), 128.8 (2 × CH), 128.2 (2 × CH), 127.4 (2 ×CH), 86.3 (CH), 76.7 (CH_2), 48.3 (CH_2), 43.2 (CH_2), 39.0 (CH_2), 21.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{20}H_{22}NO_3S]^+$ $[M+H]^+$: 356.1315, found: 356.1316.

_N_-(Buta-2,3-dien-1-yl)-4-methyl-_N_-(3-oxobutyl)benzenesulfonamide (4h)



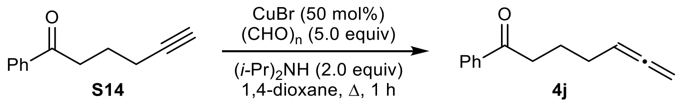
To a suspension of sulfonamide **S9**[5] (1.12 g, 5.00 mmol), Na_2CO_3 (1.06 g, 10.0 mmol), and *n*-$Bu_4NCl{\cdot}xH_2O$ (148 mg, *ca.* 0.500 mmol) in toluene (150 mL) at 0 °C was added methyl vinyl ketone (458 μL, 5.50 mmol) dropwise and the mixture was stirred at room temperature for 24 h. The reaction was quenched with saturated aqueous NH_4Cl solution (20 mL) and extracted with EtOAc (20 mL). The combined organic layers were washed with brine (20 mL), dried ($MgSO_4$), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/petroleum ether to 20% EtOAc/petroleum ether) gave *allene* **4h** (542 mg, 78%) as a colorless oil. R_f = 0.24 (20% EtOAc/petroleum ether); IR 2924, 1954 (C=C=C), 1713 (C=O), 1598, 1336, 1154, 1097, 847, 815, 727, 656, 545 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.68 (2H, d, *J* = 8.3 Hz, Ar**H**), 7.30 (2H, d, *J* = 8.0 Hz, Ar**H**), 4.90 (1H, quin, *J* = 6.9 Hz, CH2C**H**=), 4.70 (2H, dt, *J* = 6.5, 2.5 Hz, =C**H**2), 3.83 (2H, dt, *J* = 7.0, 2.5 Hz, NC**H**2CH), 3.39–3.36 (2H, m, O=CCH2C**H**2), 2.86–2.82 (2H, m, O=CC**H**2), 2.42 (3H, s, ArC**H**3), 2.15 (3H, s, C**H**3C=O); ^{13}C NMR (101 MHz, $CDCl_3$) δ 209.6 (C), 207.0 (C), 143.6 (C), 136.6 (C), 129.9 (2 × CH), 127.4 (2 × CH), 86.1 (CH), 76.6 (CH_2), 48.0 (CH_2), 43.6 (CH_2), 42.4 (CH_2), 30.4 (CH_3), 21.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{15}H_{20}NO_3S]^+$ $[M+H]^+$: 294.1158, found: 294.1163.

Dimethyl 2-(buta-2,3-dien-1-yl)-2-(3-oxobutyl)malonate (4i)



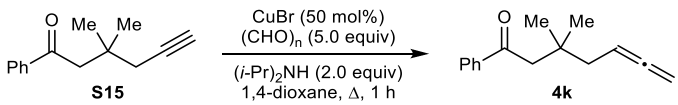
To a stirred solution of alkyne **S13**[9] (1.40 g, 6.00 mmol) in 1,4-dioxane (30 mL) at room temperature under inert atmosphere was added paraformaldehyde (900 mg, 30.0 mmol), CuBr (430 mg, 3.00 mmol), and diisopropylamine (1.7 mL, 12.0 mmol) The reaction was heated at 110 °C for 1 h, cooled to room temperature, diluted with EtOAc (50 mL), filtered through a pad of silica using EtOAc (200 mL) as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/pentane to 20% EtOAc/pentane) gave *allene* **4i** (423 mg, 23%) as a colorless oil. R_f = 0.25 (30% EtOAc/petroleum ether); IR 2954, 1955 (C=C=C), 1729 (C=O), 1435, 1372, 1198, 1093, 1044, 915, 848 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 4.95 (1H, tt, *J* = 8.0, 6.7 Hz, $CH_2C\mathbf{H}$=), 4.67 (2H, dt, *J* = 6.7, 2.4 Hz, =$C\mathbf{H}_2$), 3.72 (6H, s, 2 × $OC\mathbf{H}_3$), 2.60 (2H, dt, *J* = 8.0, 2.5 Hz, $C\mathbf{H}_2CH$=), 2.48–2.44 (2H, m, O=$CC\mathbf{H}_2$), 2.23–2.15 (2H, m, O=$CCH_2C\mathbf{H}_2$), 2.13 (3H, s, $C\mathbf{H}_3C$=O); ^{13}C NMR (126 MHz, $CDCl_3$) δ 210.2 (C), 207.3 (C), 171.4 (2 × C), 84.2 (CH), 74.9 (CH_2), 57.1 (C), 52.7 (2 × CH_3), 38.7 (CH_2), 33.2 (CH_2), 30.1 (CH_3), 26.6 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{13}H_{19}NO_5]^+$ $[M+H]^+$: 255.1227, found: 255.1227.

1-Phenylhepta-5,6-dien-1-one (4j)



To a solution of alkyne **S14**[10] (517 mg, 3.00 mmol), in 1,4-dioxane (15 mL) at room temperature under inert atmosphere was added paraformaldehyde (455 mg, 15.0 mmol), CuBr (215 mg, 1.50 mmol), and diisopropylamine (0.8 mL, 6.0 mmol). The reaction was heated at reflux for 1 h, cooled to room temperature, diluted with EtOAc (20 mL), filtered through a short plug of silica using EtOAc as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (10% EtOAc/petroleum ether) gave *allene* **4j** (309 mg, 55%) as a yellow oil. R_f = 0.14 (10% Et_2O/petroleum ether); IR 2936, 1954 (C=C=C), 1681 (C=O), 1597, 1580, 1447, 1226, 1365, 1000, 841 cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 8.00–7.92 (2H, m, Ar**H**), 7.59–7.52 (1H, m, Ar**H**), 7.50–7.42 (2H, m, Ar**H**), 5.12 (1H, quin, *J* = 6.7 Hz, $CH_2C\mathbf{H}$=), 4.67 (2H, dt, *J* = 6.5, 3.2 Hz, =$C\mathbf{H}_2$), 3.02 (2H, t, *J* = 7.3 Hz, O=$CC\mathbf{H}_2$), 2.15–2.08 (2H, m, $C\mathbf{H}_2CH$=), 1.89 (2H, quin, *J* = 7.3 Hz, $CH_2C\mathbf{H}_2CH_2$); ^{13}C NMR ($CDCl_3$, 101 MHz) δ 208.8 (C), 200.3 (C), 137.2 (C), 133.1 (CH), 128.7 (2 × CH), 128.2 (2 × CH), 89.5 (CH), 75.2 (CH_2), 37.9 (CH_2), 27.9 (CH_2), 23.7 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{13}H_{15}O]^+$ $[M+H]^+$: 187.1117, found: 187.1121.

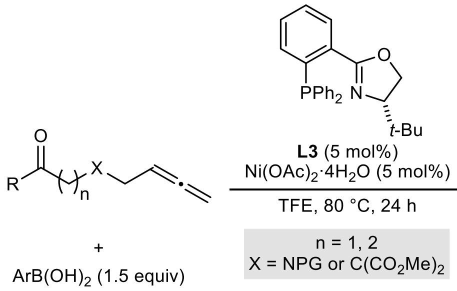
3,3-Dimethyl-1-phenylhepta-5,6-dien-1-one (4k)



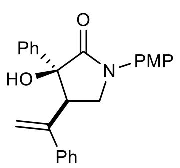
To a solution of alkyne **S15**[10] (801 mg, 4.00 mmol) in 1,4-dioxane (20 mL) at room temperature under inert atmosphere was added paraformaldehyde (606 mg, 20.0 mmol), CuBr (287 mg, 2.00 mmol), and diisopropylamine (1.1 mL, 8.0 mmol). The reaction was heated at reflux for 1 h, cooled to room temperature, diluted with EtOAc (20 mL), filtered through a short plug of silica using EtOAc as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/pentane to 20% EtOAc/pentane) gave *allene* **4k** (174 mg, 20%) as a yellow oil. R_f = 0.41 (10% EtOAc/petroleum ether); IR 2957, 1953 (C=C=C) 1672 (C=O), 1596, 1579, 1466, 1357, 1222, 1006, 747 cm^{-1}; ^{1}H NMR (CDCl$_3$, 500 MHz) δ 7.96–7.89 (2H, m, Ar**H**), 7.62–7.50 (1H, m, Ar**H**), 7.45 (2H, dd, *J* = 8.4, 7.0 Hz, Ar**H**), 5.09 (1H, tt, *J* = 8.1, 6.6 Hz, CH$_2$C**H**=), 4.59 (2H, dt, *J* = 6.7, 2.4 Hz, =C**H**$_2$), 2.89 (2H, s, O=CC**H**$_2$), 2.14 (2H, dt, *J* = 8.1, 2.4 Hz, C**H**$_2$CH=), 1.07 (6H, s, 2 × C**H**$_3$); ^{13}C NMR (CDCl$_3$, 126 MHz) δ 210.1 (C), 200.3 (C), 138.7 (C), 132.9 (CH), 128.6 (2 × CH), 128.3 (2 × CH), 86.2 (CH), 73.7 (CH$_2$), 47.6 (CH$_2$), 41.8 (CH$_2$), 34.9 (C), 27.5 (2 × CH$_3$); HRMS (ESI) Exact mass calculated for [C$_{15}$H$_{19}$O]$^+$ [M+H]$^+$: 215.1430, found: 215.1431.

Enantioselective Nickel-Catalyzed Arylative and Alkenylative Intramolecular Allylations

General Procedure



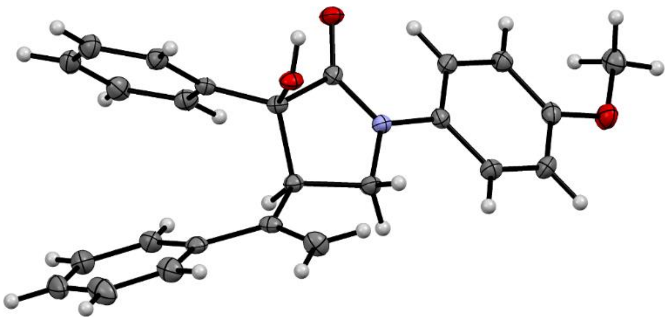
To an oven-dried microwave vial charged with a magnetic stirrer, Ni(OAc)$_2$·4H$_2$O (3.7 mg, 15 μmol), (*S*)-^{t}BuPHOX (**L3**, 5.8 mg, 15 μmol), and boronic acid (0.450 mmol) were added. The vial was sealed and flushed with nitrogen or argon for 10 min. TFE (1.5 mL) was added, the solution was immerged in an oil bath pre-heated to 80 °C and stirred for 10 min. The allene (0.300 mmol) was added to a separate vial that was sealed and flushed with argon for 10 min. TFE (0.75 mL) was added to the allene and the resulting solution was added dropwise to the one containing the first vial containing the chiral nickel complex. The vial originally containing the substrate was rinsed with additional TFE (0.75 mL) and the rinsing solution was transferred to the first microwave vial *via* syringe. The reaction mixture was stirred at 80 °C for 24 h, cooled to room temperature, diluted with EtOAc (5 mL), filtered through a short pad of silica (3 cm height × 2 cm wide) using EtOAc (20 mL) as eluent, and concentrated *in vacuo*. If necessary, the crude mixture was purified by column chromatography to give the title compound.

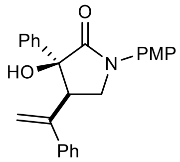


(3*S*,4*R*)-3-Hydroxy-1-(4-methoxyphenyl)-3-phenyl-4-(1-phenylvinyl)pyrrolidin-2-one (2a). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (115 mg, 99%) as a white solid. R$_f$ = 0.26 (30% EtOAc/petroleum ether); m.p. 125-127 °C (Et$_2$O); IR 3417 (OH), 2954, 1682 (C=O), 1584, 1508, 1397, 1245, 1179, 1057, 828 cm^{-1}; $[\alpha]_D^{20}$ +16.0 (*c* 1.00, CHCl$_3$);

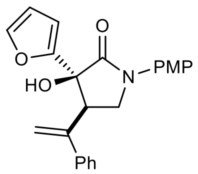
^{1}H NMR (400 MHz, $CDCl_3$) δ 7.61–7.55 (2H, m, Ar**H**), 7.41–7.37 (2H, m, Ar**H**), 7.36–7.20 (8H, m, Ar**H**), 6.98–6.92 (2H, m, Ar**H**), 5.51 (1H, s, =C**H**$_2$), 5.35 (1H, s, =C**H**$_2$), 4.03–3.92 (2H, m, C**H**$_2$N), 3.83 (3H, s, OC**H**$_3$), 3.79–3.73 (1H, m, C**H**CH_2), 3.20 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.1 (C), 157.3 (C), 146.1 (C), 142.1 (C), 141.9 (C), 131.9 (C), 128.6 (2 × CH), 128.3 (2 × CH), 128.1 (CH), 127.6 (CH), 126.9 (2 × CH), 125.6 (2 × CH), 121.9 (2 × CH), 115.9 (CH_2), 114.4 (2 × CH), 81.2 (C), 55.6 (CH_3), 51.1 (CH_2), 49.9 (CH); HRMS (ESI) Exact mass calculated for $[C_{25}H_{24}NO_3]^+$ $[M+H]^+$: 386.1751, found: 386.1756; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (80:20 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 25.9 min, t_r (major) = 33.3 min, 96% ee.

Slow diffusion of petroleum ether into a solution of **2a** in EtOAc gave crystals that were suitable for X-ray crystallography:

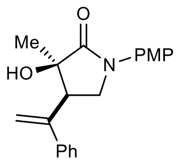




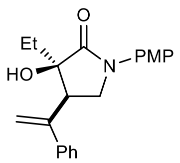
2a
CCDC 1945864
Flack parameter = 0.05(8)



(3*S*,4*R*)-3-(Furan-2-yl)-3-hydroxy-1-(4-methoxyphenyl)-4-(1-phenylvinyl)pyrrolidine-2-one (2b). The General Procedure was followed using allene **1b** (89.2 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (112 mg, 99%) as a white amorphous solid. R_f = 0.41 (40% EtOAc/petroleum ether); $[\alpha]_D^{25}$ +14.8 (*c* 0.27, $CHCl_3$); IR 3366 (OH), 2955, 1681 (C=O), 1509, 1440, 1399, 1298, 1245, 1150, 1029, 1005, 886, 828, 776, 735, 699, 595, 567, 522 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54–7.52 (2H, m, Ar**H**), 7.39–7.35 (3H, m, Ar**H**), 7.31–7.24 (3H, m, Ar**H**), 6.93–6.90 (2H, m, Ar**H**), 6.36 (1H, dd, *J* = 3.3, 0.9 Hz, Ar**H**), 6.29 (1H, dd, *J* = 3.3, 1.8 Hz, ArC**H**), 5.53 (1H, s, =C**H**$_2$), 5.31 (1H, s, =C**H**$_2$), 4.11–4.04 (2H, m, C**H**$_2$N), 3.94 (1H, dd, *J* = 8.7, 3.1 Hz, C**H**CH_2), 3.80 (3H, s, OC**H**$_3$), 3.54 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 170.8 (C), 157.2 (C), 153.5 (C), 145.7 (C), 142.8 (CH), 141.7 (C), 131.9 (C), 128.3 (2 × CH), 127.6 (CH), 126.7 (2 × CH), 121.8 (2 × CH), 115.5 (CH_2), 114.3 (2 × CH), 110.6 (CH), 107.8 (CH), 77.4 (C), 55.6 (CH_3), 51.3 (CH_2), 46.2 (CH); HRMS (ESI) Exact mass calculated for $[C_{23}H_{22}NO_4]^+$ $[M+H]^+$: 376.1543, found: 376.1542; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (60:40 *iso*-hexane:*i*-PrOH, 1.5 mL/min, 254 nm, 25 °C) t_r (major) = 25.2 min, t_r (minor) = 35.5 min, 97% ee.

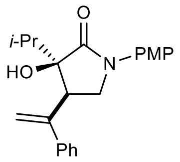


(3*R*,4*R*)-3-Hydroxy-1-(4-methoxyphenyl)-3-methyl-4-(1-phenylvinyl)pyrrolidin-2-one (2c). The General Procedure was followed using allene **1c** (73.6 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (96 mg, 99%) as a colorless solid. R_f = 0.21 (30% EtOAc/petroleum ether); m.p. 122–125 °C (Et_2O); $[\alpha]_D^{25}$ +7.41 (*c* 0.54, $CHCl_3$); IR 3348 (OH), 2979, 1688 (C=O), 1510, 1469, 1391, 1288, 1244, 1175, 1097, 1030, 944, 889, 827, 774, 700, 596, 555, 524 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.53–7.49 (2H, m, Ar**H**), 7.43–7.40 (2H, m, Ar**H**), 7.37–7.26 (3H, m, Ar**H**), 6.92–6.88 (2H, m, Ar**H**), 5.48 (1H, s, =C**H**$_2$), 5.32 (1H, s, =C**H**$_2$), 3.92 (2H, app d, *J* = 6.4 Hz, C**H**$_2$N), 3.80 (3H, s, OC**H**$_3$), 3.44–3.40 (1H, m, C**H**CH$_2$), 3.00 (1H, s, O**H**), 1.41 (3H, s, C**H**$_3$C); ^{13}C NMR (101 MHz, $CDCl_3$) δ 174.0 (C), 156.9 (C), 145.9 (C), 142.4 (C), 132.1 (C), 128.4 (2 × CH), 127.7 (CH), 126.9 (2 × CH), 121.7 (2 × CH), 115.5 (CH_2), 114.2 (2 × CH), 76.4 (C), 55.5 (CH_3), 51.0 (CH_2), 48.1 (CH), 24.4 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{20}H_{22}NO_3]^+$ $[M+H]^+$: 324.1594, found: 324.1597; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (80:20 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 26.7 min, t_r (minor) = 31.3 min, 98% ee.

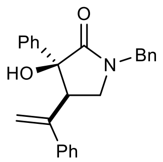


(3*R*,4*R*)-3-Ethyl-3-hydroxy-1-(4-methoxyphenyl)-4-(1-phenylvinyl)pyrrolidin-2-one (2d). The General Procedure was followed using allene **1d** (77.8 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (101 mg, >99%) as a colorless oil. R_f = 0.10 (20% EtOAc/petroleum ether); $[\alpha]_D^{25}$ +18.6 (*c* 0.43, $CHCl_3$); IR 3550 (OH), 2964, 1682 (C=O), 1514, 1488, 1404, 1253, 1157, 1031, 1018, 909, 873, 823, 781, 746, 695, 575, 526, 463 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.54–7.50 (2H, m, Ar**H**), 7.44–7.41 (2H, m, Ar**H**), 7.36–7.26 (3H, m, Ar**H**), 6.93–6.89 (2H, m, Ar**H**), 5.45 (1H, s, =C**H**$_2$), 5.27 (1H, s, =C**H**$_2$), 4.00–3.95 (1H, m, C**H**$_2$N), 3.86 (1H, dd, *J* = 10.0, 4.0 Hz, C**H**$_2$N), 3.80 (3H, s, OC**H**$_3$), 3.52 (1H, dd, *J* = 7.0, 4.0 Hz, C**H**CH$_2$), 2.93 (1H, br m, O**H**), 1.85 (1H, dt, *J* = 14.8, 7.5 Hz, CH$_3$C**H**$_2$), 1.71 (1H, dt, *J* = 14.5, 7.4 Hz, CH$_3$C**H**$_2$), 1.00 (3H, t, *J* = 7.4 Hz, C**H**$_3$CH$_2$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.8 (C), 156.9 (C), 147.0 (C), 142.4 (C), 132.1 (C), 128.3 (2 × CH), 127.7 (CH), 126.8 (2 × CH), 121.7 (2 × CH), 115.2 (CH_2), 114.2 (2 × CH), 79.4 (C), 55.5 (CH_3), 51.4 (CH_2), 45.0 (CH), 30.3 (CH_2), 8.3 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{21}H_{24}NO_3]^+$ $[M+H]^+$: 338.1751, found:

338.1751; Enantiomeric excess was determined by HPLC with a Chiralpak AS-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 32.1 min, t_r (minor) = 49.1 min, >99% ee.

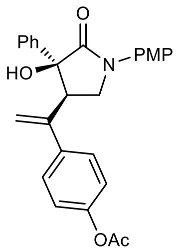


(3*R*,4*R*)-3-Hydroxy-3-isopropyl-1-(4-methoxyphenyl)-4-(1-phenylvinyl)pyrrolidin-2-one (2e). The General Procedure was followed using allene **1e** (82.0 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (105 mg, >99%) as a colorless oil. R_f = 0.23 (20% EtOAc/petroleum ether); $[\alpha]^{25}_{D}$ +14.3 (*c* 0.84, $CHCl_3$); IR 3422 (OH), 2960, 1681 (C=O), 1510, 1465, 1440, 1401, 1291, 1245, 1178, 1159, 1031, 906, 828, 796, 729, 701, 566, 527 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.53–7.49 (2H, m, Ar**H**), 7.44–7.41 (2H, m, Ar**H**), 7.36–7.26 (3H, m, Ar**H**), 6.94–6.89 (2H, m, Ar**H**), 5.43 (1H, s, =C**H**$_2$), 5.24 (1H, s, =C**H**$_2$), 4.00 (1H, dd, *J* = 10.3, 7.3 Hz, C**H**$_2$N), 3.80 (3H, s, OC**H**$_3$), 3.79–3.65 (1H, m, C**H**$_2$N), 3.60 (1H, dd, *J* = 7.3, 2.6 Hz, C**H**CH$_2$), 2.80 (1H, s, O**H**), 2.11 (1H, hept, *J* = 6.8 Hz, (CH$_3$)$_2$C**H**), 1.06 (3H, d, *J* = 6.9 Hz, (C**H**$_3$)$_2$CH), 1.01 (3H, d, *J* = 6.8 Hz, (C**H**$_3$)$_2$CH); ^{13}C NMR (101 MHz, $CDCl_3$) δ 174.1 (C), 157.0 (C), 148.3 (C), 142.4 (C), 131.9 (C), 128.3 (2 × CH), 127.6 (CH), 127.0 (2 × CH), 121.8 (2 × CH), 115.3 (CH_2), 114.2 (2 × CH), 81.6 (C), 55.5 (CH_3), 52.3 (CH_2), 43.4 (CH), 35.0 (CH), 17.4 (CH_3), 16.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{22}H_{26}NO_3]^+$ $[M+H]^+$: 352.1907, found: 352.1909; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 31.0 min, t_r (minor) = 33.9 min, >99% ee.

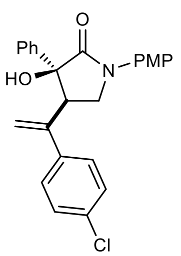


(3*S*,4*R*)-1-Benzyl-3-hydroxy-3-phenyl-4-(1-phenylvinyl)pyrrolidin-2-one (2f). *Using TFE as the solvent:* The General Procedure was followed using allene **1f** (87.4 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by passing the compound through a short pad of silica using pentane as eluent gave the title compound (110 mg, 99%) as a colorless solid. R_f = 0.29 (30% EtOAc/petroleum ether); m.p. 158–162 °C (Et_2O); $[\alpha]^{25}_{D}$ –31.6 (*c* 0.38, $CHCl_3$); IR 3326 (OH), 3060, 2912, 1683 (C=O), 1483, 1436, 1340, 1258, 1024, 950, 895, 741, 695, 659, 589, 510, 465 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.31 (5H, m, Ar**H**), 7.30–7.23 (5H, m, Ar**H**), 7.17–7.12 (3H, m, Ar**H**), 7.10–7.07 (2H, m, Ar**H**), 5.43 (1H, d, *J* = 0.3 Hz, =C**H**$_2$), 5.17 (1H, s, =C**H**$_2$), 4.70 (1H, d, *J* = 14.5 Hz, C**H**$_2$Ph), 4.51 (1H, d, *J* = 14.5 Hz, C**H**$_2$Ph), 3.61 (1H, td, *J* = 6.5, 0.9 Hz, C**H**CH$_2$), 3.47 (2H, app dd, *J* = 6.4, 1.2 Hz, CHC**H**$_2$), 2.88 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 174.2 (C), 145.1 (C), 142.0 (C), 141.8 (C), 135.8 (C), 128.9 (2 × CH), 128.5 (2 × CH), 128.2 (2 × CH), 128.0 (2 × CH), 127.9 (CH), 127.6 (CH), 127.3 (CH), 126.8 (2 × CH), 125.5 (2 × CH), 116.3 (CH_2), 80.2 (C), 50.5 (CH), 49.0 (CH_2), 47.3 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{25}H_{24}NO_2]^+$ $[M+H]^+$: 370.1802, found: 370.1803; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 19.4 min, t_r (minor) = 22.2 min, 87% ee.

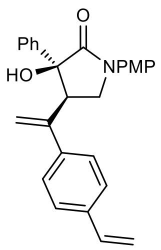
Using MeCN as the solvent: A modification of the General Procedure was followed using allene **1f** (87.4 mg, 0.30 mmol) and phenylboronic acid (54.9 mg, 0.45 mmol) but using MeCN in place of TFE as the solvent. Purification by column chromatography (20% EtOAc/petroleum ether) gave the title compound (71.8 mg, 65%) as a colorless solid. $[\alpha]_D^{25}$ –34.8 (*c* 0.46, $CHCl_3$); Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C); t_r (major) = 19.8 min, t_r (minor) = 22.8 min, 99% ee.



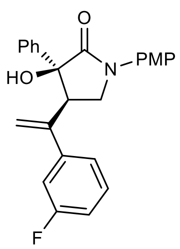
4-{1-[(3*R*,4*S*)-4-Hydroxy-1-(4-methoxyphenyl)-5-oxo-4-phenylpyrrolidin-3-yl]vinyl}phenyl acetate (2g). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 4-acetoxyphenylboronic acid (81.0 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 30% EtOAc/pentane) gave the title compound (133 mg, >99%) as a white solid. R_f = 0.26 (30% EtOAc/petroleum ether); m.p. 57-59 °C (Et_2O); IR 3365 (OH), 2935, 1752 (C=O), 1686 (C=O), 1510, 1247, 1194, 908, 829, 697 cm^{-1}; $[\alpha]_D^{28}$ +16.0 (*c* 1.00, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.62–7.53 (2H, m, Ar**H**), 7.42–7.34 (2H, m, Ar**H**), 7.34–7.21 (5H, m, Ar**H**), 6.98–6.88 (4H, m, Ar**H**), 5.48 (1H, s, =C$\mathbf{H}_2$), 5.34 (1H, s, =C$\mathbf{H}_2$), 3.99–3.92 (2H, m, C$\mathbf{H}_2$N), 3.82 (3H, s, OC$\mathbf{H}_3$), 3.70 (1H, dd, *J* = 6.5, 4.9 Hz, C**H**CH_2), 3.31 (1H, s, O**H**), 2.28 (2H, s, CC$\mathbf{H}_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.0 (C), 169.5 (C), 157.2 (C), 150.1 (C), 145.1 (C), 142.0 (C), 139.6 (C), 131.9 (C), 128.6 (2 × CH), 128.1 (CH), 128.0 (2 × CH), 125.6 (2 × CH), 121.9 (2 × CH), 121.3 (2 × CH), 116.2 (CH_2), 114.4 (2 × CH), 81.1 (C), 55.6 (CH_3), 51.1 (CH_2), 50.0 (CH), 21.2 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{27}H_{25}NNaO_5]^+$ $[M+Na]^+$: 466.1625, found: 466.1619; Enantiomeric excess was determined by HPLC with a Chiralpak OD-H column (90:10 *iso*-hexane:EtOH, 1.0 mL/min, 210 nm, 25 °C) t_r (minor) = 29.0 min, t_r (major) = 37.0 min, 97% ee.



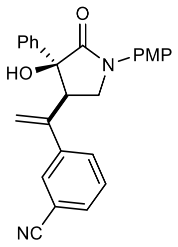
(3*S*,4*R*)-4-[1-(4-Chlorophenyl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2h). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 4-chlorophenylboronic acid (70.4 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (125 mg, 99%) as a white solid. R_f = 0.21 (30% EtOAc/petroleum ether); m.p. 54-56 °C (Et_2O); IR 3401 (OH), 2905, 1672 (C=O), 1511, 1489, 1395, 1247, 1102, 830, 516 cm^{-1}; $[\alpha]_D^{20}$ +12.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58–7.54 (2H, m, Ar**H**), 7.34–7.26 (5H, m, Ar**H**), 7.18–7.13 (4H, m, Ar**H**), 6.95–6.91 (2H, m, Ar**H**), 5.45 (1H, s, =C**H**$_2$), 5.33 (1H, s, =C**H**$_2$), 3.95 (2H, d, *J* = 5.9 Hz, C**H**$_2$N), 3.82 (3H, s, OC**H**$_3$), 3.67 (1H, t, *J* = 5.9 Hz, C**H**CH_2), 3.60 (1H, s, O**H**); ^{13}C (101 MHz, $CDCl_3$) δ 173.1 (C), 157.2 (C), 144.6 (C), 141.9 (C), 140.4 (C), 133.3 (C), 131.8 (C), 128.5 (2 × CH), 128.3 (2 × CH), 128.2 (2 × CH), 128.0 (CH), 125.6 (2 × CH), 121.9 (2 × CH), 116.4 (CH_2), 114.3 (2 × CH), 81.1 (C), 55.6 (CH_3), 50.8 (CH_2), 50.0 (CH); HRMS (ESI) Exact mass calculated for $[C_{25}H_{23}ClNO_3]^+$ $[M+H]^+$: 420.1361, found: 420.1362; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (80:20 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 22.1 min, t_r (major) = 29.3 min, 98% ee.



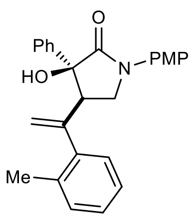
(3*S*,4*R*)-3-Hydroxy-1-(4-methoxyphenyl)-3-phenyl-4-[1-(4-vinylphenyl)-vinyl]pyrrolidin-2-one (2i). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 4-vinylphenylboronic acid (66.6 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 30% EtOAc/pentane) gave the title compound (87.6 mg, 71%) as a white solid. R_f = 0.26 (30% EtOAc/petroleum ether); m.p. 117-119 °C (Et_2O); IR 3404 (OH), 2921, 1684 (C=O), 1508, 1397, 1244, 1179, 1027, 828, 752, 710 cm^{-1}; $[\alpha]_D^{21}$ +8.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.62–7.56 (2H, m, Ar**H**), 7.42–7.37 (2H, m, Ar**H**), 7.37–7.20 (7H, m, Ar**H**), 7.00–6.90 (2H, m, Ar**H**), 6.68 (1H, dd, *J* = 17.6, 10.9 Hz, C**H**=CH_2), 5.72 (1H, dd, *J* = 17.6, 0.9 Hz, CH=C**H**$_2$), 5.53 (1H, s, C=C**H**$_2$), 5.33 (1H, s, C=C**H**$_2$), 5.24 (1H, dd, *J* = 10.9, 0.9 Hz, CH=C**H**$_2$), 4.05–3.91 (2H, m, C**H**$_2$N), 3.83 (3H, s, OC**H**$_3$), 3.79–3.72 (1H, m, C**H**CH_2), 3.10 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.1 (C), 157.3 (C), 145.7 (C), 142.1 (C), 141.4 (C), 136.9 (C), 136.4 (CH), 131.9 (C), 128.7 (2 × CH), 128.1 (CH), 127.0 (2 × CH), 126.2 (2 × CH), 125.6 (2 × CH), 121.9 (2 × CH), 115.5 (CH_2), 114.4 (2 × CH), 114.0 (CH_2), 81.2 (C), 55.7 (CH_3), 51.1 (CH_2), 49.6 (CH); HRMS (ESI) Exact mass calculated for $[C_{27}H_{26}NO_3]^+$ $[M+H]^+$: 412.1907, found: 412.1908; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (80:20 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 26.5 min, t_r (major) = 33.3 min, 99% ee.



(3*S*,4*R*)-4-[1-(4-Fluorophenyl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2j). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 3-fluorophenylboronic acid (63.0 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (121 mg, >99%) as a white solid. R_f = 0.17 (30% EtOAc/petroleum ether); m.p. 120-121 °C (Et_2O); IR 3378 (OH), 2925, 1672 (C=O), 1580, 1512, 1247, 1064, 829, 695, 528 cm^{-1}; $[\alpha]_D^{22}$ +28.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.64–7.54 (2H, m, Ar**H**), 7.40–7.34 (2H, m, Ar**H**), 7.34–7.25 (3H, m, Ar**H**), 7.19 (1H, td, *J* = 8.0, 6.0 Hz, Ar**H**), 7.04 (1H, ddd, *J* = 7.8, 1.7, 1.0 Hz, Ar**H**), 7.00–6.88 (4H, m, Ar**H**), 5.51 (1H, s, =C**H**$_2$), 5.36 (1H, s, =C**H**$_2$), 4.03–3.92 (2H, m, C**H**$_2$N), 3.83 (3H, s, OC**H**$_3$), 3.73–3.67 (1H, m, C**H**CH_2), 3.21 (1H, s, O**H**); ^{13}C (101 MHz, $CDCl_3$) δ 173.0 (C), 162.7 (d, $J_{C\text{-}F}$ = 245.6 Hz, C), 157.3 (C), 145.0 (d, $J_{C\text{-}F}$ = 2.1 Hz, C), 144.3 (d, $J_{C\text{-}F}$ = 7.6 Hz, C), 141.9 (C), 131.9 (C), 129.7 (d, $J_{C\text{-}F}$ = 8.3 Hz, CH), 128.7 (2 × CH), 128.2 (CH), 125.5 (2 × CH), 122.6 (d, $J_{C\text{-}F}$ = 2.8 Hz, CH), 121.8 (2 × CH), 116.6 (CH_2), 114.41 (2 × CH), 114.38 (d, $J_{C\text{-}F}$ = 21.1 Hz, CH), 114.0 (d, $J_{C\text{-}F}$ = 22.0 Hz, CH), 81.2 (C), 55.7 (CH_3), 51.0 (CH_2), 49.8 (CH); HRMS (ESI) Exact mass calculated for $[C_{25}H_{22}FNNaO_3]^+$ $[M+Na]^+$: 426.1476, found: 426.1479; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (80:20 *iso*-hexane:*i*-PrOH), 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 19.7 min, t_r (major) = 25.1 min, 98% ee.

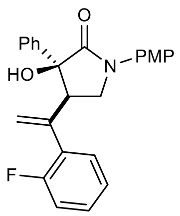


3-{1-[(3*R*,4*S*)-4-Hydroxy-1-(4-methoxyphenyl)-5-oxo-4-phenylpyrrolidin-3-yl]vinyl}benzonitrile (2k). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 3-cyanophenylboronic acid (66.1 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 50% EtOAc/pentane) gave the title compound (111 mg, 90%) as a white solid. R_f = 0.18 (30% EtOAc/petroleum ether); m.p. 76-78 °C (Et_2O); IR 3349 (OH), 2931, 2228 (CN), 1679 (C=O), 1510, 1398, 1246, 1180, 829, 697 cm^{-1}; $[\alpha]_D^{20}$ +16.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.59–7.53 (2H, m, Ar**H**), 7.47–7.43 (2H, m, Ar**H**), 7.43–7.40 (1H, m, Ar**H**), 7.32–7.25 (6H, m, Ar**H**), 6.97–6.91 (2H, m, Ar**H**), 5.47 (1H, s, =C**H**$_2$), 5.38 (1H, s, =C**H**$_2$), 3.97 (2H, d, *J* = 5.9 Hz, C**H**$_2$N), 3.81 (3H, s, OC**H**$_3$), 3.65 (1H, td, *J* = 5.9, 1.0 Hz, C**H**CH_2), 3.24 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 172.9 (C), 157.3 (C), 143.9 (C), 143.1 (C), 141.6 (C), 131.7 (C), 131.5 (CH), 130.9 (CH), 130.7 (CH) ,129.0 (CH), 128.6 (2 × CH), 128.3 (CH), 125.5 (2 × CH), 121.9 (2 × CH), 118.8 (CN), 117.9 (CH_2), 114.4 (2 × CH), 112.3 (C), 81.1 (C), 55.6 (CH_3), 50.6 (CH_2), 50.1 (CH); HRMS (ESI) Exact mass calculated for $[C_{26}H_{23}N_2O_3]^+$ $[M+H]^+$: 411.1703, found: 411.1707; Enantiomeric excess was determined by HPLC with a Chiralpak OD-H column (80:20 *iso*-hexane:EtOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 35.2 min, t_r (major) = 50.2 min, 99% ee.



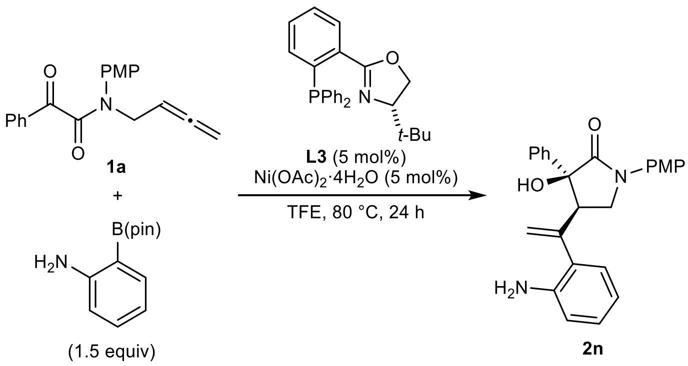
(3*S*,4*R*)-3-Hydroxy-1-(4-methoxyphenyl)-3-phenyl-4-[1-(*o*-tolyl)vinyl]pyrrolidin-2-one (2l). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 2-methylphenylboronic acid (61.2 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 30%

EtOAc/pentane) gave the title compound (83.2 mg, 69%) as a white solid. R_f = 0.43 (30% EtOAc/petroleum ether); m.p. 147-149 °C ($CHCl_3$); IR 3373 (OH), 2914, 1673 (C=O), 1511, 1444, 1245, 1032, 962, 828, 616 cm^{-1}; $[\alpha]_D^{25}$ –10.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.60–7.48 (2H, m, Ar**H**), 7.31–7.21 (5H, m, Ar**H**), 7.15–7.01 (4H, m, Ar**H**), 7.00–6.88 (2H, m, Ar**H**), 5.49 (1H, d, *J* =1.1 Hz, =C**H**$_2$), 5.21 (1H, d, *J* =1.0 Hz, =C**H**$_2$), 3.95–3.87 (2H, m, C**H**$_2$N), 3.82 (3H, s, OC**H**$_3$), 3.63–3.52 (1H, m, C**H**CH$_2$), 3.25 (1H, s, O**H**), 2.25 (3H, s, ArC**H**$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.3 (C), 157.2 (C), 145.3 (C), 142.0 (C), 141.7 (C), 134.8 (C), 132.0 (C), 130.2 (CH), 128.9 (CH), 128.4 (2 × CH), 127.9 (CH), 127.2 (CH), 125.7 (2 × CH), 125.5 (CH), 122.0 (2 × CH), 117.8 (CH_2), 114.3 (2 × CH), 81.3 (C), 55.6 (CH_3), 51.1 (CH), 50.6 (CH_2), 20.2 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{26}H_{26}NO_3]^+$ $[M+H]^+$: 400.1907, found: 400.1905; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 39.3 min, t_r (major) = 47.3 min, 84% ee.

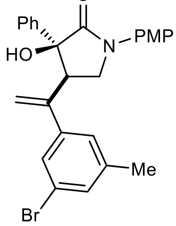


(3*S*,4*R*)-4-[1-(2-Fluorophenyl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2m). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 2-fluorophenylboronic acid (63.0 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 30% EtOAc/pentane) gave the title compound (82.3 mg, 68%) as a white solid. R_f = 0.22 (30% EtOAc/petroleum ether); m.p. 167-170 °C (Et_2O); IR 3398 (OH), 2844, 1672 (C=O), 1513, 1486, 1303, 1245, 1230, 831, 758 cm^{-1}; $[\alpha]_D^{20}$ –12.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.58–7.50 (2H, m, Ar**H**), 7.31–7.18 (6H, m Ar**H**), 7.16 (1H, dddd, *J* = 8.2, 7.2, 5.2, 1.9 Hz, Ar**H**), 7.03 (1H, td, *J* = 7.5, 1.2 Hz, Ar**H**), 6.96–6.90 (2H, m, Ar**H**), 6.84 (1H, ddd, *J* = 10.8, 8.2, 1.2 Hz, Ar**H**), 5.46 (1H, s, =C**H**$_2$), 5.38 (1H, s, =C**H**$_2$), 4.03 (1H, dd, *J* = 9.8, 5.5 Hz, C**H**$_2$N), 3.97 (1H, dd, 9.8, 6.6 Hz, C**H**$_2$N), 3.82 (3H, s, OC**H**$_3$), 3.77 (1H, ddd, *J*=6.6, 5.5, 1.0 Hz, C**H**CH$_2$), 3.09 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.1 (C), 159.5 (d, $J_{C\text{-}F}$ = 245.1 Hz, C), 157.2 (C), 141.3 (d, $J_{C\text{-}F}$ = 55.8 Hz, C), 132.0 (C), 131.0 (d, $J_{C\text{-}F}$ = 3.7 Hz, CH), 129.7 (d, $J_{C\text{-}F}$ = 14.0 Hz, C), 129.2 (d, $J_{C\text{-}F}$ = 8.6 Hz, CH), 128.4 (2 × CH), 127.9 (CH), 125.7 (2 × CH), 124.1 (d, *J* = 3.6 Hz, CH), 122.0 (2 × CH), 119.2 (CH_2), 115.4 (d, $J_{C\text{-}F}$ = 22.7 Hz, CH), 114.3 (2 × CH), 110.1 (C), 81.2 (C), 55.7 (CH_3), 50.4 (d, $J_{C\text{-}F}$ = 2.8 Hz, CH), 50.3 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{25}H_{23}FNO_3]^+$ $[M+H]^+$: 404.1656, found: 404.1652; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (85:15 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 27.5 min, t_r (major) = 32.9 min, 97% ee.

(3*S*,4*R*)-4-[1-(2-Aminophenyl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2n)

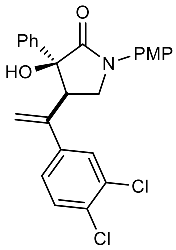


A modification of the General Procedure (in that the pinacol boronate was used instead of the boronic acid) was followed using allene **1a** (92.2 mg, 0.300 mmol) and 2-aminophenylboronic acid pinacol ester (98.6 mg, 0.450 mmol). Purification by column chromatography (20% EtOAc/pentane to 50% EtOAc/pentane) gave the title compound (57.2 mg, 48%) as a white solid. R_f = 0.13 (30% EtOAc/petroleum ether); m.p. 68-70 °C ($CHCl_3$); IR 3364 (OH), 2927, 1657 (C=O), 1615, 1510, 1325, 1121, 1071, 928, 695 cm^{-1}; $[\alpha]_D^{24}$ –6.00 (*c* 1.00, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.47 (2H, dd, *J* = 9.2, 2.7 Hz, Ar**H**), 7.40–7.34 (2H, m, Ar**H**), 7.32–7.21 (3H, m, Ar**H**), 7.01 (1H, td, *J* =7.7, 1.5 Hz, Ar**H**), 6.94–6.86 (3H, m, Ar**H**), 6.67–6.59 (2H, m, Ar**H**), 5.45 (1H, d, *J* =1.5 Hz, =C**H**$_2$), 5.30 (1H, d, *J* =1.2 Hz, =C**H**$_2$), 4.03 (3H, br s, N**H**$_2$ and O**H**), 3.97–3.84 (2H, m, C**H**$_2$N), 3.81 (3H, s, OC**H**$_3$), 3.70–3.63 (1H, m, C**H**CH$_2$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.1 (C), 157.2 (C), 143.9 (C), 143.1 (C), 141.9 (C), 132.0 (C), 129.1 (CH), 128.54 (C), 128.51 (2 × CH), 128.46 (CH), 128.0 (CH), 125.7 (2 × CH), 122.1 (2 × CH), 118.8 (CH_2), 118.7 (CH), 116.4 (CH), 114.3 (2 × CH), 81.4 (C), 55.6 (CH_3), 51.5 (CH), 50.4 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{25}H_{25}N_2O_3]^+$ $[M+H]^+$: 401.1860, found: 401.1862; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column (70:30 *iso*-hexane:*i*-PrOH, 1.5 mL/min, 254 nm, 25 °C) t_r (major) = 12.6 min, t_r (minor) = 18.3 min, 56% ee.

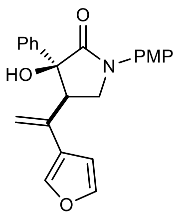


(3*S*,4*R*)-4-[1-(3-Bromo-5-methylphenyl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2o). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 3-methyl-5-bromophenylboronic acid (96.7 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (143 mg, >99%) as a white solid. R_f = 0.31 (30% EtOAc/petroleum ether); m.p. 59-62 °C (Et_2O); IR 3359 (OH), 2916, 1678 (C=O), 1510, 1442, 1246, 1180, 1140, 1030, 827 cm^{-1}; $[\alpha]_D^{25}$ +20.0 (*c* 1.00, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$) δ 7.61–7.55 (2H, m, Ar**H**), 7.36–7.21 (5H, m, Ar**H**), 7.15 (2H, dd, *J* = 1.6, 0.8 Hz, Ar**H**), 6.96–6.91 (2H, m, Ar**H**), 6.84 (1H, td, *J* = 1.5, 0.8 Hz, Ar**H**), 5.48 (1H, s, =C**H**$_2$), 5.36 (1H, d, *J* = 0.9 Hz, =C**H**$_2$), 4.02–

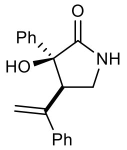
3.90 (2H, m, C**H**$_2$N), 3.82 (3H, s, OC**H**$_3$), 3.64 (1H, t, *J* = 6.2 Hz C**H**CH$_2$), 3.45 (1H, s, O**H**), 2.19 (3H, d, *J* = 0.8 Hz, ArC**H**$_3$); ^{13}C NMR (101 MHz, CDCl$_3$) δ 173.0 (C), 157.2 (C), 144.3 (C), 143.7 (C), 141.8 (C), 139.8 (C), 131.9 (C), 131.0 (CH), 128.5 (2 × CH), 128.1 (CH), 127.1 (CH), 126.4 (CH), 125.6 (2 × CH), 122.1 (C), 121.9 (2 × CH), 116.8 (CH$_2$), 114.4 (2 × CH), 81.1 (C), 55.6 (CH$_3$), 50.9 (CH$_2$), 50.0 (CH), 21.2 (CH$_3$); HRMS (ESI) Exact mass calculated for $[C_{26}H_{25}BrNO_3]^+$ $[M+H]^+$: 478.1012, found: 478.1023; Enantiomeric excess was determined by HPLC with a Chiralpak IC column 90:10 (*iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 41.2 min, t_r (major) = 54.2 min, 98% ee.



(3*S*,4*R*)-4-[1-(3,4-Dichlorophenyl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2p). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 3,4-dichlorophenylboronic acid (85.9 mg, 0.450 mmol). Filtration through a silica pad without purification by column chromatography gave the title compound (136 mg, >99%) as a white solid. R_f = 0.27 (30% EtOAc/petroleum ether); m.p. 61-64 °C (Et$_2$O); 3348 (OH), 2954, 1677 (C=O), 1509, 1469, 1396, 1244, 1027, 825, 696 cm^{-1}; $[\alpha]_D^{25}$ +8.0 (*c* 1.00, CHCl$_3$); ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.62–7.53 (2H, m, Ar**H**), 7.32–7.23 (7H, m, Ar**H**), 7.05 (1H, dd, *J* = 8.3, 2.2 Hz, Ar**H**), 6.97–6.91 (2H, m, Ar**H**), 5.47 (1H, s, =C**H**$_2$), 5.35 (1H, d, *J* = 0.9 Hz, =C**H**$_2$), 3.96 (2H, d, *J* = 5.9 Hz, C**H**$_2$N), 3.83 (3H, s, OC**H**$_3$), 3.66–3.58 (1H, m, C**H**CH$_2$), 3.42 (1H, s, O**H**); ^{13}C NMR (101 MHz, CDCl$_3$) δ 173.0 (C), 157.3 (C), 143.7 (C), 142.0 (C), 141.7 (C), 132.2 (C), 131.8 (C), 131.4 (C), 130.0 (CH), 129.0 (CH), 128.6 (2 × CH), 128.2 (CH), 126.3 (CH), 125.5 (2 × CH), 121.9 (2 × CH), 117.2 (CH$_2$), 114.4 (2 × CH), 81.1 (C), 55.6 (CH$_3$), 50.7 (CH$_2$), 50.0 (CH); HRMS (ESI) Exact mass calculated for $[C_{25}H_{22}Cl_2NO_3]^+$ $[M+H]^+$: 454.0971, found: 454.0972; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (80:20 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 19.2 min, t_r (major) = 25.3 min, 98% ee.

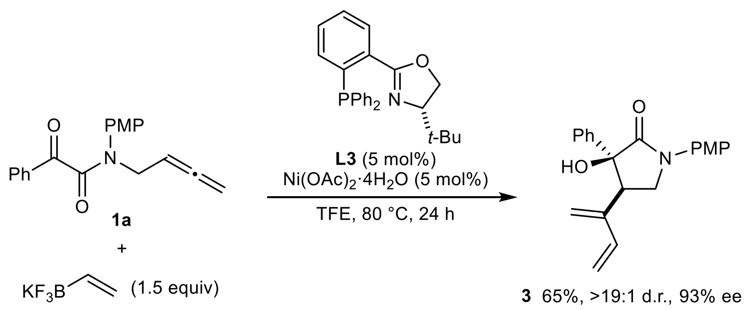


(3*S*,4*R*)-4-[1-(Furan-3-yl)vinyl]-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (2q). The General Procedure was followed using allene **1a** (92.2 mg, 0.300 mmol) and 3-furylboronic acid (50.4 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 30% EtOAc/pentane) gave the title compound (103 mg, 91%) as a white solid as a 7:1 mixture of diastereomers. R_f = 0.22 (30% EtOAc/petroleum ether); m.p. 160-162 °C (Et$_2$O); IR 3309 (OH), 2949, 1687 (C=O), 1510, 1396, 1291, 1273, 1214, 906, 698 cm^{-1}; $[\alpha]_D^{25}$ +48.0 (*c* 1.00, CHCl$_3$); ^{1}H NMR (400 MHz, CDCl$_3$) *major diasteromer*: δ 7.70–7.59 (2H, m, Ar**H**), 7.49–7.42 (2H, m, Ar**H**), 7.42–7.31 (4H, m, Ar**H**), 7.15 (1H, t, *J* = 1.2 Hz, Ar**H**), 7.05–6.94 (2H, m, Ar**H**), 6.48 (1H, dd, *J* = 1.9, 0.9 Hz, Ar**H**), 5.54 (1H, s, =C**H**$_2$), 5.23 (1H, s, =C**H**$_2$), 4.05–3.93 (2H, m, C**H**$_2$N), 3.85 (3H, s, OC**H**$_3$), 3.57–3.49 (1H, m, C**H**CH$_2$), 3.23 (1H, s, O**H**); *characteristic signals for the minor diastereomer*: 7.14 (1H, t, *J* = 1.2 Hz, Ar**H**), 3.35 (1H, s, O**H**); ^{13}C NMR (101 MHz, CDCl$_3$) *major diasteromer*: δ 172.9 (C), 157.3 (C), 143.3 (CH), 142.4 (C), 139.5 (CH), 136.5 (C), 131.9 (C), 128.8 (2 × CH), 128.3 (CH), 127.2 (C), 125.5 (2 × CH), 121.8 (2 × CH), 114.4 (2 × CH), 113.6 (CH$_2$), 108.8 (CH), 80.8 (C), 55.6 (CH$_3$), 50.7 (CH$_2$), 49.9 (CH); HRMS (ESI) Exact mass calculated for $[C_{23}H_{22}NO_4]^+$ $[M+H]^+$: 376.1543, found: 376.1542; Enantiomeric excess was determined by HPLC with a Chiralpak ODH column (85:15 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 18.1 min, t_r (major) = 20.9 min, 91% ee.

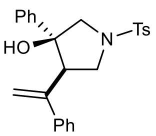


(3*S*,4*R*)-3-Hydroxy-3-phenyl-4-(1-phenylvinyl)pyrrolidin-2-one (2r). A modification of the General Procedure (in that the reaction time was 40 h rather than 24 h) was followed using allene **1g** (60.4 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (8% MeOH/CH$_2$Cl$_2$) gave the title compound (75.3 mg, 90%) as a white solid. R_f = 0.37 (8% MeOH/CH$_2$Cl$_2$); m.p. 200–204 °C (CH$_2$Cl$_2$); $[\alpha]_D^{25}$ +36.4 (*c* 0.22, (CH$_3$)$_2$CO); IR 3263 (OH), 1692 (C=O), 1403, 1279, 1128, 931, 795, 745, 692, 602, 549, 514, 429 cm^{-1}; ^{1}H NMR (400 MHz, (CD$_3$)$_2$SO) δ 8.16 (1H, s, N**H**), 7.23–7.10 (5H, m, Ar**H**), 7.09–6.96 (5H, m, Ar**H**), 5.88 (1H, s, O**H**), 5.34 (1H, d, *J* = 1.2 Hz, =C**H**$_2$), 5.31 (1H, s, =C**H**$_2$), 3.57 (1H, t, *J* = 7.8 Hz, C**H**CH$_2$), 3.48-3.38 (2H, m, NC**H**$_2$); ^{13}C NMR (101 MHz, (CD$_3$)$_2$SO) δ 176.1 (C), 144.2 (C), 142.8 (C), 142.1 (C), 127.6 (2 × CH), 127.1 (2 × CH), 126.7 (CH), 126.4 (CH), 126.3 (2 × CH), 126.1 (2 × CH), 116.2 (CH$_2$), 78.6 (C), 52.1 (CH), 43.6 (CH$_2$); HRMS (ESI) Exact mass calcd for $[C_{18}H_{17}NNaO_2]^+$ $[M+Na]^+$: 302.1151, found: 302.1144. Enantiomeric excess was determined by HPLC with a Chiralpak IC column (70:30 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C); t_r (major) = 10.5 min, t_r (minor) = 18.8 min, 99% ee.

(3*S*,4*R*)-4-(Buta-1,3-dien-2-yl)-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (3)

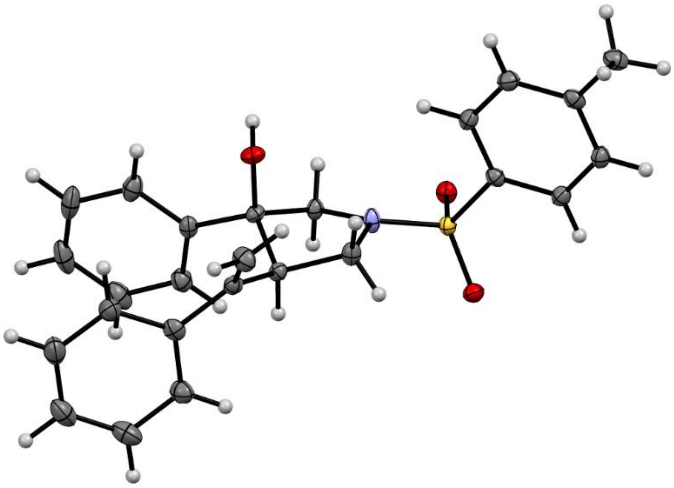


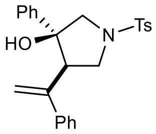
A modification of the General Procedure (in that potassium vinyltrifluoroborate was used instead of a boronic acid) was followed using allene **1a** (92.2 mg, 0.300 mmol) and potassium vinyltrifluoroborate (60.3 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 30% EtOAc/pentane) gave the title compound (83.4 mg, 65%) as a white oil. R_f = 0.26 (30% EtOAc/petroleum ether); IR 3369 (OH), 2931, 1681 (C=O), 1593, 1510, 1441, 1399, 1245, 1180, 828 cm^{-1}; $[\alpha]_D^{25}$ +92.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.69–7.61 (2H, m, Ar**H**), 7.47–7.40 (2H, m, Ar**H**), 7.40–7.28 (3H, m, Ar**H**), 7.00–6.93 (2H, m, Ar**H**), 6.41 (1H, ddd, *J* = 17.5, 11.0, 0.8 Hz, CH_2=C**H**), 5.36 (1H, s, C**H**$_2$=C), 5.20 (1H, d, *J* = 1.0 Hz, C**H**$_2$=C), 5.12 (1H, d, *J* = 17.5 Hz, C**H**$_2$=CH), 5.04 (1H, dd, *J* = 11.0, 0.9 Hz, CHC**H**$_2$), 3.93 (1H, dd, *J* = 10.0, 6.8 Hz, C**H**$_2$N), 3.88–3.84 (1H, m, C**H**$_2$N), 3.83 (3H, s, OC**H**$_3$), 3.53 (1H, dd, *J* = 6.8, 4.0 Hz, C**H**CH_2N), 3.18 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.1 (C), 157.2 (C), 143.3 (C), 142.3 (C), 138.8 (CH), 131.9 (C), 128.8 (2 × CH), 128.2 (CH), 125.5 (2 × CH), 121.7 (2 × CH), 117.2 (CH_2), 114.6 (CH_2), 114.4 (2 × CH), 80.8 (C), 55.6 (CH_3), 50.7 (CH_2), 46.3 (CH); HRMS (ESI) Exact mass calculated for $[C_{21}H_{22}NO_3]^+$ $[M+H]^+$: 336.1594, found: 336.1589; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column (90:10 *iso*-hexane:*i*-PrOH), 1.0 mL/min, 230 nm, 25 °C) t_r (minor) = 16.7 min, t_r (major) = 20.6 min, 93% ee.



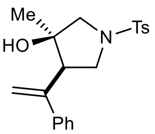
(3*S*,4*R*)-3-Phenyl-4-(1-phenylvinyl)-1-tosylpyrrolidin-3-ol (5a). The General Procedure was followed using allene **4a** (102 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (20% EtOAc/petroleum ether) gave the title compound (116 mg, 92%) as a colorless amorphous solid. R_f = 0.33 (20% EtOAc/petroleum ether); $[\alpha]_D^{25}$ –36.4 (*c* 0.33, $CHCl_3$); IR 3486 (OH), 2894, 1632, 1595, 1489, 1446, 1292, 1137, 1102, 907, 818, 752, 682, 639, 595, 544, 516, 470 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.81–7.78 (2H, m, Ar**H**), 7.38–7.35 (2H, m, Ar**H**), 7.17–7.13 (2H, m, Ar**H**), 7.11–7.01 (6H, m, Ar**H**), 6.88–6.84 (2H, m, Ar**H**), 5.32 (1H, s, =C**H**$_2$), 5.15 (1H, s, =C**H**$_2$), 3.92 (1H, dd, *J* = 9.3, 7.2 Hz, CHC**H**$_2$), 3.76 (1H, d, *J* = 11.4 Hz, CC**H**$_2$N), 3.75–3.70 (1H, m, C**H**CH_2), 3.64 (1H, d, *J* = 11.4 Hz, CC**H**$_2$N), 3.54 (1H, dd, *J* = 11.4, 9.3 Hz, CHC**H**$_2$), 2.47 (3H, s, ArC**H**$_3$), 2.26 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 143.9 (C), 143.7 (C), 141.6 (C), 140.8 (C), 134.0 (C), 129.8 (2 × CH), 128.1 (2 × CH), 128.0 (2 × CH), 127.7 (2 × CH), 127.4 (CH), 127.3 (CH), 126.6 (2 × CH), 125.1 (2 × CH), 117.3 (CH_2), 80.4 (C), 62.8 (CH_2), 53.6 (CH), 51.4 (CH_2), 21.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{25}H_{26}NO_3S]^+$ $[M+H]^+$: 420.1628, found: 420.1631; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 23.0 min, t_r (major) = 31.9 min, 84% ee.

Slow diffusion of petroleum ether into a solution of **5a** in EtOAc gave crystals that were suitable for X-ray crystallography:

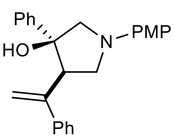




5a
CCDC 1945865
Flack parameter –0.008(5)



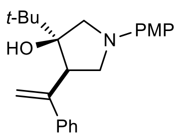
(3*R*,4*R*)-3-Methyl-4-(1-phenylvinyl)-1-tosylpyrrolidin-3-ol (5b). The General Procedure was followed using allene **4b** (83.8 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (20% EtOAc/petroleum ether) gave the title compound (103 mg, 96%) as a colorless oil. R_f = 0.38 (20% EtOAc/petroleum ether); $[\alpha]_D^{25}$ –80.0 (*c* 0.35, $CHCl_3$); IR 3512 (OH), 2968, 1626, 1598, 1493, 1380, 1152, 1092, 934, 812, 778, 704, 664, 588, 547 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.77 (2H, d, *J* = 8.2 Hz, Ar**H**), 7.34 (2H, d, *J* = 8.2 Hz, Ar**H**), 7.33–7.24 (5H, m, Ar**H**), 5.46 (1H, s, =C**H**$_2$), 5.15 (1H, s, =C**H**$_2$), 3.75 (1H, dd, *J* = 9.5, 7.3 Hz, C**H**CH_2), 3.47–3.42 (2H, m, one of CHC**H**$_2$ and one of CC**H**$_2$N), 3.35 (1H, d, *J* = 11.0 Hz, CC**H**$_2$N), 3.17 (1H, dd, *J* = 11.2, 7.3 Hz, CHC**H**$_2$), 2.45 (3H, s, ArC**H**$_3$), 1.53 (1H, s, O**H**), 0.94 (3H, s, C**H**$_3$COH); ^{13}C NMR (126 MHz, $CDCl_3$) δ 144.0 (C), 143.6 (C), 142.5 (C), 134.3 (C), 129.8 (2 × CH), 128.8 (2 × CH), 128.1 (CH), 127.7 (2 × CH), 126.6 (2 × CH), 116.8 (CH_2), 77.0 (C), 60.7 (CH_2), 52.0 (CH), 51.4 (CH_2), 25.0 (CH_3), 21.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{20}H_{24}NO_3S]^+$ $[M+H]^+$: 358.1471, found: 358.1474; Enantiomeric excess was determined by HPLC with a Chiralcel OD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 27.2 min, t_r (major) = 30.6 min, 83% ee.



(3*S*,4*R*)-1-(4-Methoxyphenyl)-3-phenyl-4-(1-phenylvinyl)pyrrolidin-3-ol (5c). The General Procedure was followed using allene **4c** (87.9 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (10% EtOAc/pentane) gave the title compound (69.1 mg, 62%) as a pale yellow solid. R_f = 0.47 (20% EtOAc/petroleum ether); m.p. 170–174 °C (Et_2O); $[\alpha]_D^{25}$ –21.1 (*c* 0.19, $CHCl_3$); IR 3529 (OH), 2906, 1620, 1511, 1471, 1445, 1371, 1346, 1270, 1238, 1178, 1109, 1038, 898, 815, 766, 664, 596, 511, 410 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.40–7.37 (2H, m, Ar**H**), 7.21–7.16 (2H, m, Ar**H**), 7.15–7.10 (4H, m, Ar**H**), 7.07–7.03 (2H, m, Ar**H**), 6.90–6.86 (2H, m, Ar**H**), 6.58–6.53 (2H, m, Ar**H**), 5.46

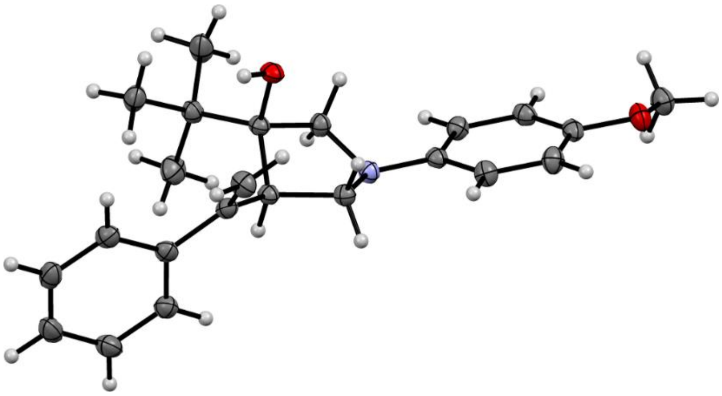
(1H, d, J = 0.8 Hz, =C**H**$_2$), 5.41 (1H, s, =C**H**$_2$), 4.01–3.96 (1H, m, C**H**CH$_2$), 3.83 (1H, d, J = 10.0 Hz, CC**H**$_2$N), 3.80–3.74 (1H, m, CHC**H**$_2$), 3.78 (3H, s, OC**H**$_3$), 3.68 (1H, dd, J = 10.1, 9.0 Hz, CHC**H**$_2$), 3.63 (1H, d, J = 10.4 Hz, CC**H**$_2$N), 2.49 (1H, s, O**H**); ^{13}C NMR (101 MHz, CDCl$_3$) δ 151.4 (C), 145.8 (C), 142.8 (C), 142.5 (C), 142.4 (C), 128.1 (4 × CH), 127.4 (CH), 127.1 (CH), 126.8 (2 × CH), 125.4 (2 × CH), 116.8 (CH$_2$), 115.2 (2 × CH), 112.6 (2 × CH), 80.7 (C), 64.5 (CH$_2$), 56.1 (CH$_3$), 53.8 (CH), 52.6 (CH$_2$); HRMS (ESI) Exact mass calculated for [$C_{25}H_{26}NO_2$]$^+$ [M+H]$^+$: 372.1958, found: 372.1962; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 28.8 min, t_r (minor) = 37.0 min, 75% ee.

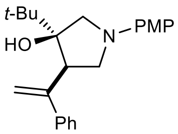
Using MeCN as the solvent: A modification of the General Procedure was followed using allene **4c** (87.9 mg, 0.30 mmol) and phenylboronic acid (54.9 mg, 0.45 mmol) but using MeCN in place of TFE as the solvent. Purification by column chromatography (20% EtOAc/petroleum ether) gave the title compound (60.4 mg, 54%) as a pale yellow solid. $[\alpha]_D^{25}$ –28.6 (*c* 0.28, CHCl$_3$); Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C); t_r (major) = 29.1 min, t_r (minor) = 37.3 min, 80% ee.



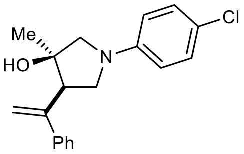
(3*S*,4*R*)-3-(*tert*-Butyl)-1-(4-methoxyphenyl)-4-(1-phenylvinyl)pyrrolidin-3-ol (5d). The General Procedure was followed using allene **xx** (81.9 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (1% EtOAc/CH$_2$Cl$_2$) gave a 7.7:1 inseparable mixture of the title compound and unreacted allene **4d** (85.2 mg, 73% yield of **5d**, adjusted for the presence of unreacted **4d**), as a colorless oil. R_f = 0.50 (20% EtOAc/petroleum ether); $[\alpha]_D^{25}$ –47.1 (*c* 0.68, CHCl$_3$); IR 2965, 1953, 1716, 1673, 1511, 1465, 1365, 1240, 1179, 1036, 974, 905, 812, 775, 710, 547 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.42–7.26 (5H, m, Ar**H**), 6.88–6.86 (2H, m, Ar**H**), 6.61–6.54 (2H, m, Ar**H**), 5.55 (1H, s, =C**H**$_2$), 5.54 (1H, s, =C**H**$_2$), 3.78–3.74 (1H, m, one of CHC**H**$_2$), 3.77 (3H, s, OC**H**$_3$), 3.67–3.53 (3H, m, CC**H**$_2$N and two of C**H**C**H**$_2$), 3.27 (1H, d, J = 10.3 Hz, CC**H**$_2$N), 2.12 (1H, s, O**H**), 0.86 (9H, s, C(C**H**$_3$)$_3$); ^{13}C NMR (101 MHz, CDCl$_3$) δ 151.3 (C), 147.4 (C), 143.5 (C), 142.8 (C), 128.7 (2 × CH), 127.7 (CH), 126.8 (2 × CH), 117.4 (CH$_2$), 115.2 (2 × CH), 112.6 (2 × CH), 85.0 (C), 58.7 (CH$_2$), 56.7 (CH$_2$), 56.1 (CH$_3$), 46.8 (CH), 37.3 (C), 26.2 (3 × CH$_3$); HRMS (ESI) Exact mass calculated for [$C_{23}H_{30}NO_2$]$^+$ [M+H]$^+$: 352.2271, found: 352.2272; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 11.5 min, t_r (minor) = 12.9 min, 99% ee.

Recrystallization of **5d** from EtOAc gave crystals that were suitable for X-ray crystallography:

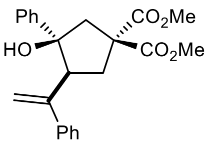




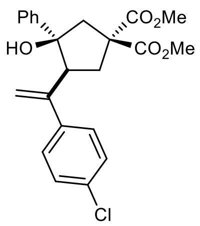
5d
CCDC 1945866
Flack parameter –0.06(8)



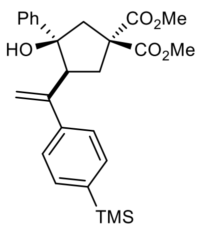
(3*R*,4*R*)-1-(4-Chlorophenyl)-3-methyl-4-(1-phenylvinyl)pyrrolidin-3-ol (5e). The General Procedure was followed using allene **4e** (70.7 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (10% EtOAc/pentane) gave the title compound (89.3 mg, 91%) as a pale yellow solid. R_f = 0.43 (20% EtOAc/petroleum ether); m.p. 90–94 °C (Et_2O); $[\alpha]_D^{25}$ –53.3 (*c* 0.30, $CHCl_3$); IR 3546 (OH), 2974, 2845, 1629, 1596, 1498, 1471, 1376, 1324, 1184, 1120, 939, 908, 813, 778, 703, 647, 600, 509, 458 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.44–7.32 (5H, m, Ar**H**), 7.21–7.17 (2H, m, Ar**H**), 6.49–6.45 (2H, m, Ar**H**), 5.60 (1H, d, *J* = 0.6 Hz, =C**H**$_2$), 5.41 (1H, s, =C**H**$_2$), 3.68–3.59 (2H, m, CHC**H**$_2$), 3.49–3.38 (3H, m, CC**H**$_2$N and C**H**CH$_2$), 1.94 (1H, s, O**H**), 1.17 (3H, s, C**H**$_3$); ^{13}C NMR (101 MHz, $CDCl_3$) δ 146.1 (C), 145.2 (C), 143.1 (C), 129.0 (2 × CH), 128.7 (2 × CH), 127.9 (CH), 126.7 (2 × CH), 120.6 (C), 116.4 (CH_2), 112.4 (2 × CH), 77.1 (C), 61.4 (CH_2), 52.1 (CH), 51.9 (CH_2), 25.4 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{19}H_{21}ClNO]^+$ $[M+H]^+$: 314.1306, found: 314.1302; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 11.0 min, t_r (minor) = 25.1 min, 90% ee.



Dimethyl (3*S*,4*S*)-3-hydroxy-3-phenyl-4-(1-phenylvinyl)cyclopentane-1,1-dicarboxylate (5f). A modification of the General Procedure (in that MeCN was used as the solvent in place of TFE) was followed using allene **4f** (90.7 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/petroleum ether to 20% EtOAc/petroleum ether) gave the title compound (37.1 mg, 33%) as a colorless oil. R_f = 0.41 (30% EtOAc/petroleum ether); $[\alpha]_D^{20}$ +0.28 (*c* 1.00, $CHCl_3$); IR 3520 (OH), 2953, 1727 (C=O), 1494, 1434, 1251, 1198, 1168, 1033, 907, 756, 697, 550 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.31–7.27 (2H, m, Ar**H**), 7.13–7.07 (2H, m, Ar**H**), 7.06–7.01 (4H, m, Ar**H**), 6.95–6.89 (2H, m, Ar**H**), 5.34–5.33 (2H, m, C=C**H**$_2$), 3.81 (3H, s, C**H**$_3$), 3.80 (3H, s, C**H**$_3$), 3.73 (1H, dd, *J* = 12.5, 7.2 Hz, C**H**CH$_2$), 2.89 (1H, dd, *J* = 13.6, 12.5 Hz, CHC**H**$_2$), 2.87–2.80 (2H, m, HOCC**H**$_2$), 2.69 (1H, dd, *J* = 13.6, 7.2 Hz, CHC**H**$_2$) 2.47 (1H, s, O**H**); ^{13}C NMR (126 MHz, $CDCl_3$) δ 173.5 (C), 173.0 (C), 146.7 (C), 143.4 (C), 142.5 (C), 128.0 (2 × CH), 127.9 (2 × CH), 127.1 (CH), 126.79 (2 × CH), 126.77 (CH), 125.2 (2 × CH), 116.5 (CH_2), 82.3 (C), 57.2 (C), 54.8 (CH), 53.24 (CH_3), 53.17 (CH_3), 50.6 (CH_2), 38.5 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{23}H_{24}NaO_5]^+$ $[M+Na]^+$: 403.1516, found: 403.1523. Enantiomeric excess was determined by HPLC with a Chiralpak OD-H column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 9.1 min, t_r (minor) = 10.5 min, 90% ee.

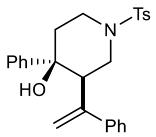


Dimethyl (3*S*,4*S*)-4-[1-(4-chlorophenyl)vinyl]-3-hydroxy-3-phenylcyclopentane-1,1-dicarboxylate (5g). A modification of the General Procedure (in that MeCN was used as the solvent in place of TFE) was followed using allene **4f** (90.7 mg, 0.300 mmol) and 4-chlorophenylboronic acid (70.4 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 40% EtOAc/pentane) gave the title compound (57.9 mg, 47%) as a colorless oil. R_f = 0.42 (30% EtOAc/petroleum ether); IR 3523 (OH), 2953, 1726 (C=O), 1622, 1491, 1434, 1250, 1099, 964, 731 cm^{-1}; $[\alpha]_D^{25}$ +40.0 (*c* 1.00, $CHCl_3$) ; ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.20–7.15 (2H, m, Ar**H**), 7.06–6.94 (3H, m, Ar**H**), 6.93–6.86 (2H, m, Ar**H**), 6.77–6.70 (2H, m, Ar**H**), 5.27 (1H, s, =C**H**$_2$), 5.25 (1H, s, =C**H**$_2$), 3.73 (3H, s, C**H**$_3$), 3.72 (3H, s, C**H**$_3$), 3.62–3.50 (1H, m, C**H**CH$_2$), 2.78 (1H, dd, *J* = 13.6, 12.5 Hz, CHC**H**$_2$), 2.76 (2H, br s, HOCC**H**$_2$), 2.60 (1H, dd, *J* = 13.6, 7.3 Hz, CHC**H**$_2$), 2.36 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 173.4 (C), 172.9 (C), 145.5 (C), 143.2 (C), 140.9 (C), 132.9 (C), 128.1 (2 × CH), 128.00 (2 × CH), 127.95 (2 × CH), 126.8 (CH), 125.1 (2 × CH), 117.0 (CH_2), 82.3 (C), 57.1 (C), 55.0 (CH), 53.25 (CH_3), 53.19 (CH_3), 50.5 (CH_2), 38.3 (CH_2); HRMS (ESI) Exact mass calculated for $[C_{23}H_{24}ClO_5]^+$ $[M+H]^+$: 415.1307, found: 415.1305; Enantiomeric excess was determined by HPLC with a Chiralpak AD-H column (90:10 *iso*-hexane:*i*PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (minor) = 12.3 min, t_r (major) = 21.2 min, 93% ee.

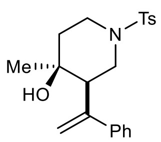


Dimethyl (3*S*,4*S*)-3-hydroxy-3-phenyl-4-{1-[4-(trimethylsilyl)phenyl]-vinyl}cyclopentane-1,1-dicarboxylate (5h). A modification of the General Procedure (in that MeCN was used as the solvent in place of TFE) was followed using allene **4f** (90.7 mg, 0.300 mmol) and 4-(trimethylsilyl)phenylboronic acid (87.3 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/pentane to 20% EtOAc/pentane) gave the title compound (46.0 mg, 34%) as a colorless oil. R_f = 0.56 (30% EtOAc/petroleum ether); IR 3523 (OH), 2953, 1729 (C=O), 1597, 1495, 1247, 1168, 1092, 908, 826 cm^{-1}; $[\alpha]_D^{25}$ +32.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.26 (2H, d, *J* = 7.2 Hz, Ar**H**), 7.20–7.13 (2H, m, Ar**H**), 7.11–7.03 (2H, m, Ar**H**), 7.03–6.97 (1H, m, Ar**H**), 6.89–6.83

(2H, m, Ar**H**), 5.36 (1H, s, =C**H**$_2$), 5.34 (1H, s, =C**H**$_2$), 3.81 (3H, s, C**H**$_3$), 3.79 (3H, s, C**H**$_3$), 3.70 (1H, dd, *J* = 12.4, 7.2 Hz, C**H**CH$_2$), 2.89 (1H, dd, *J* = 13.6, 12.5 Hz, CHC**H**$_2$), 2.84 (2H, s, HOCC**H**$_2$), 2.68 (1H, dd, *J* = 13.6, 7.3 Hz, CHC**H**$_2$), 2.44 (1H, br s, O**H**), 0.20 (9H, s, Si(C**H**$_3$)$_3$); ^{13}C NMR (101 MHz, CDCl$_3$) δ 173.5 (C), 172.9 (C), 146.7 (C), 143.5 (C), 142.7 (C), 139.0 (C), 132.9 (2 × CH), 127.9 (2 × CH), 126.7 (CH), 126.2 (2 × CH), 125.2 (2 × CH), 116.5 (CH$_2$), 82.3 (C), 57.1 (C), 54.9 (CH), 53.22 (CH$_3$), 53.15 (CH$_3$), 50.6 (CH$_2$), 38.3 (CH$_2$), –1.1 (3 × CH$_3$); HRMS (ESI) Exact mass calculated for $[C_{26}H_{33}O_5Si]^+$ $[M+H]^+$: 453.2092, found: 453.2083; Enantiomeric excess was determined by HPLC with a Chiralpak AS-H column (97:3 *iso*-hexane:*i*PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 11.3 min, t_r (minor) = 13.2 min, 89% ee.

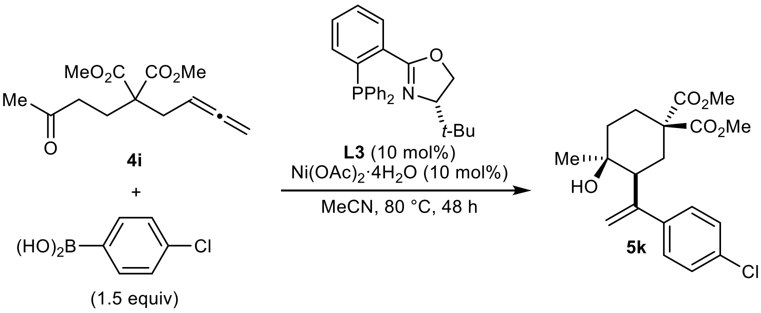


(3*R*,4*S*)-4-Phenyl-4-(1-phenylvinyl)-1-tosylpiperidin-4-ol (5i). A modification of the General Procedure (in that the reaction time was 48 h rather than 24 h) was followed using allene **4g** (107 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (10% EtOAc/pentane) gave the title compound (65.6 mg, 50%) as a colorless solid. R_f = 0.18 (20% EtOAc/petroleum ether); m.p. 151–152 °C (Et$_2$O); $[\alpha]_D^{25}$ +107 (*c* 0.15, CHCl$_3$); IR 3548 (OH), 2980, 1599, 1444, 1341, 1159, 1091, 1043, 988, 917, 846, 814, 742, 693, 659, 573, 547, 434 cm^{-1}; ^{1}H NMR (400 MHz, CDCl$_3$) δ 7.76–7.72 (2H, m, Ar**H**), 7.39–7.37 (2H, m, Ar**H**), 7.07–6.95 (8H, m, Ar**H**), 6.75–6.73 (2H, m, Ar**H**), 5.14 (1H, s, =C**H**$_2$), 5.03 (1H, s, =C**H**$_2$), 3.91 (1H, ddd, *J* = 11.5, 4.1, 1.9 Hz, C**H**$_2$N), 3.78 (1H, ddt, *J* = 11.6, 4.5, 2.0 Hz, C**H**$_2$N), 3.53 (1H, dd, *J* = 12.1, 4.0 Hz, C**H**$_2$N), 2.93–2.81 (2H, m, C**H**$_2$N and C**H**CH$_2$), 2.48 (3H, s, ArC**H**$_3$), 2.24–2.19 (1H, m, C**H**$_2$CH$_2$N), 2.15 (1H, d, *J* = 2.2 Hz, O**H**), 1.80 (1H, dt, *J* = 13.8, 2.5 Hz, C**H**$_2$CH$_2$N); ^{13}C NMR (101 MHz, CDCl$_3$) δ 148.9 (C), 144.9 (C), 143.8 (C), 143.6 (C), 133.8 (C), 130.0 (2 × CH), 127.92 (2 × CH), 127.87 (2 × CH), 127.8 (2 × CH), 127.0 (CH), 126.9 (CH), 126.4 (2 × CH), 124.7 (2 × CH), 116.0 (CH$_2$), 72.5 (C), 49.9 (CH), 47.2 (CH$_2$), 42.5 (CH$_2$), 39.0 (CH$_2$), 21.7 (CH$_3$); HRMS (ESI) Exact mass calculated for $[C_{26}H_{28}NO_3S]^+$ $[M+H]^+$: 434.1784, found: 434.1792; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (90:10 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C) t_r (major) = 33.3 min, t_r (minor) = 36.0 min, 99% ee.



(3*R*,4*S*)-4-Methyl-4-(1-phenylvinyl)-1-tosylpiperidin-4-ol (5j). A modification of the General Procedure (in that MeCN was used as the solvent in place of TFE) was followed using allene **4h** (88.0 mg, 0.300 mmol) and phenylboronic acid (54.9 mg, 0.450 mmol). Purification by column chromatography (5% EtOAc/petroleum ether to 20% EtOAc/petroleum ether) gave the title compound (74.5 mg, 67%) as a sticky amorphous solid. R_f = 0.20 (20% EtOAc/petroleum ether); $[\alpha]_D^{25}$ +36.0 (*c* 1.00, CHCl$_3$); IR 3493 (OH), 2927, 2869, 1716, 1597, 1448, 1337, 1155, 1089, 907, 737, 547 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.69–7.67 (2H, m, Ar**H**), 7.37–7.26 (7H, m), 5.41 (1H, s, =C**H**$_2$), 5.04 (1H, s, =C**H**$_2$), 3.73 (1H, ddd, *J* = 11.3, 3.9, 2.0 Hz, C**H**$_2$N), 3.67 (1H, ddt, *J* = 11.5, 4.8, 2.3 Hz, C**H**$_2$N), 2.98 (1H, dd, *J* = 12.1, 3.9 Hz, C**H**$_2$N), 2.75–2.67 (2H, m, C**H**$_2$N and C**H**CH_2), 2.45 (3H, s, ArC**H**$_3$), 1.81–1.67 (2H, m, C**H**$_2$$CH_2$N), 1.52 (1H, s, O**H**), 0.94 (3H, s, C**H**$_3$COH); ^{13}C NMR (126 MHz, $CDCl_3$) δ 148.3 (C), 143.7 (C), 143.6 (C), 133.7 (C), 129.9 (2 × CH), 128.8 (2 × CH), 127.9 (CH), 127.8 (2 × CH), 126.4 (2 × CH), 115.6 (CH_2), 68.7 (C), 49.0 (CH), 47.1 (CH_2), 42.3 (CH_2), 38.3 (CH_2), 29.8 (CH_3), 21.7 (CH_3); HRMS (ESI) Exact mass calculated for $[C_{21}H_{26}NO_3S]^+$ $[M+H]^+$: 372.1628, found: 372.1627; Enantiomeric excess was determined by HPLC with a Chiralpak AS-H column (90:10 *iso*-hexane:*i*-PrOH, 1.5 mL/min, 210 nm, 25 °C) t_r (major) = 29.3 min, t_r (minor) = 35.2 min, 85% ee.

Dimethyl (3*S*,4*S*)-3-[1-(4-chlorophenyl)vinyl]-4-hydroxy-4-methylcyclohexane-1,1-dicarboxylate (5k)

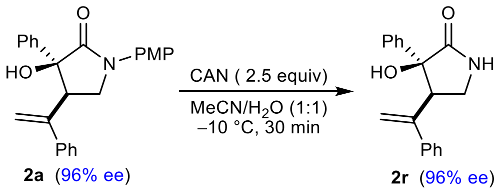


To an oven-dried microwave vial charged with a magnetic stirrer, $Ni(OAc)_2{\cdot}4H_2O$ (7.5 mg, 30 μmol), (*S*)-^{t}BuPHOX (**L3**, 11.6 mg, 30 μmol), and 4-chlorophenylboronic acid (70.4 mg, 0.450 mmol) were added. The vial was sealed and flushed with nitrogen or argon for 10 min. MeCN (1.5 mL) was added, the solution was immerged in an oil bath pre-heated to 80 °C and stirred for 10 min. Allene **4i** (76.3 mg, 0.300 mmol) was added to a separate vial that was sealed and flushed with argon for 10 min. MeCN (0.75 mL) was added to the allene and the resulting solution was added dropwise to the one containing the first vial containing the chiral nickel complex. The vial originally containing the substrate was rinsed with additional MeCN (0.75 mL) and the rinsing solution was transferred to the first microwave vial *via* syringe. The reaction mixture was stirred at 80 °C for 48 h, cooled to room temperature, diluted with EtOAc (5 mL), filtered through a short pad of silica (3 cm height × 2 cm wide) using EtOAc (20 mL) as eluent, and concentrated *in vacuo*. Purification of the residue by column chromatography (5% EtOAc/pentane to 20% EtOAc/pentane) gave the title compound (83.2 mg, 76%) as a yellow oil. R_f = 0.29 (30% EtOAc/petroleum ether); IR 3538 (OH), 2952, 1721 (C=O), 1489, 1431, 1302, 1226, 1155, 1119, 893 cm^{-1}; $[\alpha]_D^{25}$ +88.0 (*c* 1.00, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$) δ 7.31–7.27 (4H, m, Ar**H**), 5.40 (1H, s, =C**H**$_2$), 5.27 (1H, s, =C**H**$_2$), 3.81 (3H, s, OC**H**$_3$), 3.73

(3H, s, OC**H**$_3$), 2.82 (1H, dd, *J* = 13.2, 3.4 Hz, C**H**CH$_2$), 2.33 (1H, ddd, *J* =13.3, 3.5, 2.2 Hz, CHC**H**$_2$), 2.28–2.13 (3H, m, CHC**H**$_2$ and C**H**$_2$), 1.74 (1H, ddd, *J* = 14.3, 3.9, 2.9 Hz, C**H**$_2$), 1.61 (1H, br s, O**H**), 1.45 (1H, ddd, *J* =14.4, 13.4, 4.8 Hz, C**H**$_2$), 0.90 (3H, s, C**H**$_3$COH); ^{13}C NMR (101 MHz, CDCl$_3$) δ 172.4 (C), 171.9 (C), 149.7 (C), 143.2 (C), 133.4 (C), 128.8 (2 × CH), 127.6 (2 × CH), 115.7 (CH$_2$), 69.7 (C), 55.5 (C), 52.9 (CH$_3$), 52.7 (CH$_3$), 46.8 (CH), 36.7 (CH$_2$), 33.6 (CH$_2$), 30.0 (CH$_3$), 26.5 (CH$_2$); HRMS (ESI) Exact mass calculated for $[C_{19}H_{24}ClO_5]^+$ $[M+H]^+$: 367.1307, found: 367.1307; Enantiomeric excess was determined by HPLC with a Chiralpak IC column (95:5 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 210 nm, 25 °C) t_r (minor) = 14.5 min, t_r (major) = 28.9 min, 76% ee.

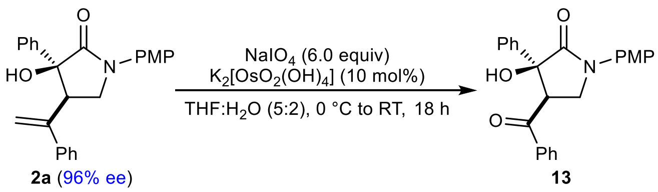
Further Transformations

(3*S*,4*R*)-3-Hydroxy-3-phenyl-4-(1-phenylvinyl)pyrrolidin-2-one (2r)



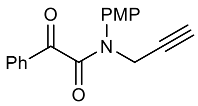
To a solution of pyrrolidin-2-one **2a** (77.0 mg, 0.20 mmol, 96% ee) in MeCN (4 mL) at −10 °C was added a solution of CAN (274 mg, 0.50 mmol) in H_2O (4 mL) dropwise. The reaction was stirred for 30 min at this temperature, diluted with H_2O (20 mL), and extracted with EtOAc (2 × 15 mL). The combined organic layers were dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (8% MeOH/CH_2Cl_2) gave the *lactam* **2r** (54.7 mg, 98%) as a white solid that displayed spectrosocopic data consistent with those reported above. $[\alpha]_D^{25}$ +32.0 (*c* 0.25, $(CH_3)_2CO$). Enantiomeric excess was determined by HPLC with a Chiralpak IC column (70:30 *iso*-hexane:*i*-PrOH, 1.0 mL/min, 254 nm, 25 °C); t_r (major) = 10.5 min, t_r (minor) = 18.8 min, 96% ee.

(3*S*,4*R*)-4-Benzoyl-3-hydroxy-1-(4-methoxyphenyl)-3-phenylpyrrolidin-2-one (12)

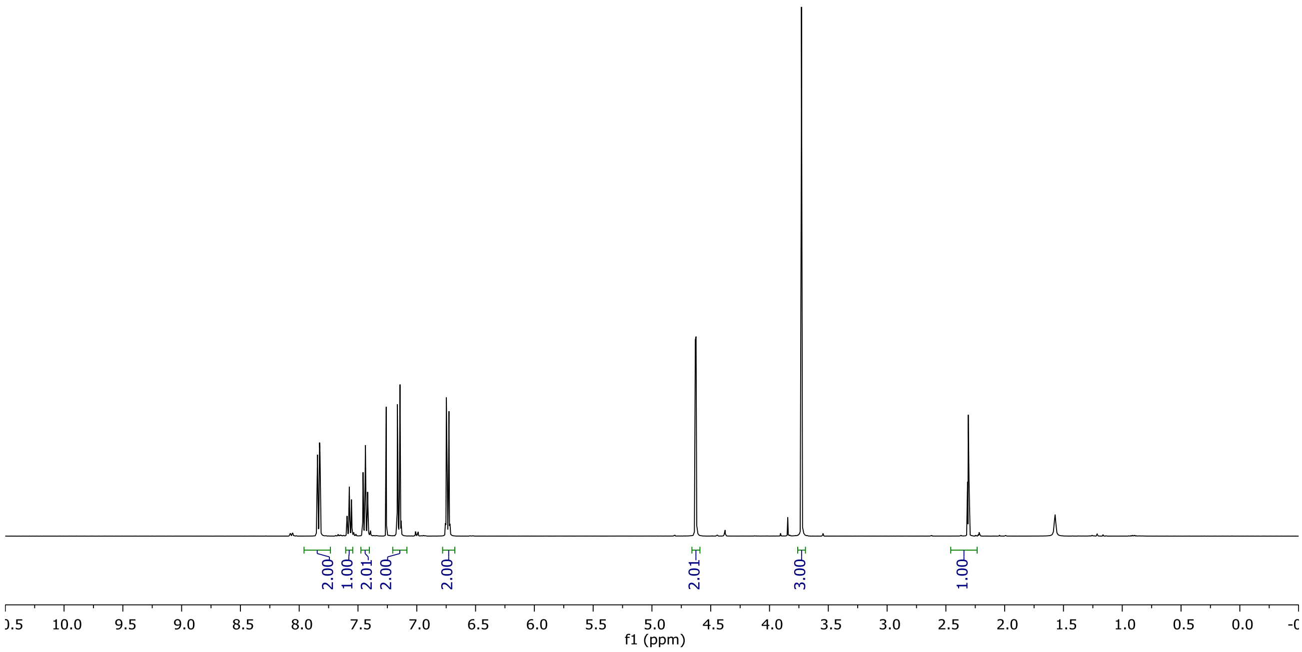


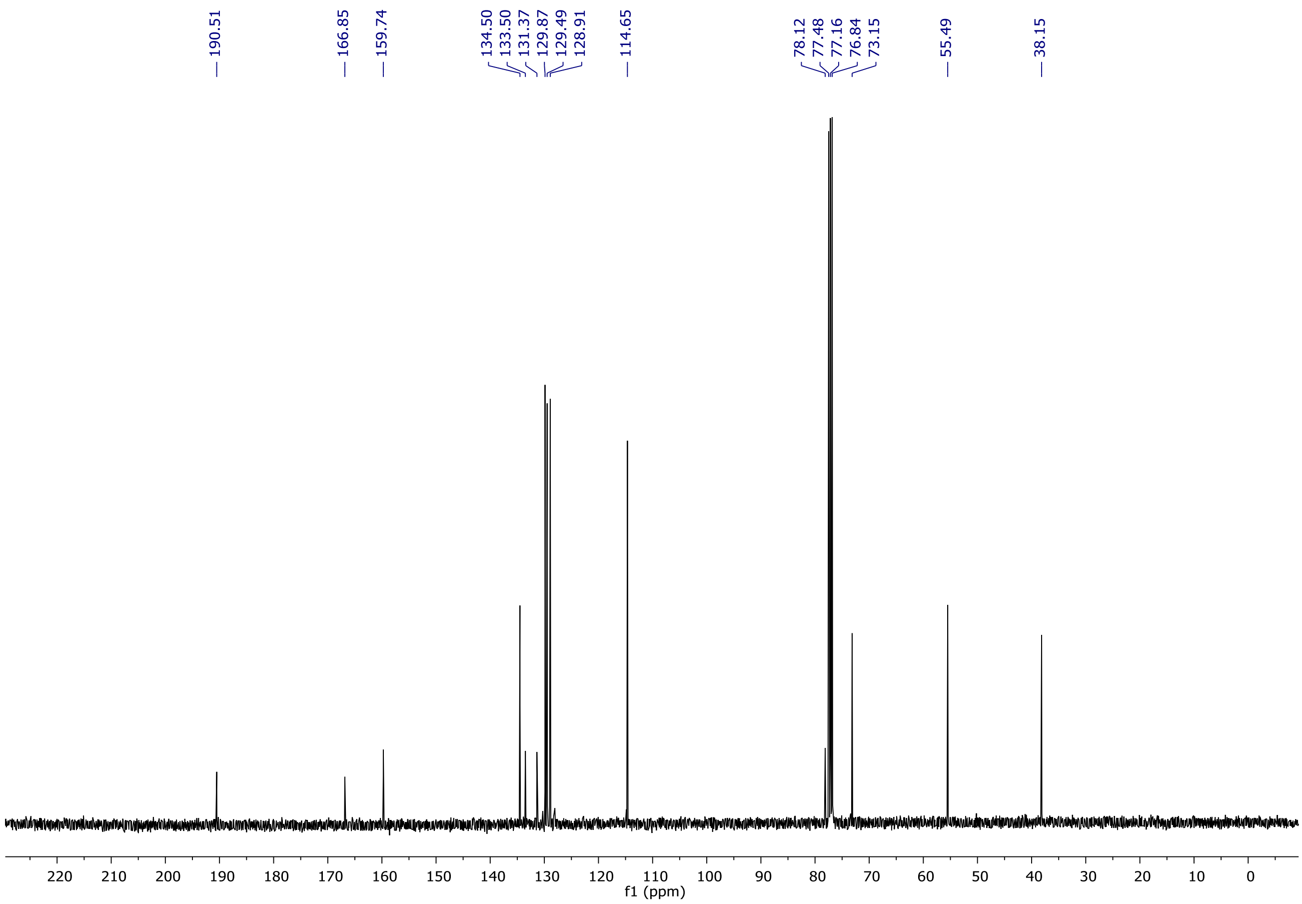
To a mixture of **2a** (77.0 mg, 0.200 mmol) and $NaIO_4$ (257 mg, 1.20 mmol) in THF (4 mL) and H_2O (1.6 mL) at 0 °C was added $K_2[OsO_2(OH)_4]$ (7.4 mg, 0.020 mmol) in one portion and the mixture was stirred for 3 h at 0 °C, and then allowed to stand for 18 h at room temperature. The mixture was filtered to remove the white solid, and the filtrate was concentrated *in vacuo*. EtOAc (30 mL) was added and the mixture was washed with H_2O (2 × 15 mL), saturated aqueous $NaHCO_3$ solution (15 mL), and brine (15 mL), and then dried (Na_2SO_4), filtered, and concentrated *in vacuo*. Purification of the residue by column chromatography (40% EtOAc/cyclohexane) gave the *ketone* **12** (70.6 mg, 91%) as a white solid. R_f = 0.38 (40% EtOAc/cyclohexane); m.p. 160−162 °C (Et_2O); $[\alpha]_D^{25}$ −22.6 (*c* 0.53, $CHCl_3$); IR 3377, 2981, 1675 (C=O), 1511, 1246, 1224, 1180, 1030, 829, 687, 623, 522 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 7.90–7.84 (2H, m, Ar**H**), 7.72–7.65 (2H, m, Ar**H**), 7.62–7.55 (1H, m, Ar**H**), 7.53–7.34 (7H, m, Ar**H**), 7.02–6.94 (2H, m, Ar**H**), 4.46 (1H, dd, *J* = 7.0, 2.8 Hz, NC**H**$_2$), 4.36 (1H, dd, *J* = 10.0, 2.8 Hz, NC**H**$_2$), 3.96 (1H, dd, *J* = 10.0, 6.9 Hz, C**H**CH_2), 3.84 (3H, s, OC**H**$_3$), 3.48 (1H, s, O**H**); ^{13}C NMR (101 MHz, $CDCl_3$) δ 197.0 (C), 172.0 (C), 157.6 (C), 142.2 (C), 137.3 (C), 133.7 (CH), 131.8 (C), 129.1 (2 × CH), 128.74 (2 × CH), 128.69 (2 × CH), 128.63 (CH), 125.0 (2 × CH), 122.5 (2 × CH), 114.5 (2 × CH), 80.6 (C), 55.7 (CH_3), 50.5 (CH), 47.9 (CH_2); HRMS (ESI) Exact mass calcd for $[C_{24}H_{21}NO_4Na]^+$ $[M + Na]^+$: 410.1363, found: 410.1359.

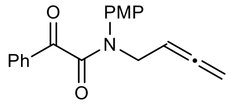
NMR Spectra



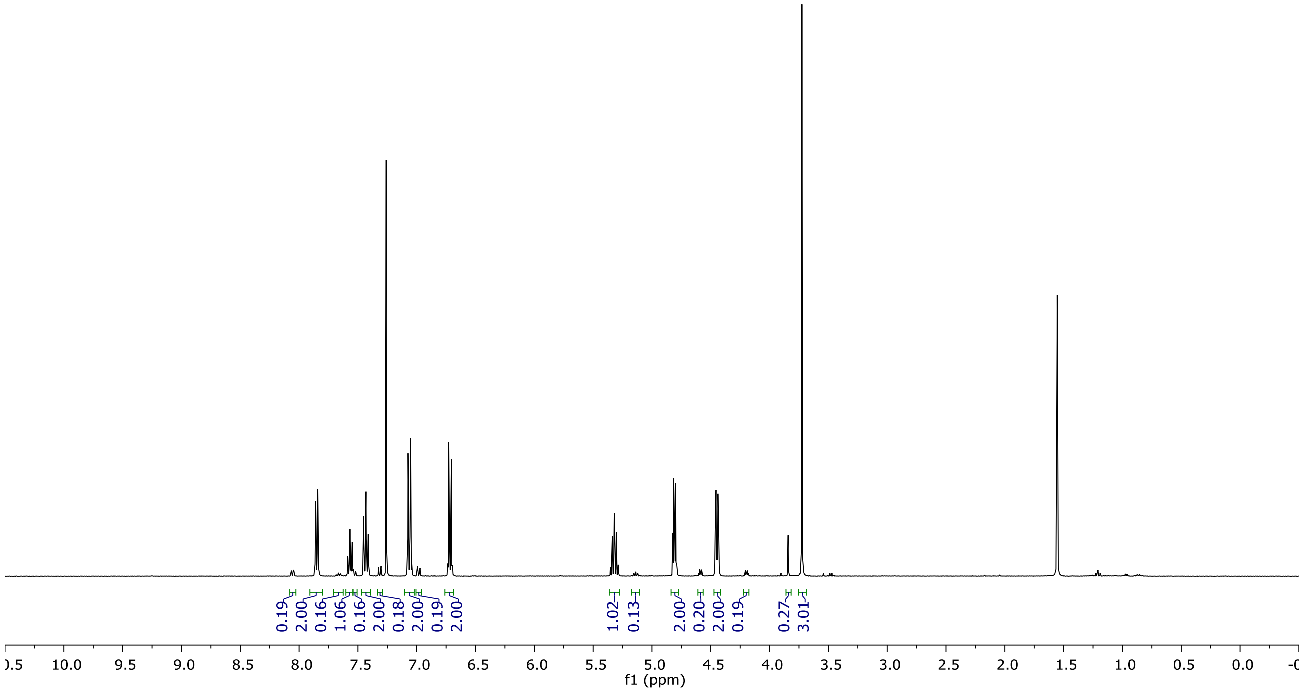
S2

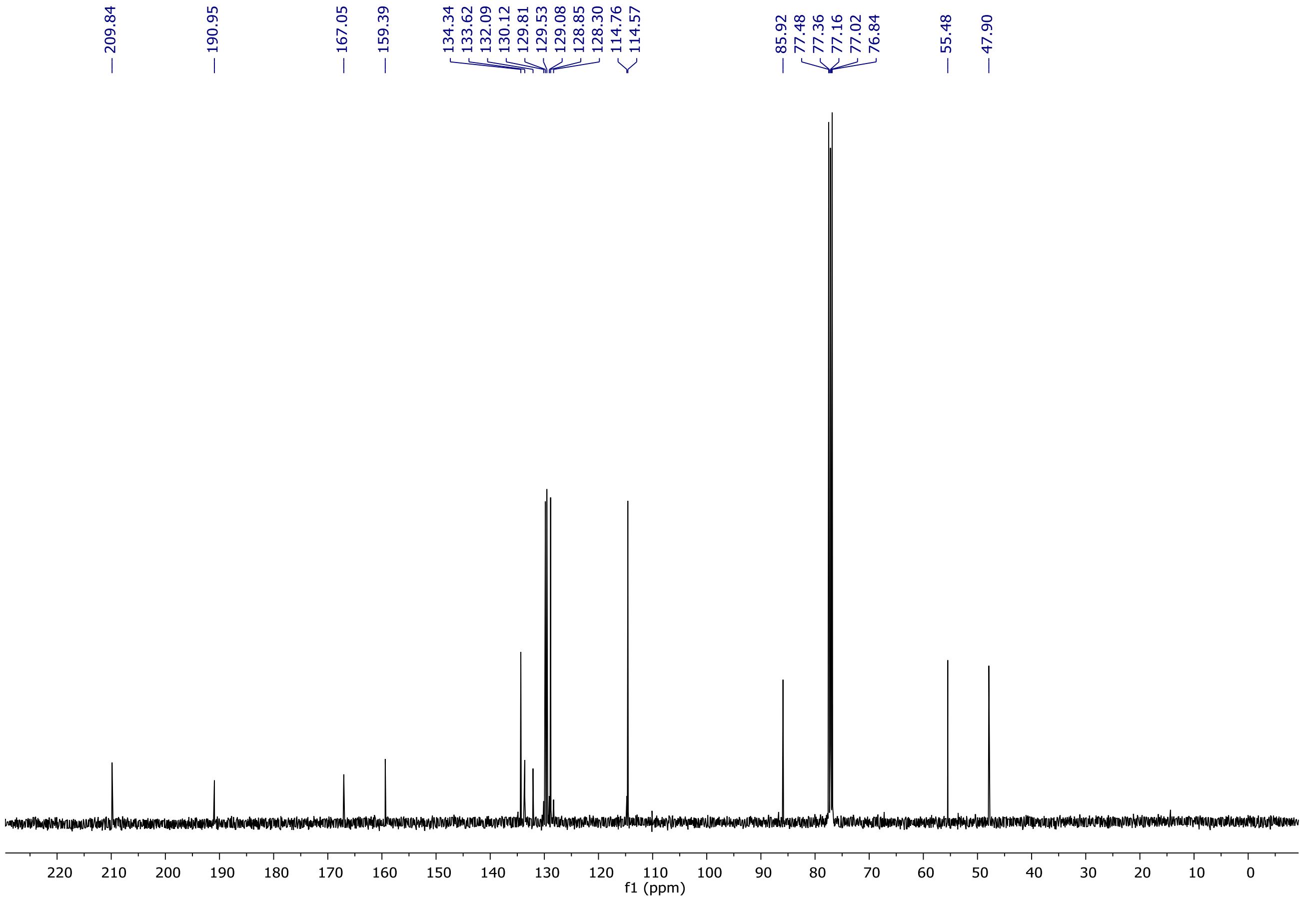


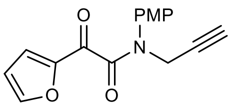




1a
10:1 mixture of rotamers



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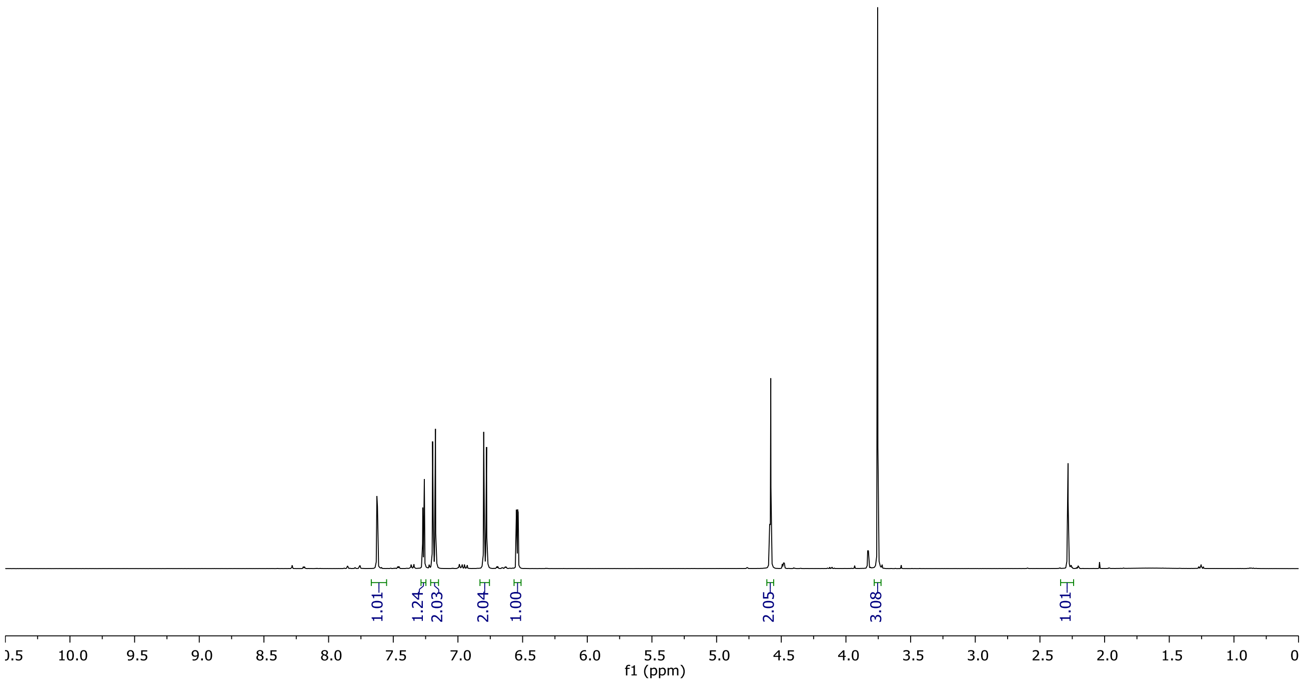
PMP
N
O
O

S3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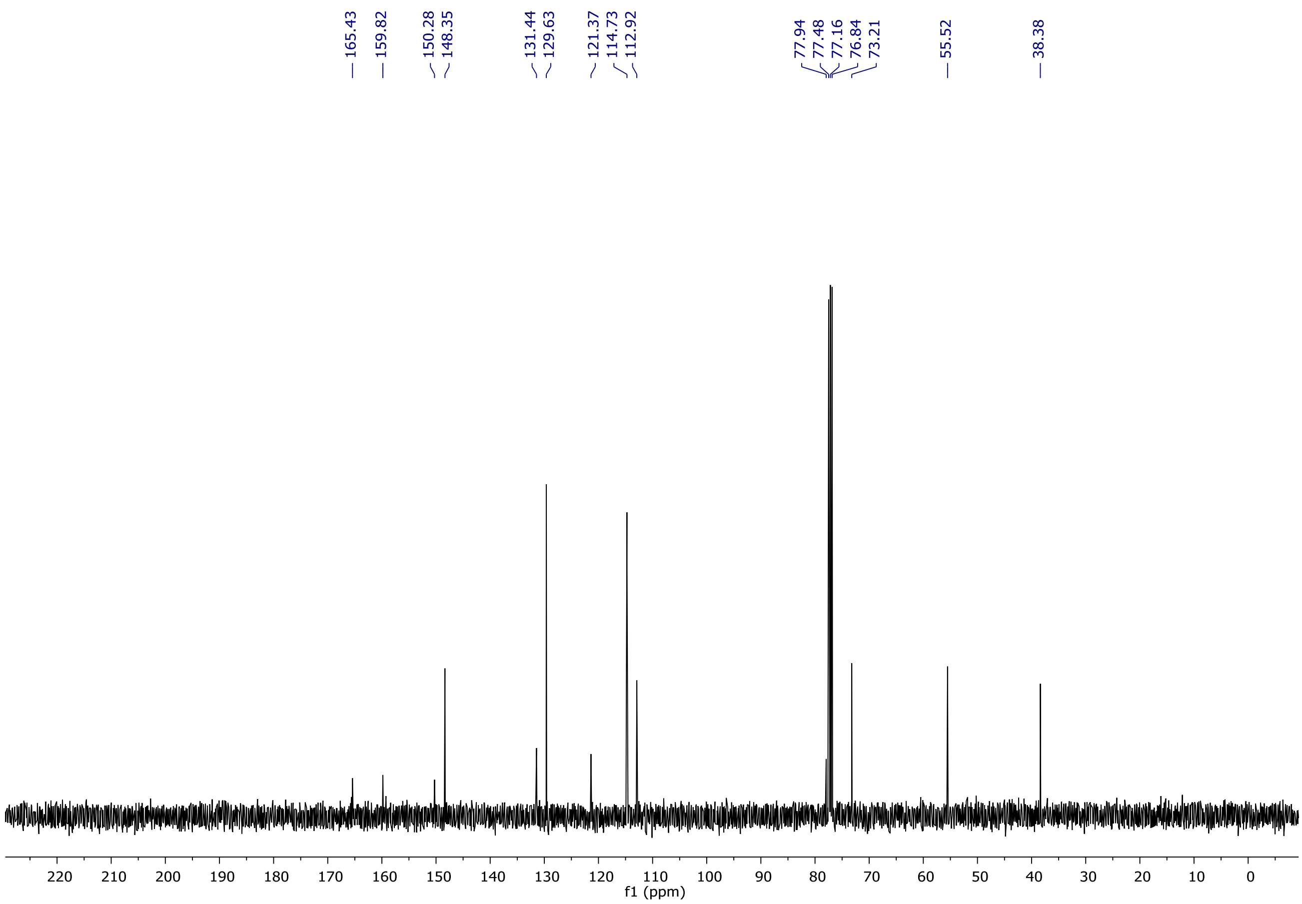
1.24
2.03
2.04
1.00
2.05
3.08
1.01
f1 (ppm)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159.82
150.28
148.35
131.44
129.63
121.37
114.73
112.92
77.94
77.48
77.16
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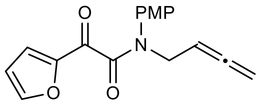
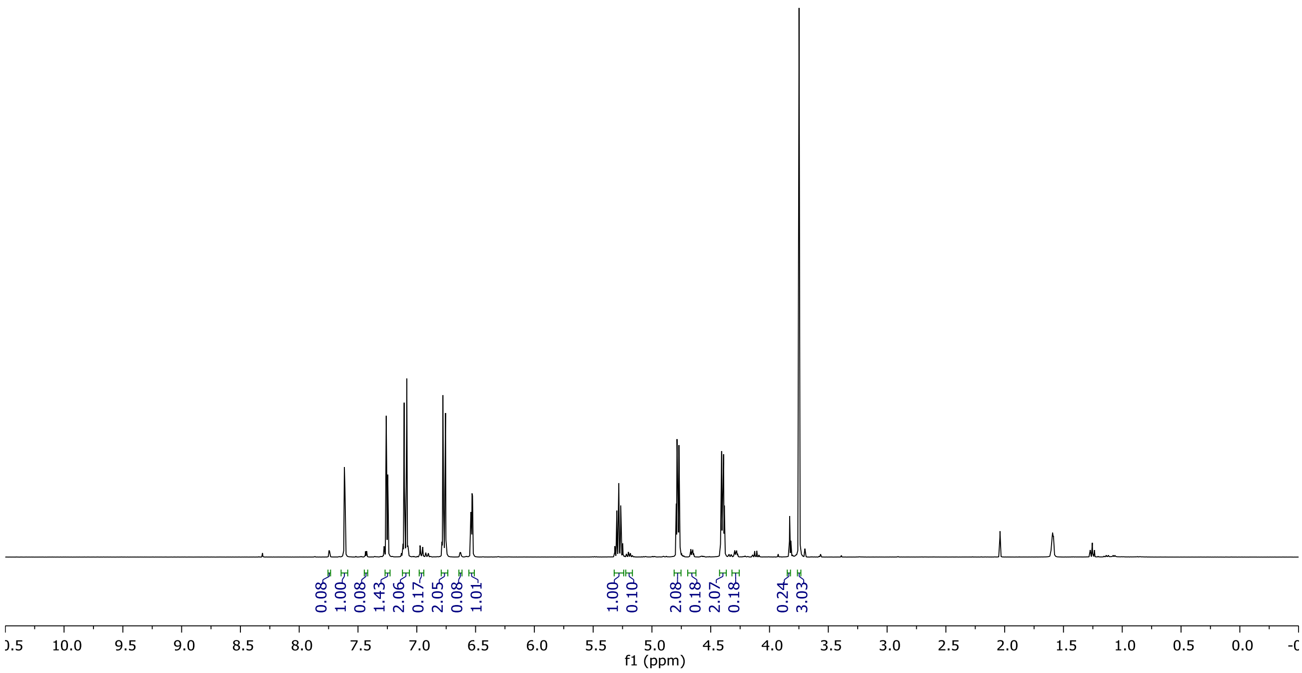
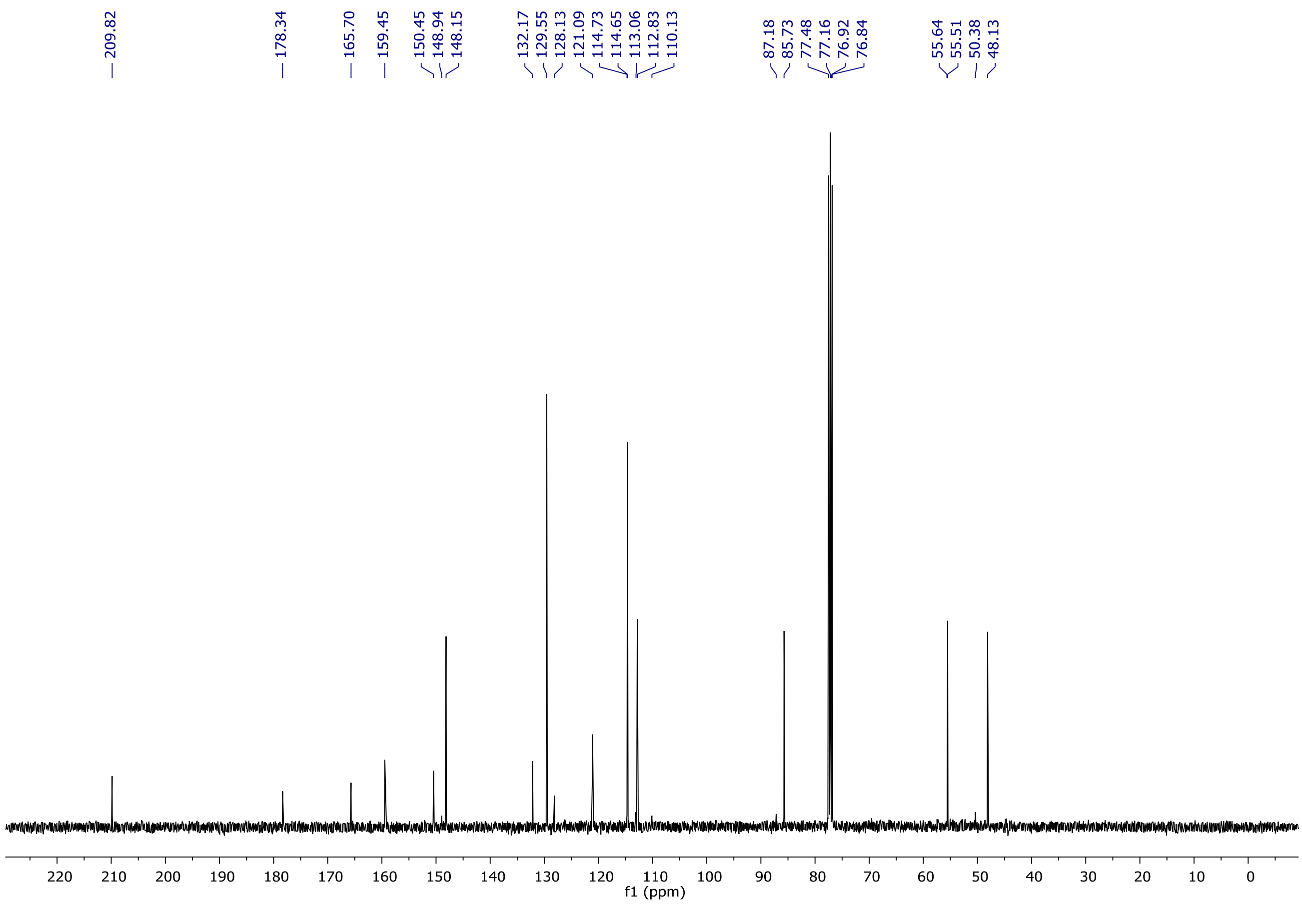
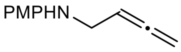
73.21
55.52
38.38
f1 (ppm)



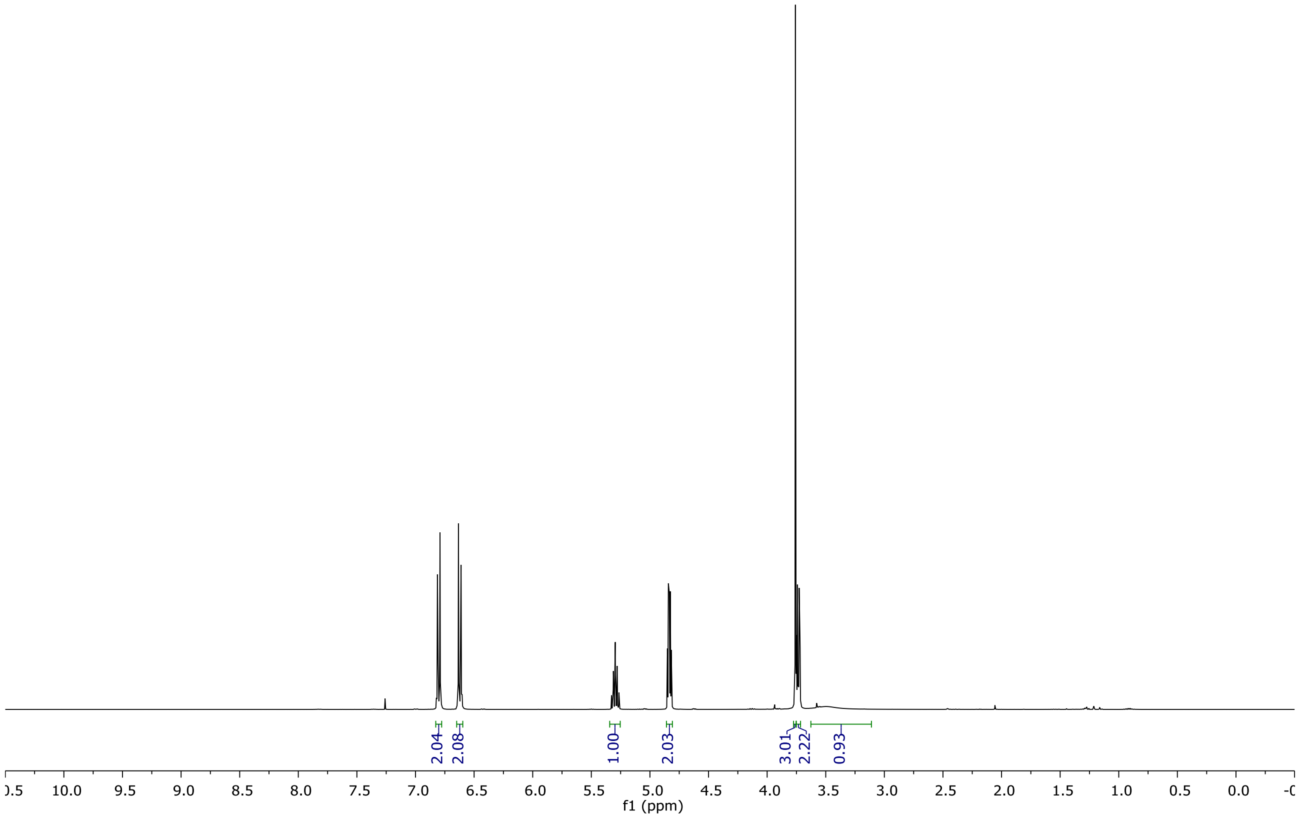
1b
10:1 mixture of rotamers






PMPHN

S5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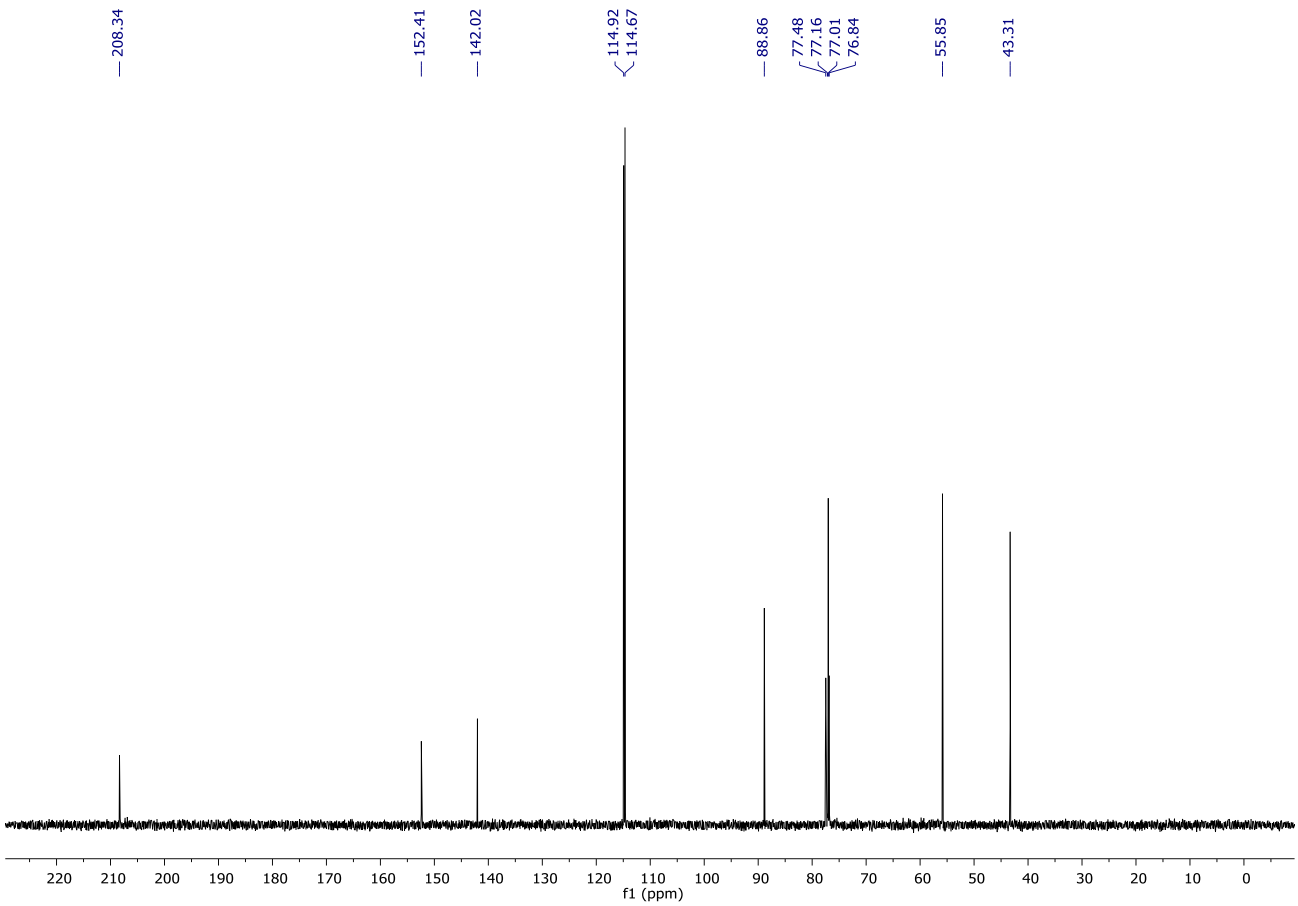
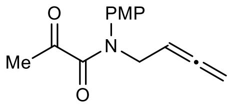
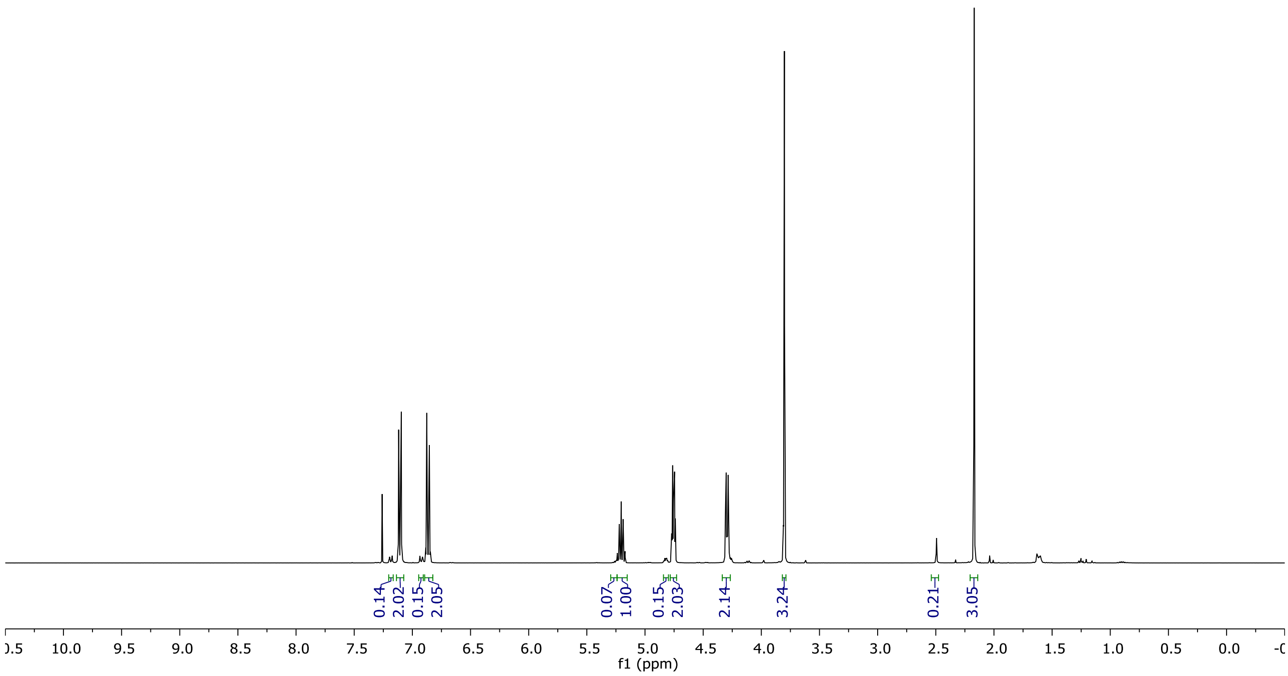
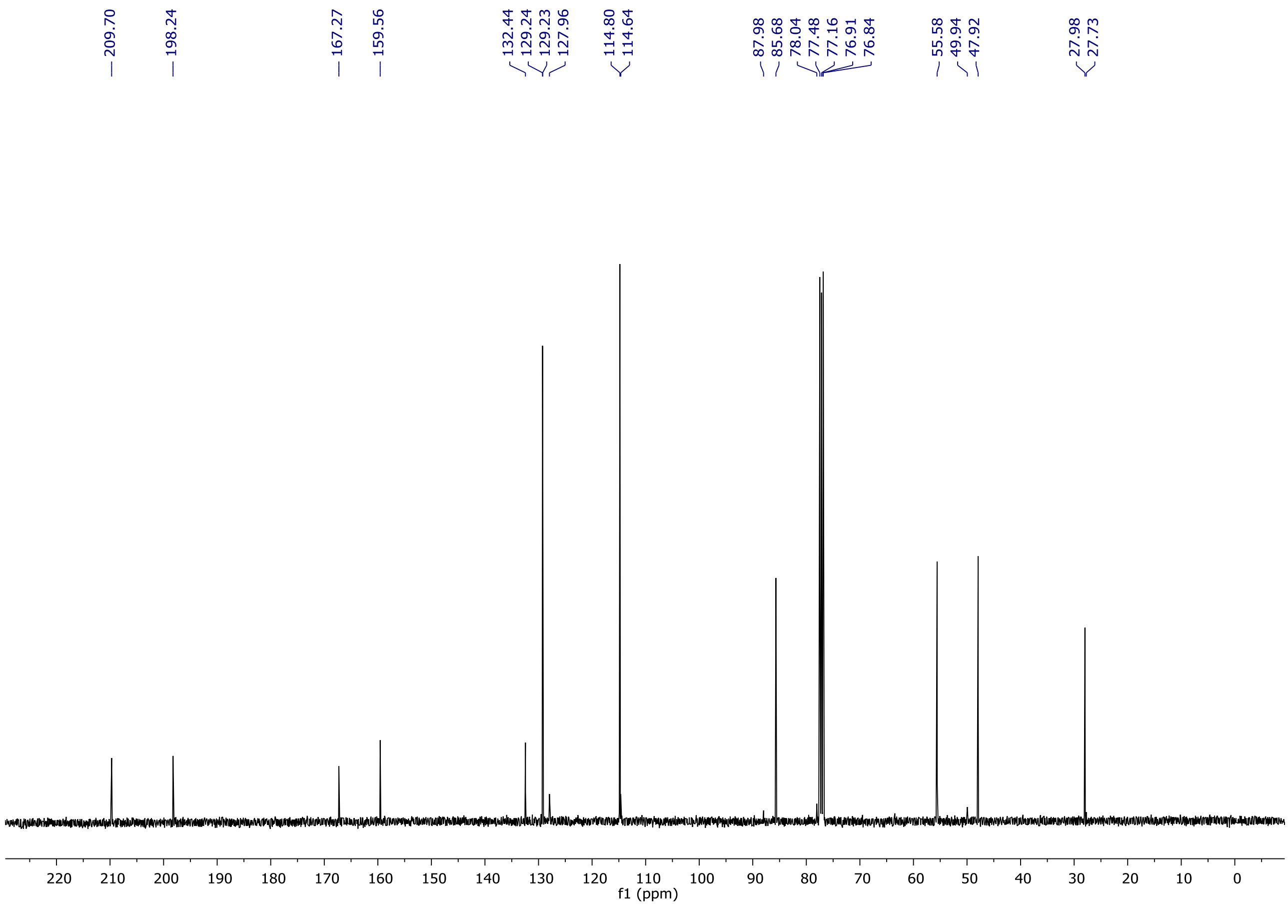
2.08
1.00
2.03
3.01
2.22
0.93
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

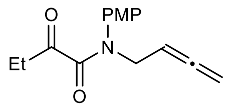

208.34
152.41
142.02
114.92
114.67
88.86
77.48
77.16
77.01
76.84
55.85
43.31
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



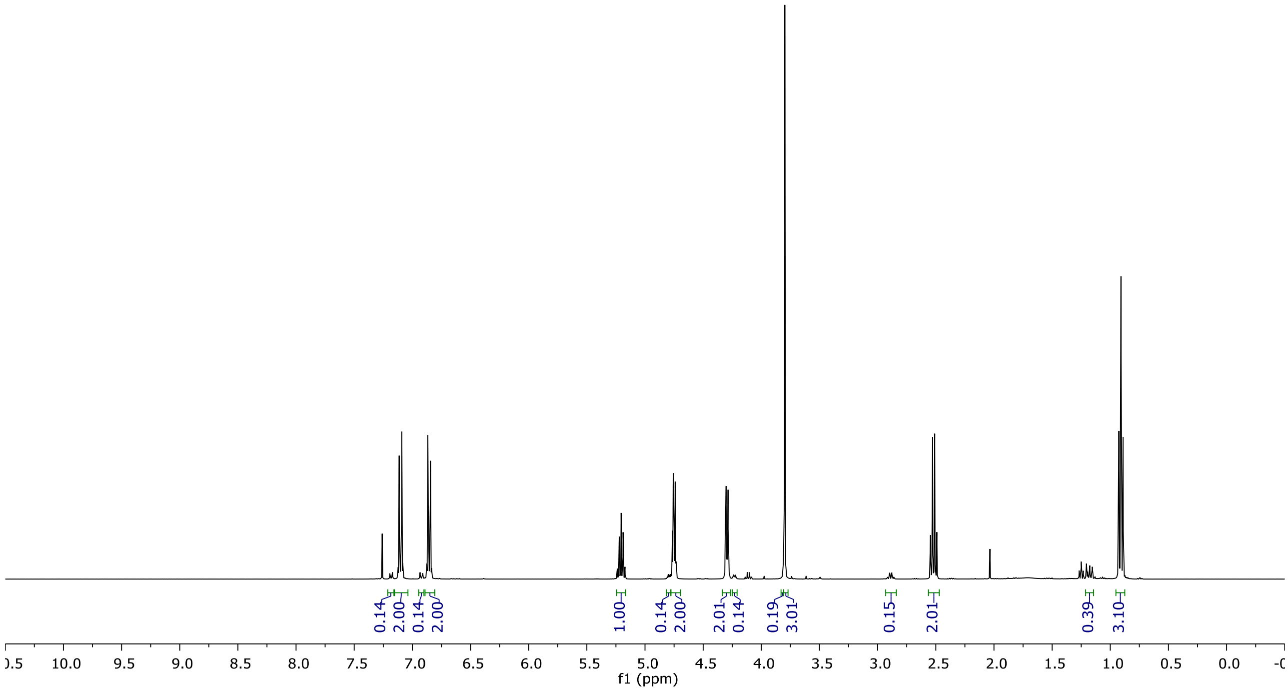
1c
14:1 mixture of rotamers

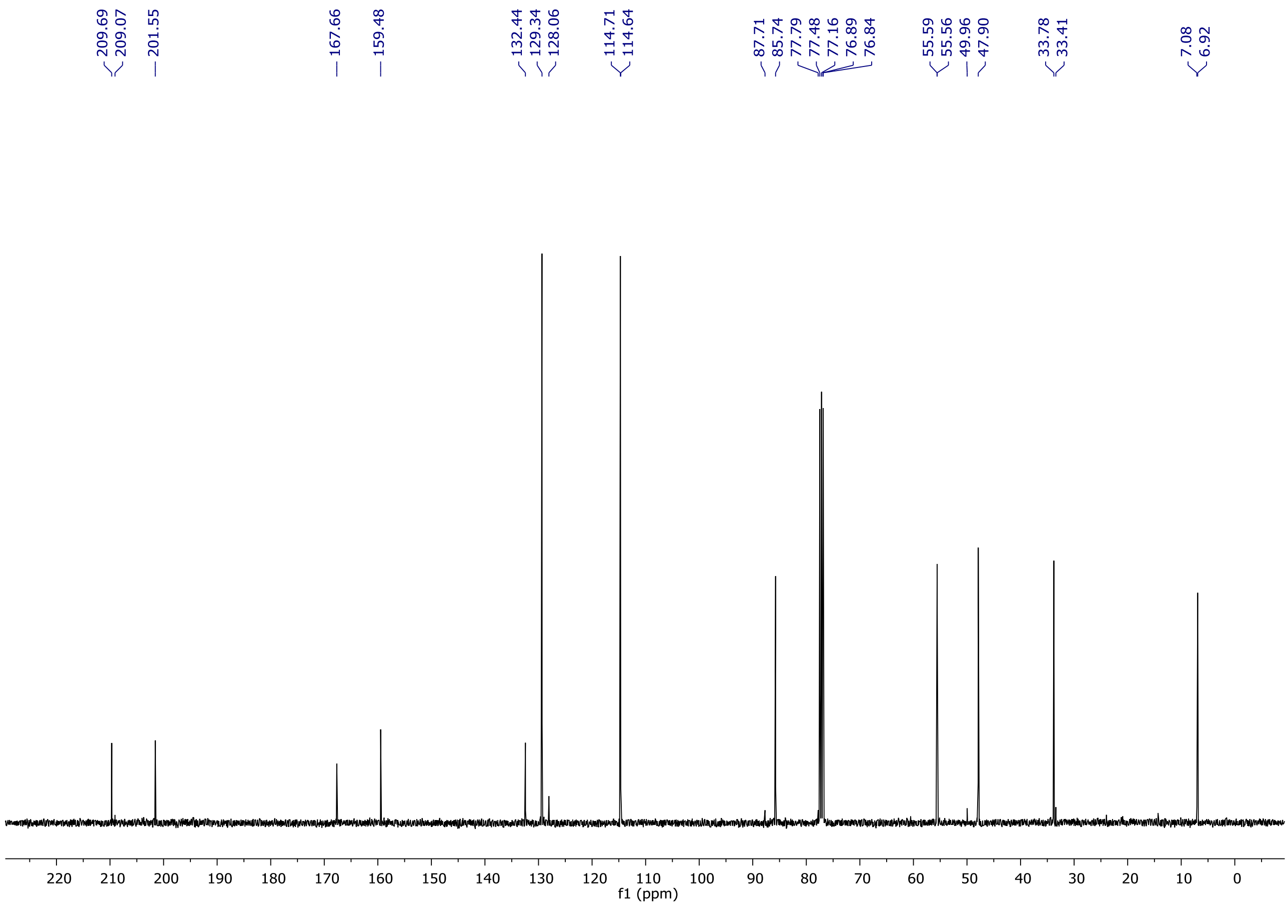


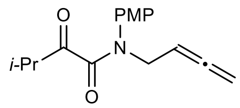




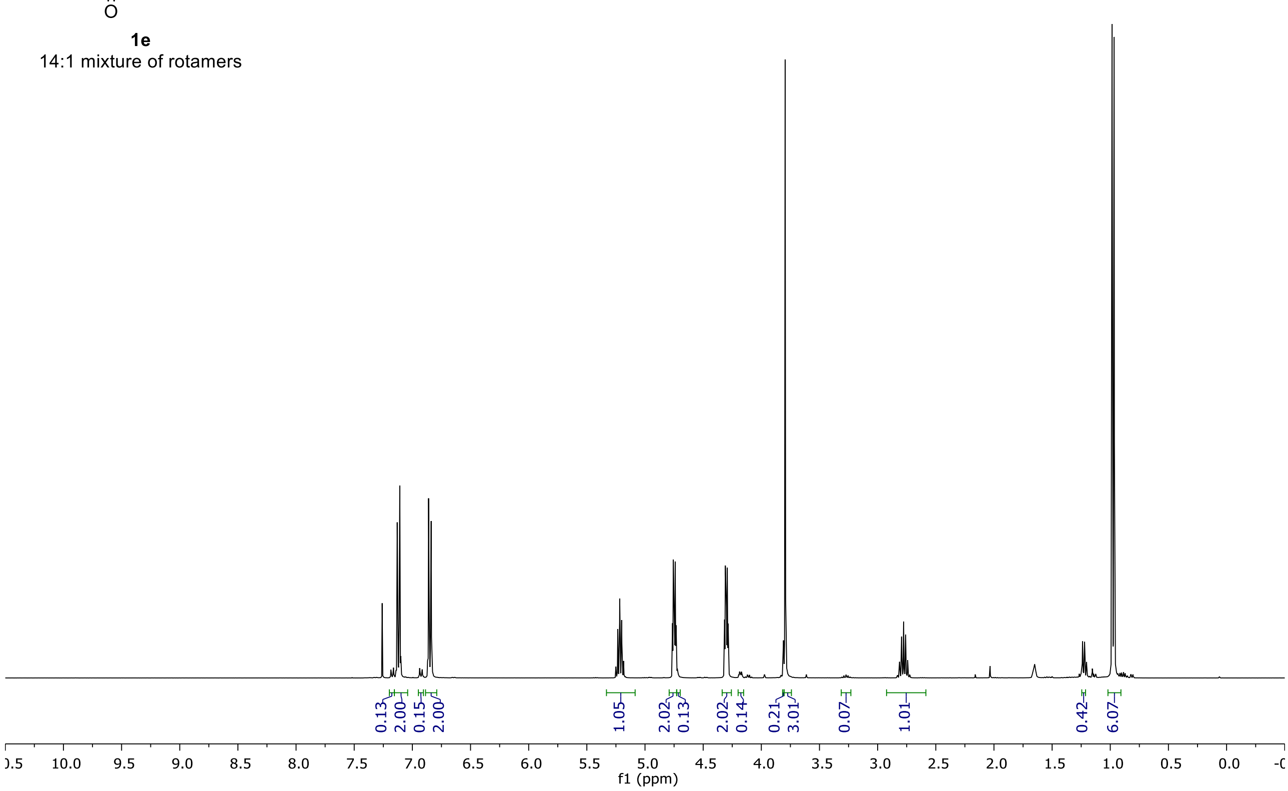
1d
14:1 mixture of rotamers

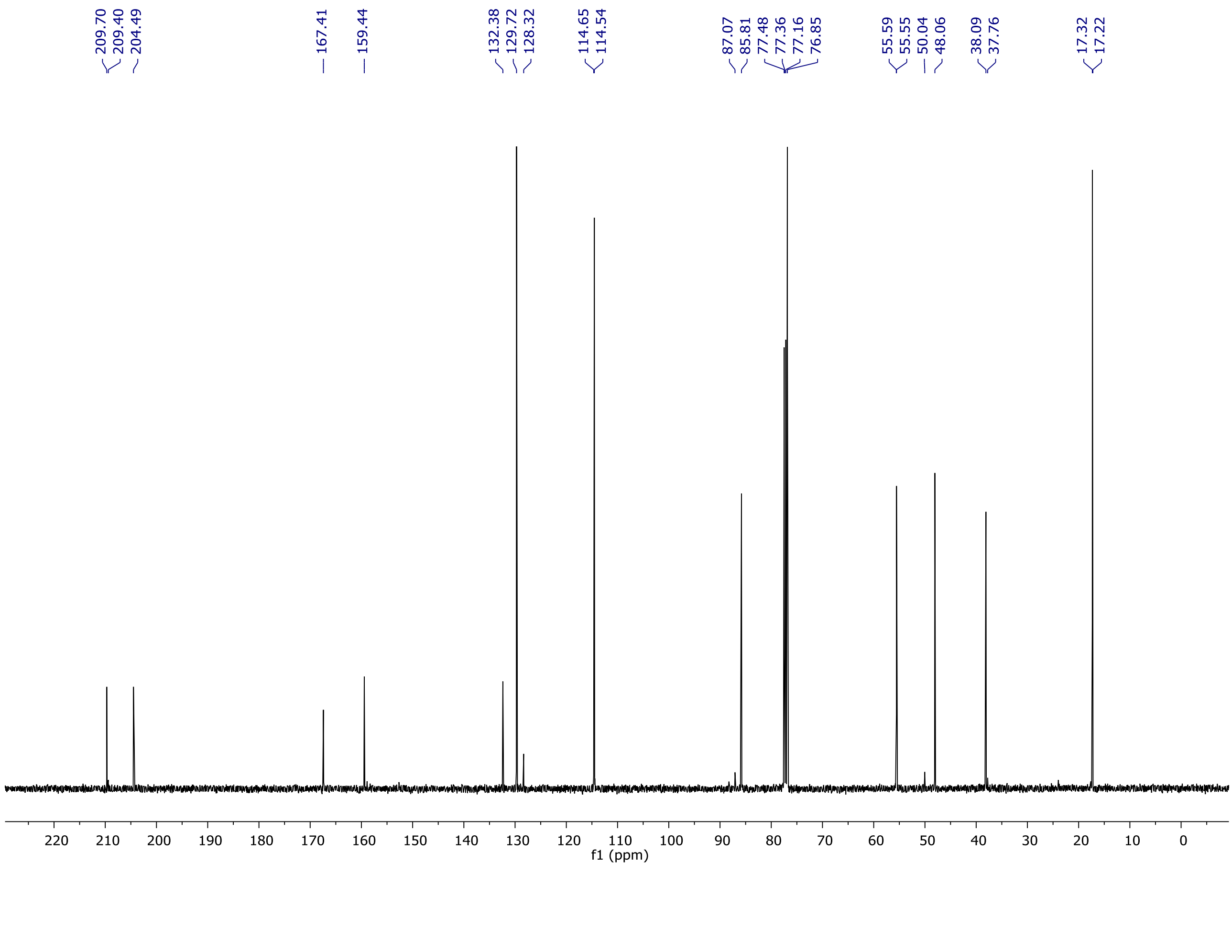


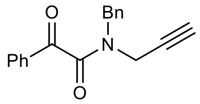




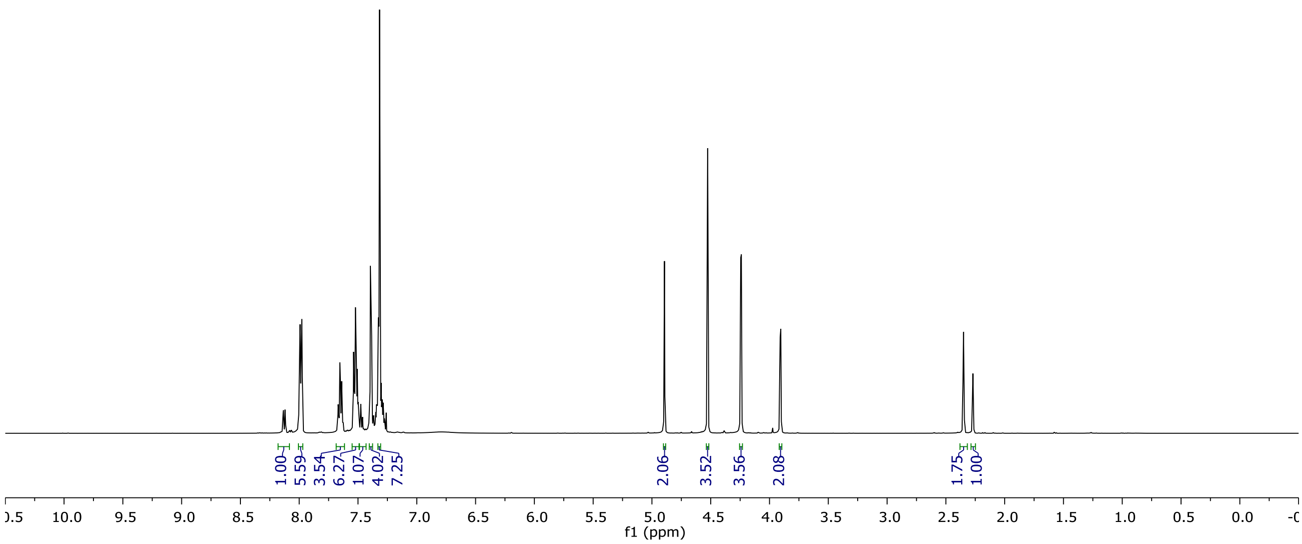
1e
14:1 mixture of rotamers

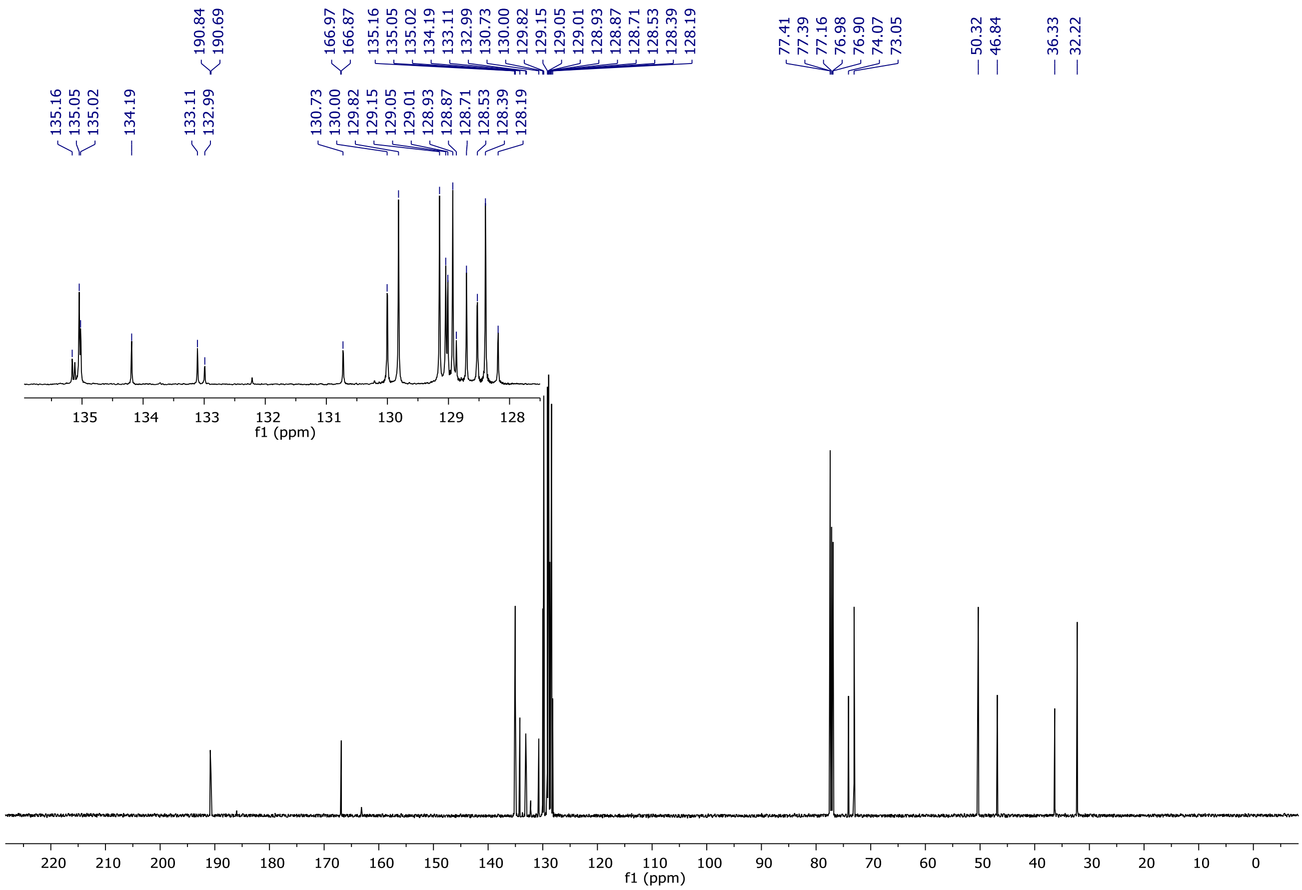


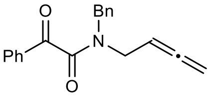




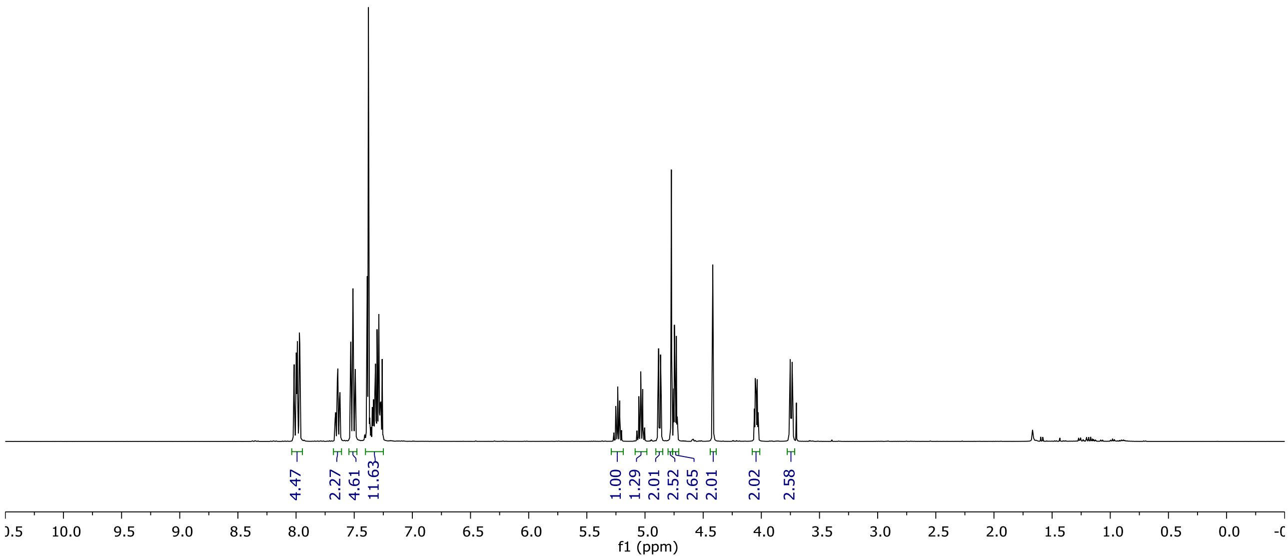
S7
1.7:1 mixture of rotamers

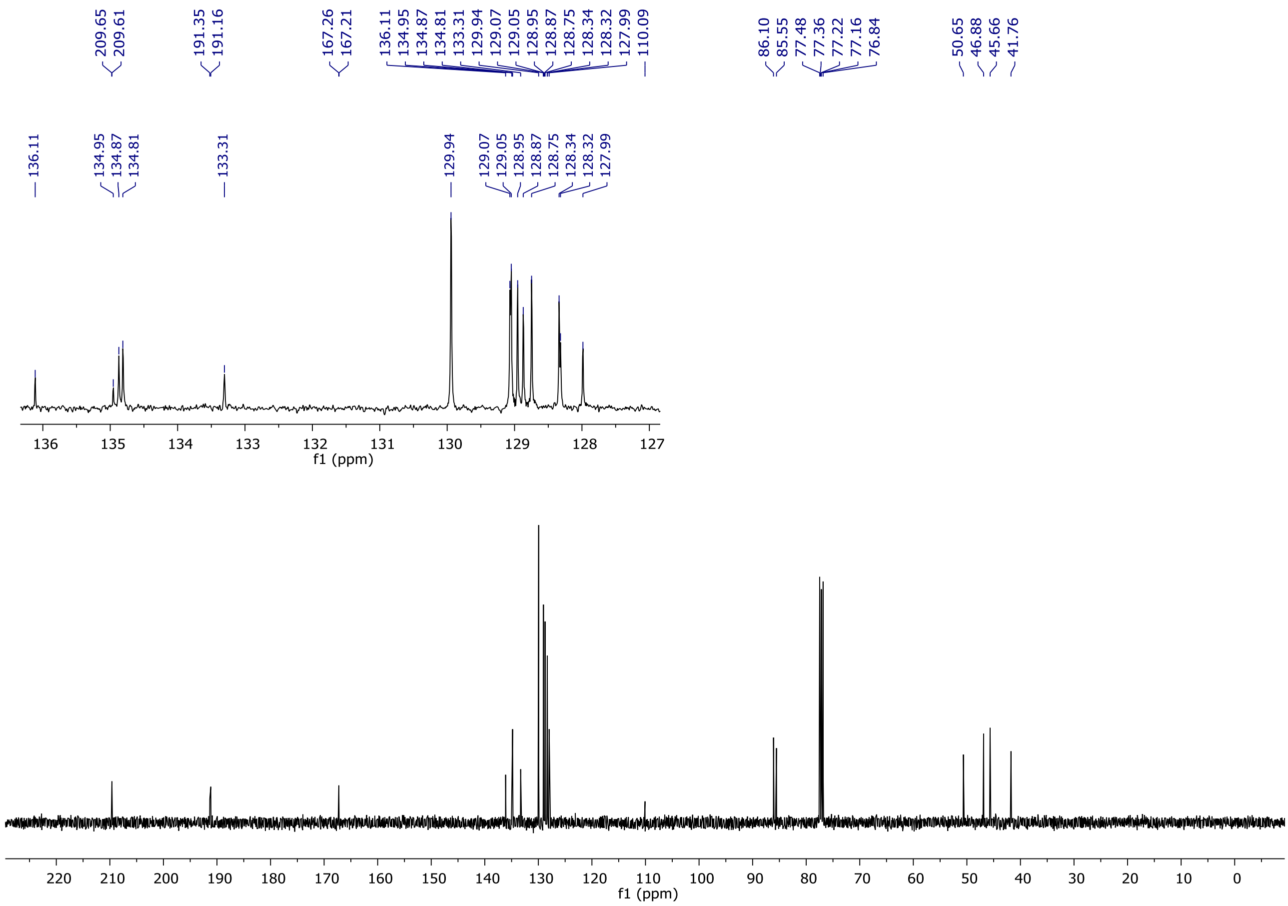


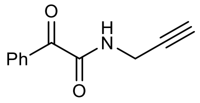



O
Bn
N
Ph
O

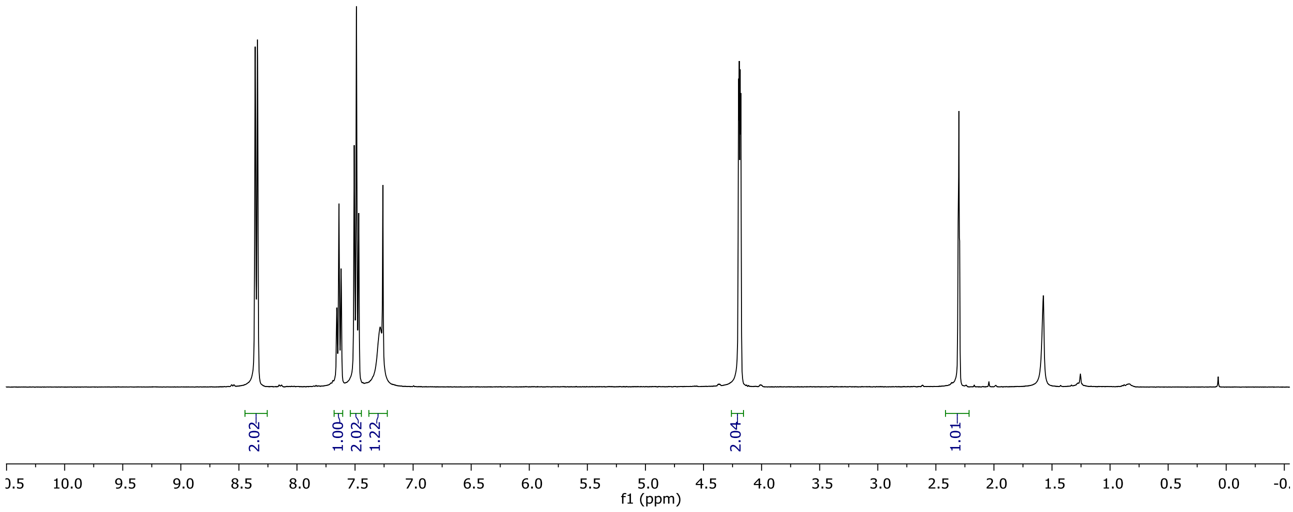
1f

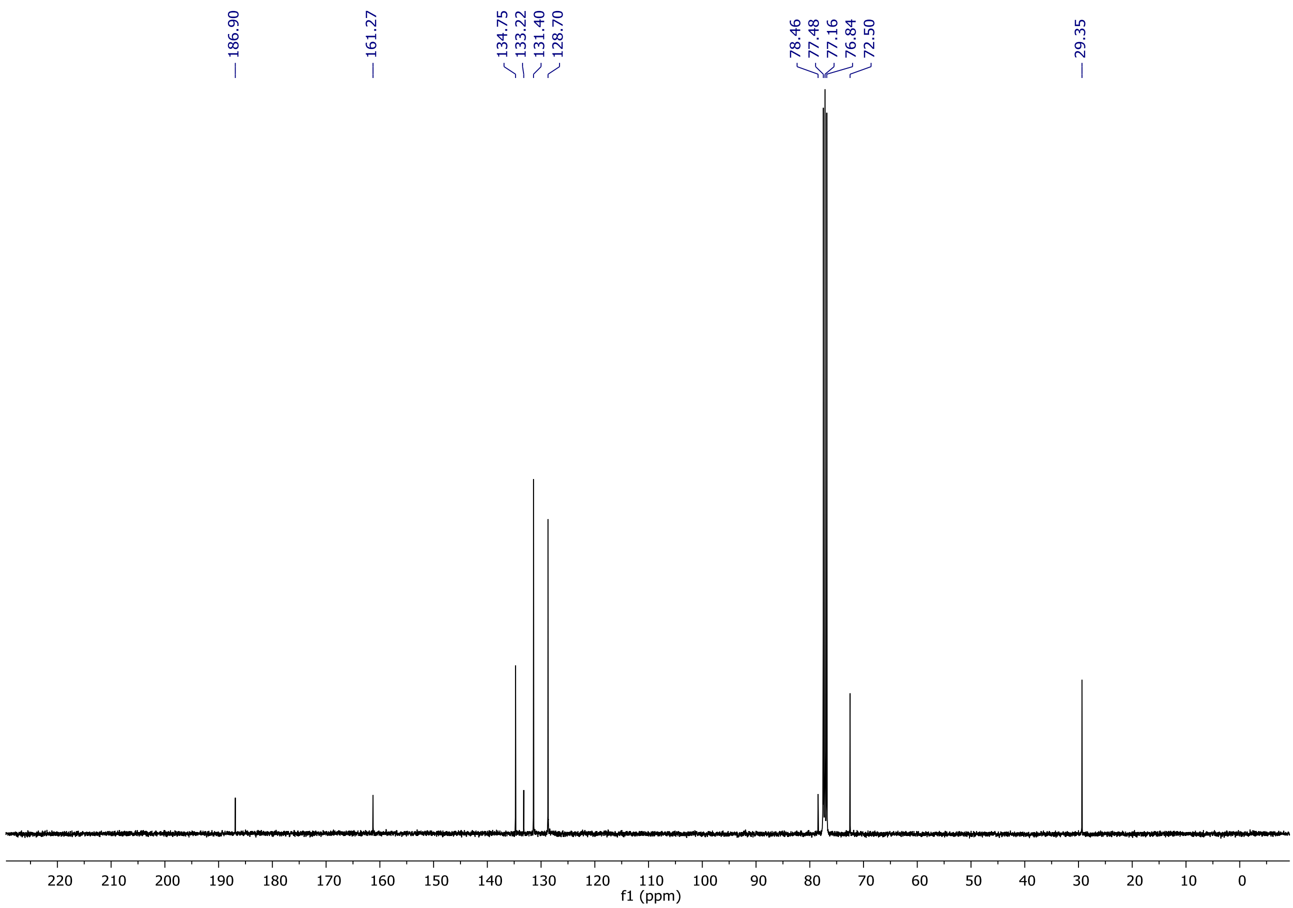

4.47
2.27
4.61
11.63
1.00
1.29
2.01
2.52
2.65
2.01
2.02
2.58
f1 (ppm)

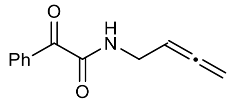

209.65
209.61
191.35
191.16
167.26
167.21
136.11
134.95
134.87
134.81
133.31
129.94
129.07
129.05
128.95
128.87
128.75
128.34
128.32
127.99
110.09
86.10
85.55
77.48
77.36
77.22
77.16
76.84
50.65
46.88
45.66
41.76
f1 (ppm)
f1 (ppm)


O
Ph
H
N
O

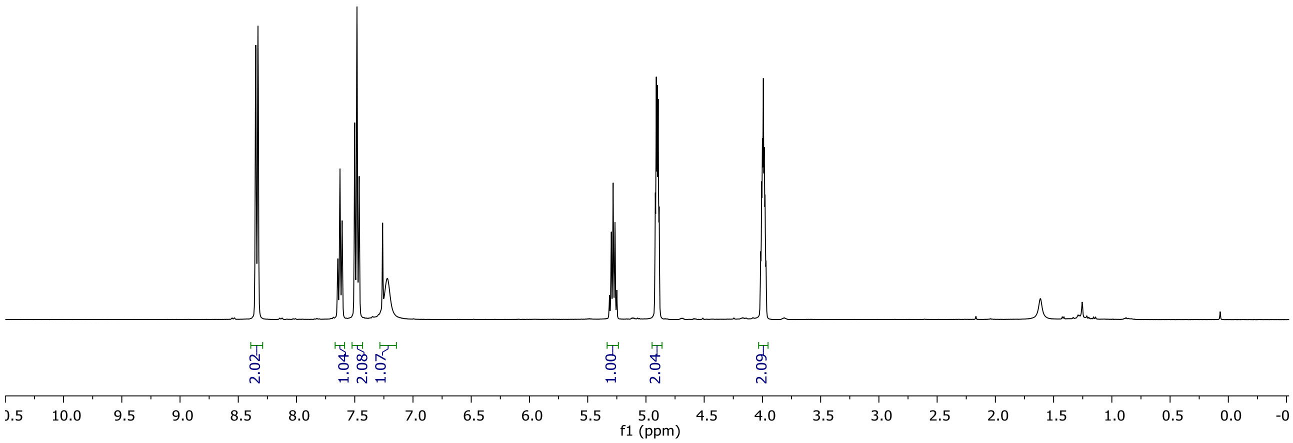
S8

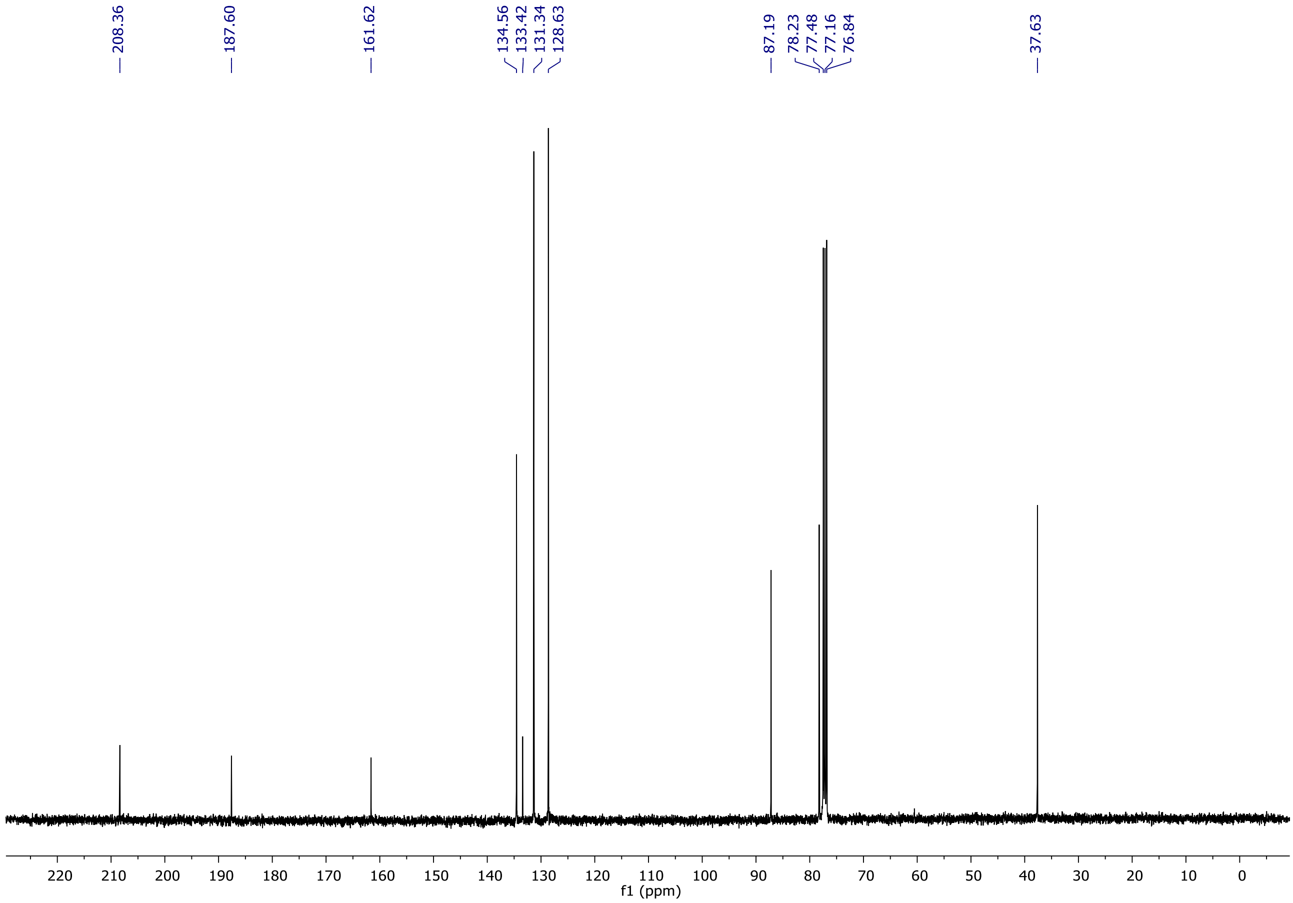

2.02
1.00
2.02
1.22
2.04
1.01
f1 (ppm)

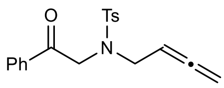

186.90
161.27
134.75
133.22
131.40
128.70
78.46
77.48
77.16
76.84
72.50
29.35
f1 (ppm)


Ph
O
H
N
O

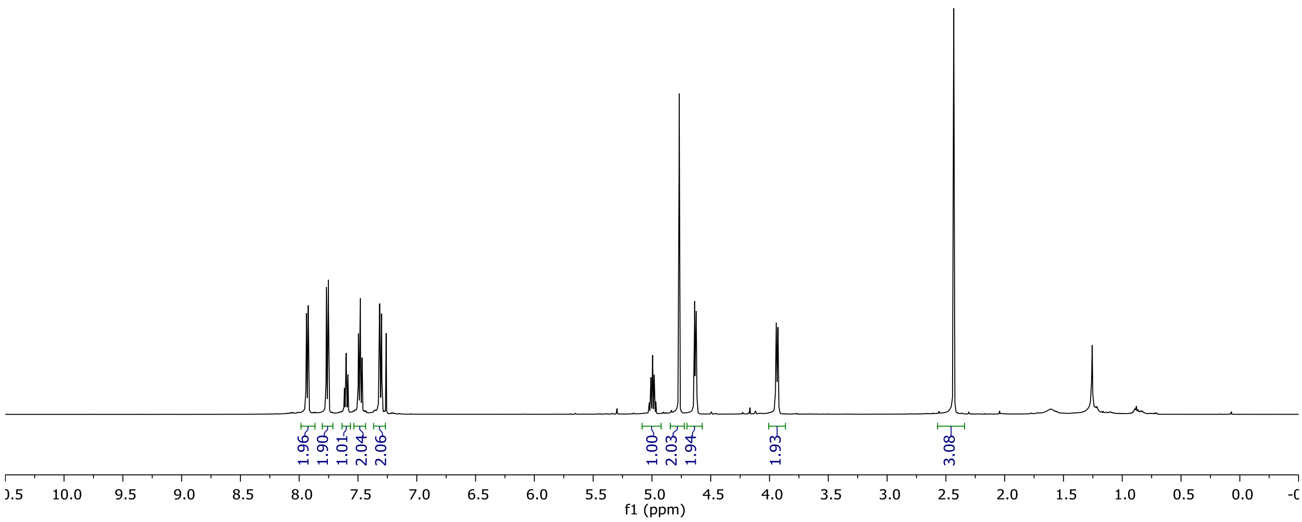
1g

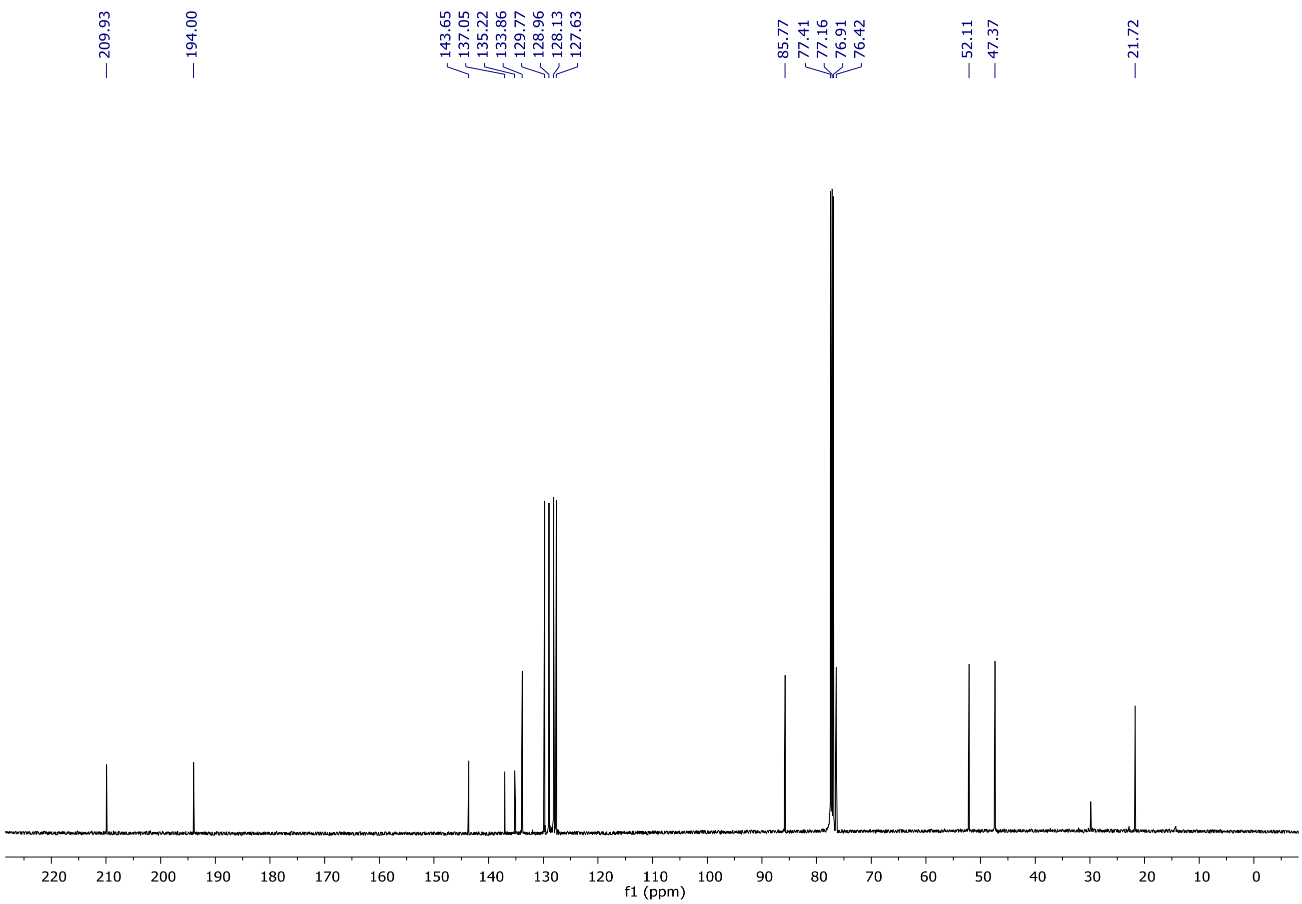

2.02
1.04
2.08
1.07
1.00
2.04
2.09
f1 (ppm)


208.36
187.60
161.62
134.56
133.42
131.34
128.63
87.19
78.23
77.48
77.16
76.84
37.63
f1 (ppm)


O
Ts
N
Ph

4a


1.96
1.90
1.01
2.04
2.06
1.00
2.03
1.94
1.93
3.08
f1 (ppm)


209.93
194.00
143.65
137.05
135.22
133.86
129.77
128.96
128.13
127.63
85.77
77.41
77.16
76.91
76.42
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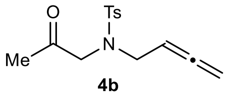
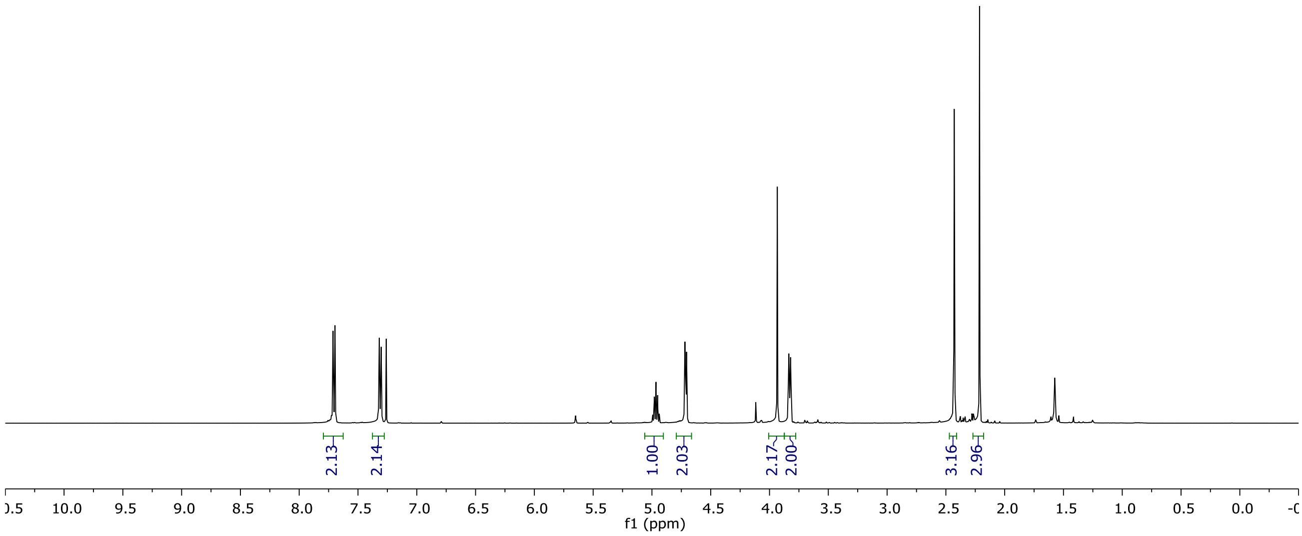
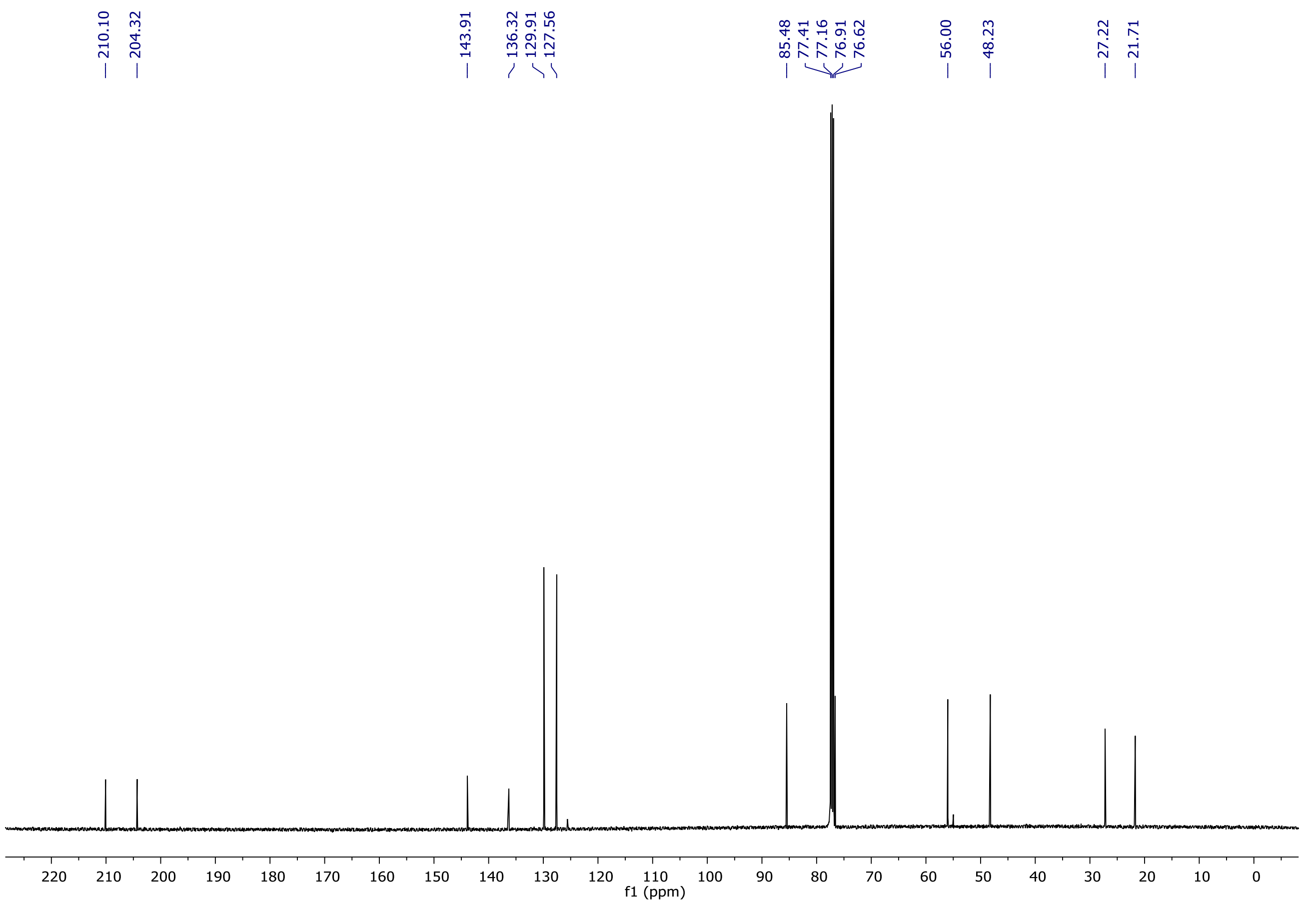
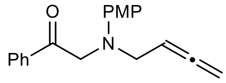
47.37
21.72
f1 (ppm)


O
Ts
N
Me

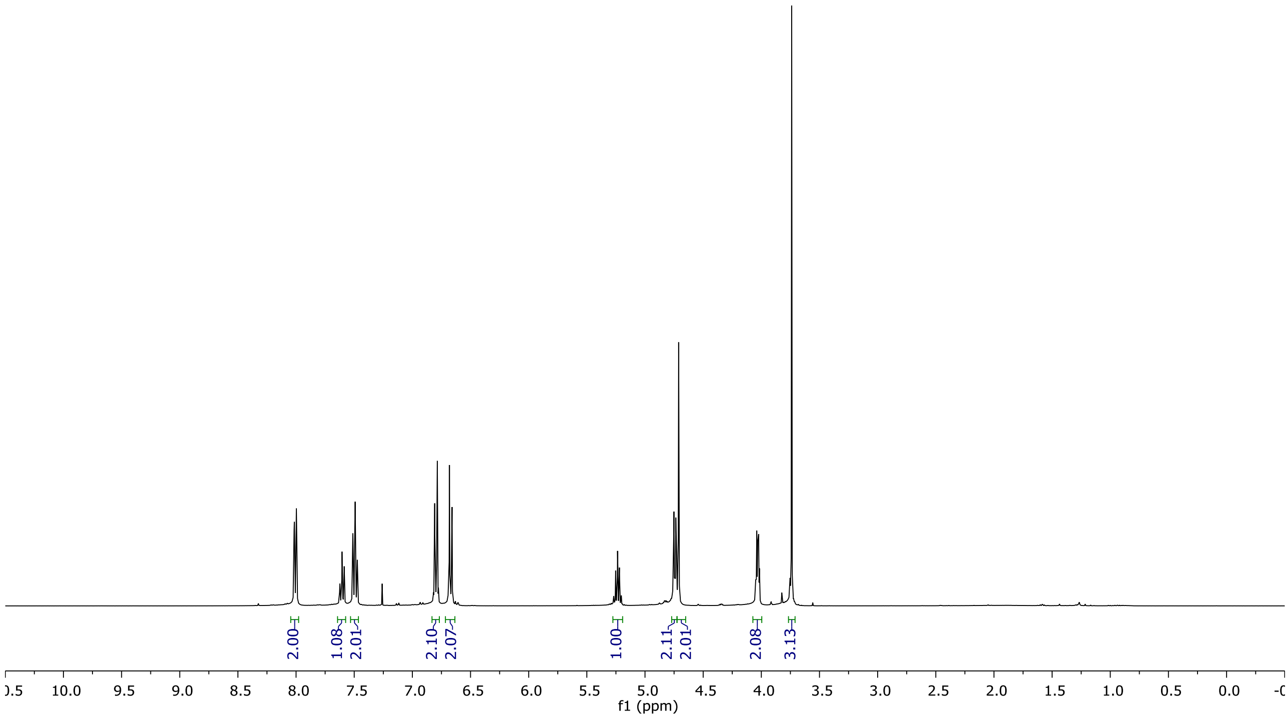
4b

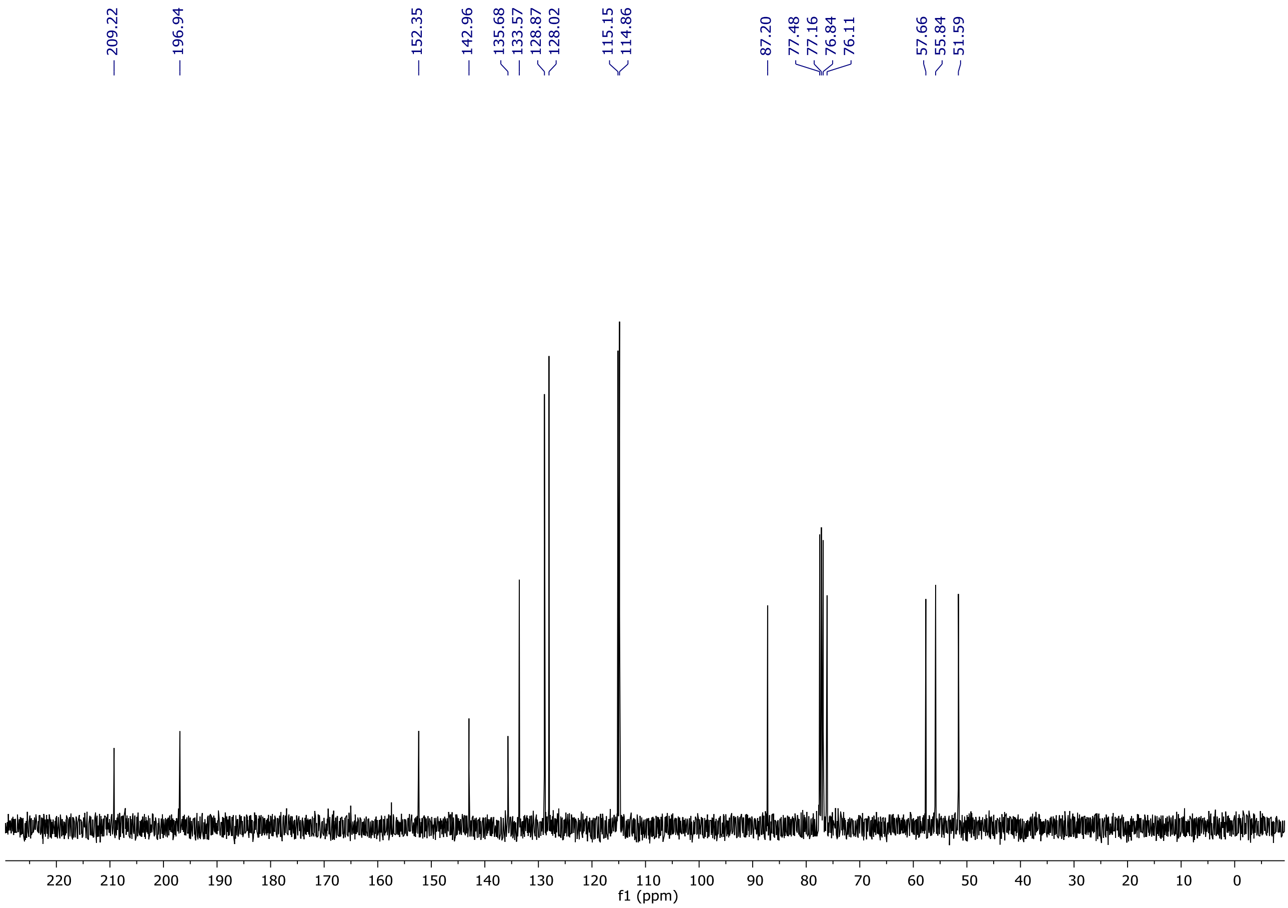

2.13
2.14
1.00
2.03
2.17
2.00
3.16
2.96
f1 (ppm)

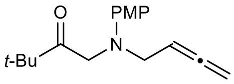

210.10
204.32
143.91
136.32
129.91
127.56
85.48
77.41
77.16
76.91
76.62
56.00
48.23
27.22
21.71
f1 (ppm)


O
PMP
N
Ph

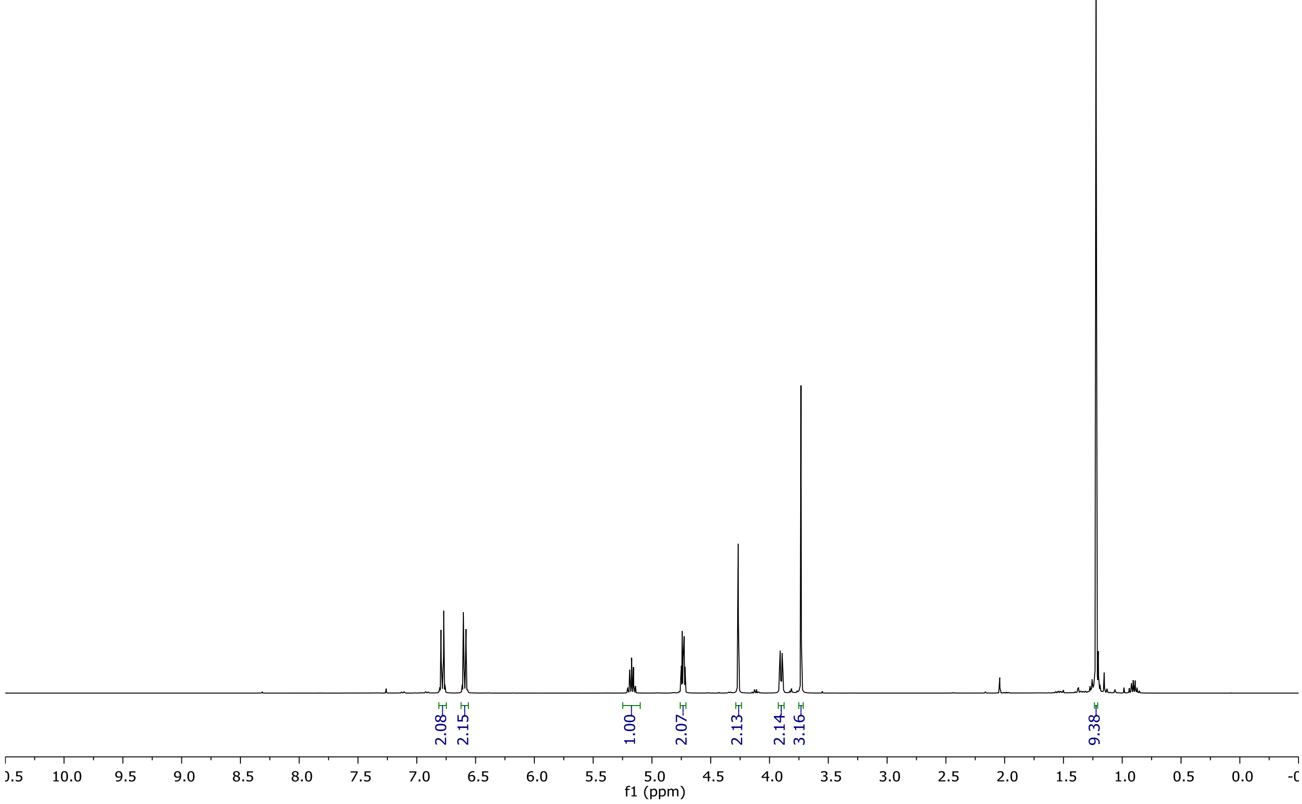
4c

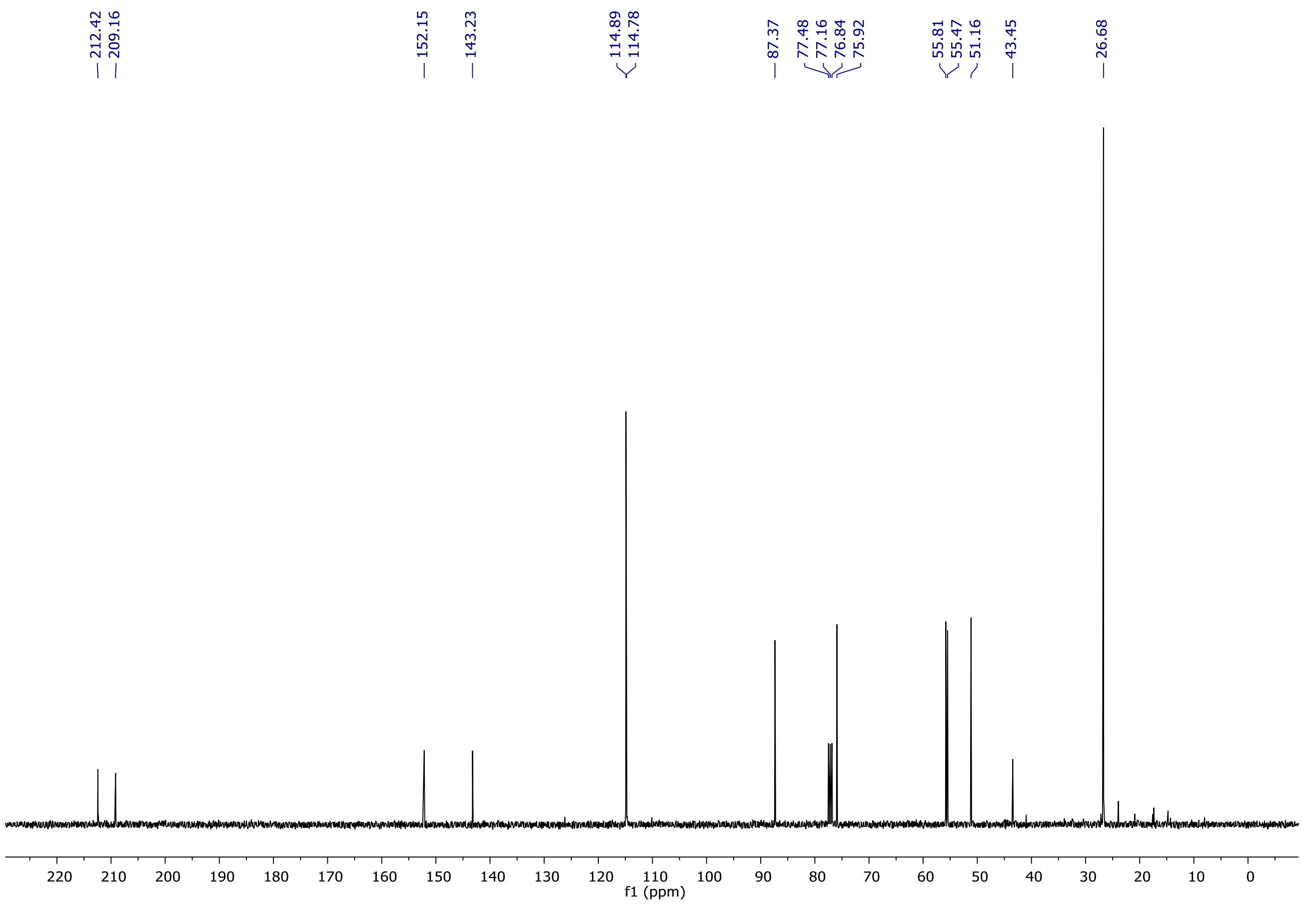

2.00
1.08
2.01
2.10
2.07
1.00
2.11
2.01
2.08
3.13
f1 (ppm)

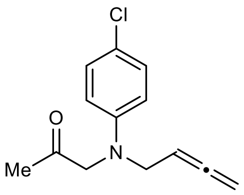

209.22
196.94
152.35
142.96
135.68
133.57
128.87
128.02
115.15
114.86
87.20
77.48
77.16
76.84
76.11
57.66
55.84
51.59
f1 (ppm)


O
PMP
N
t-Bu

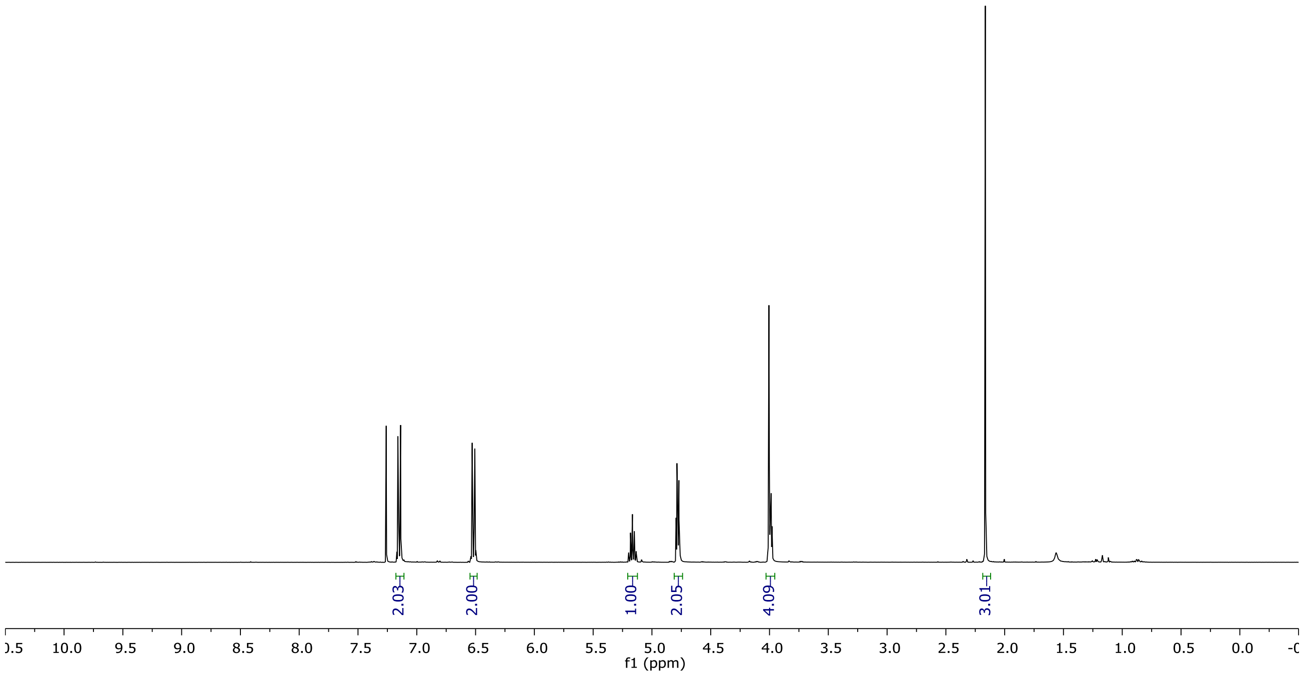
4d

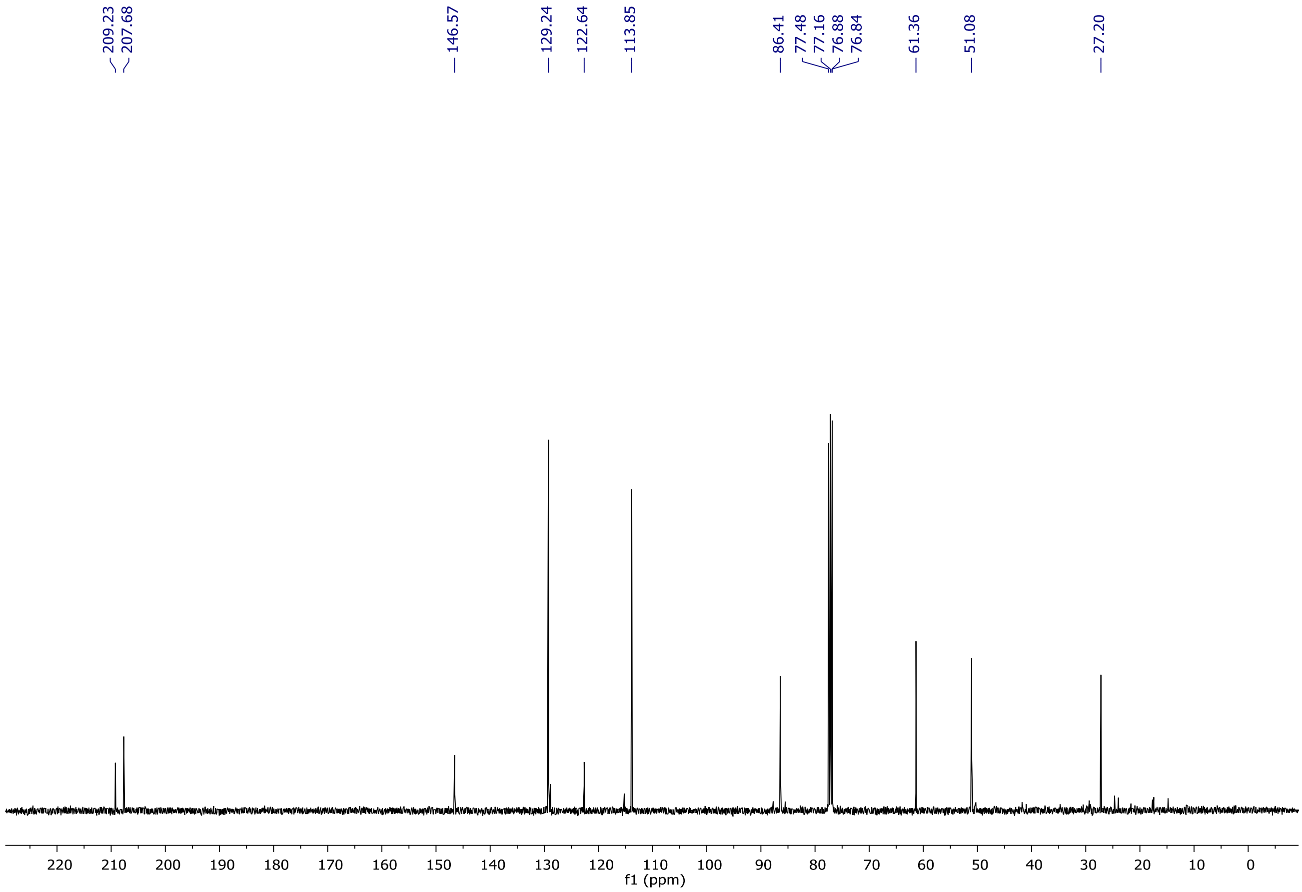

2.08
2.15
1.00
2.07
2.13
2.14
3.16
9.38
f1 (ppm)

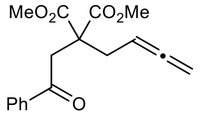

212.42
209.16
152.15
143.23
114.89
114.78
87.37
77.48
77.16
76.84
75.92
55.81
55.47
51.16
43.45
26.68
f1 (ppm)



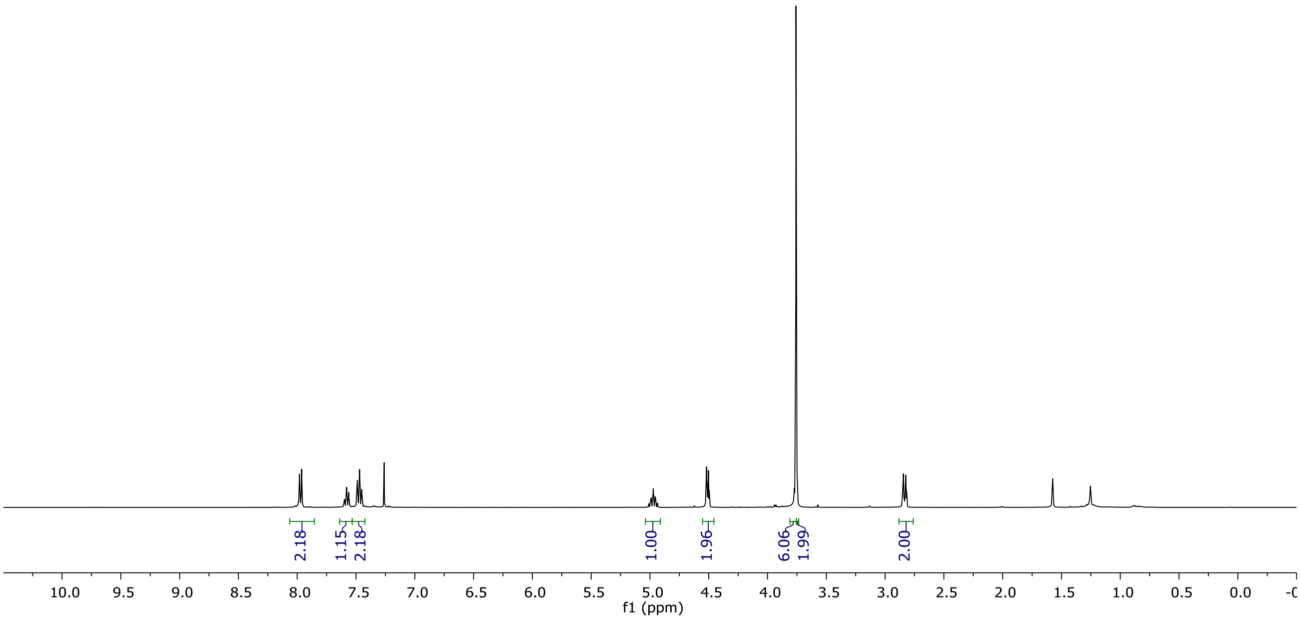
4e

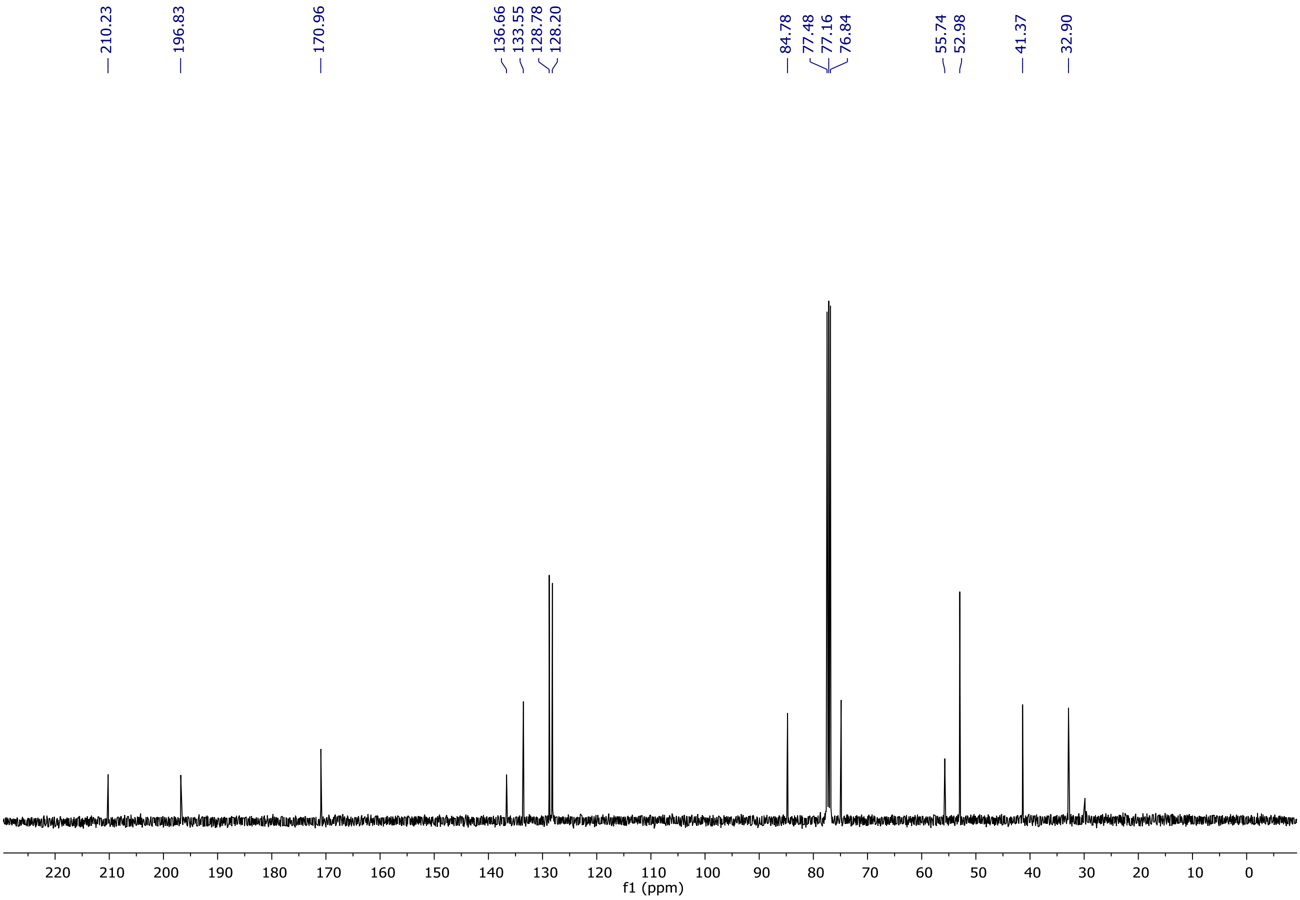


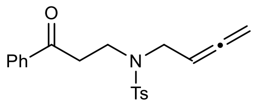



MeO2C
CO2Me
Ph
O

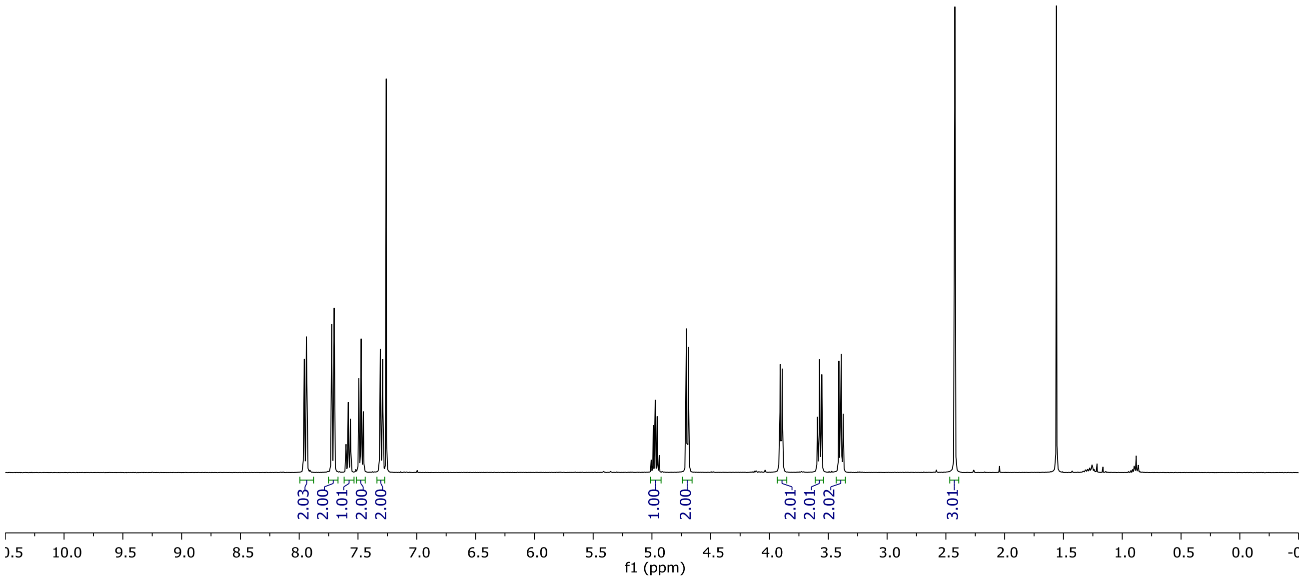
4f

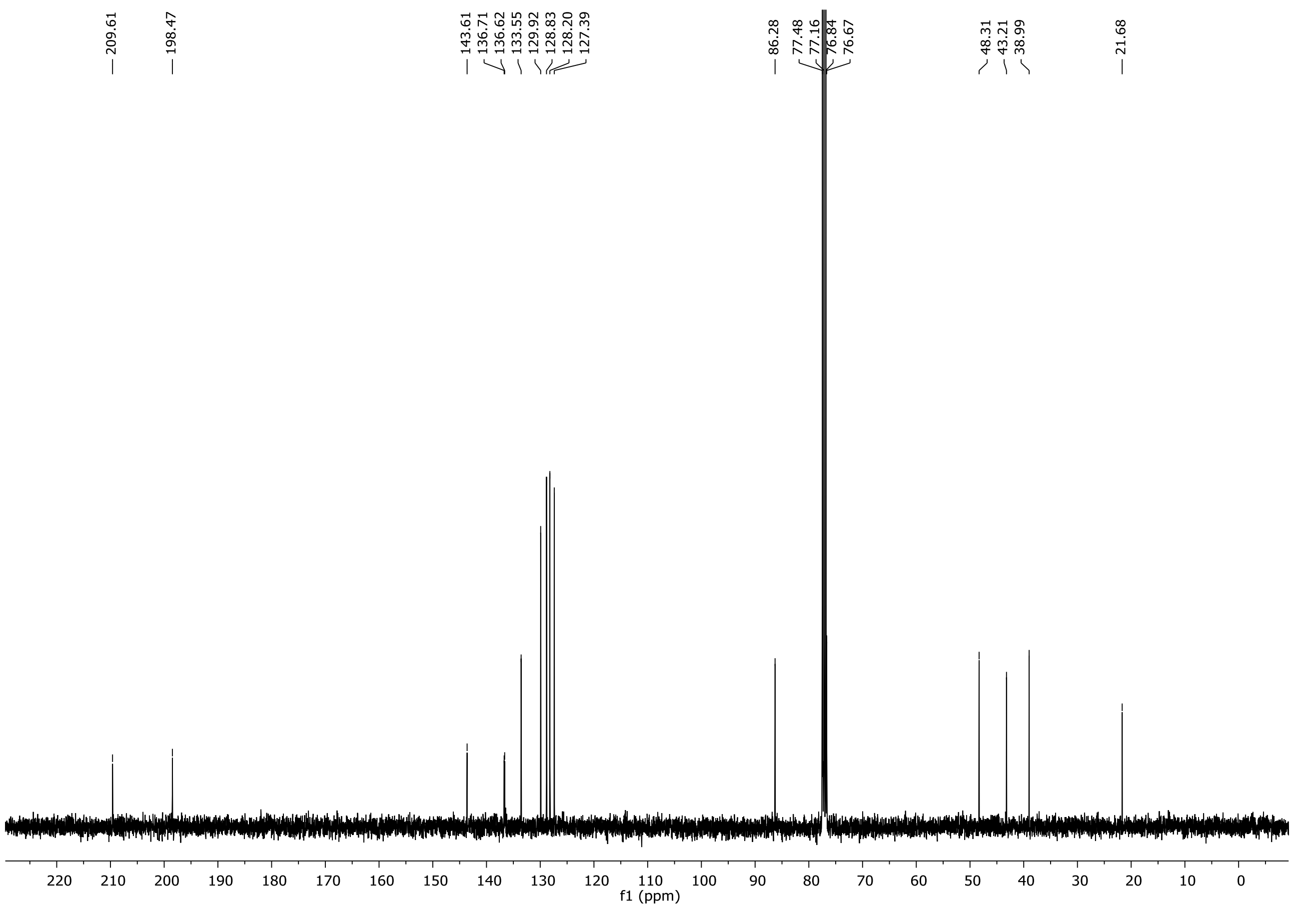

2.18
1.15
2.18
1.00
1.96
6.06
1.99
2.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

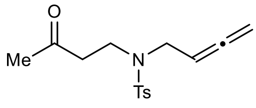

210.23
196.83
170.96
136.66
133.55
128.78
128.20
84.78
77.48
77.16
76.84
55.74
52.98
41.37
32.90
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Ph
N
Ts

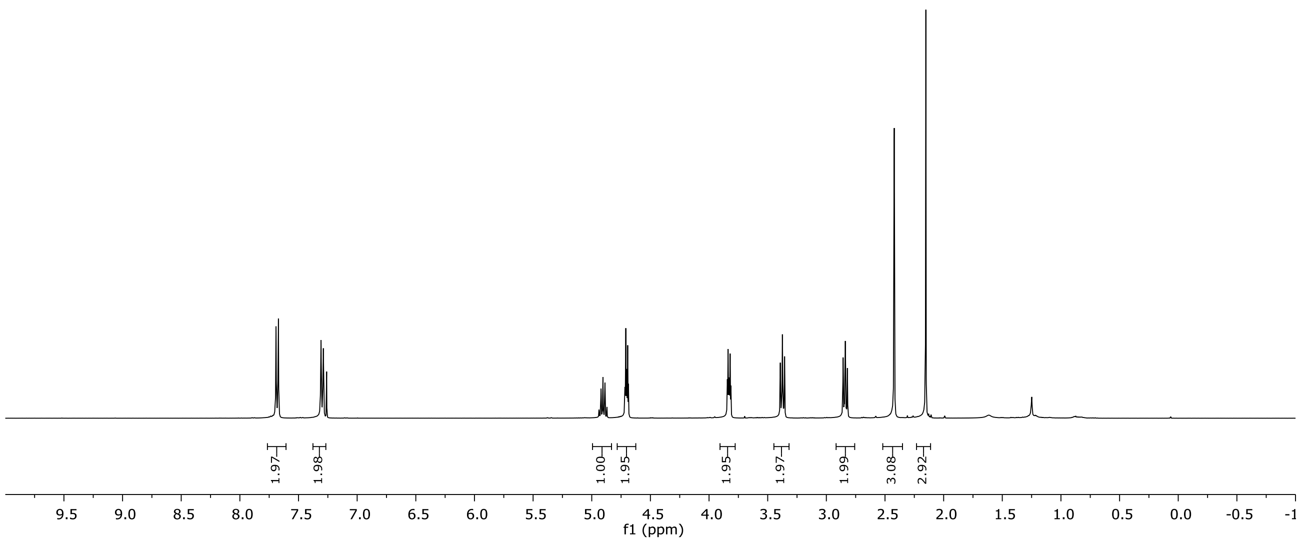
4g

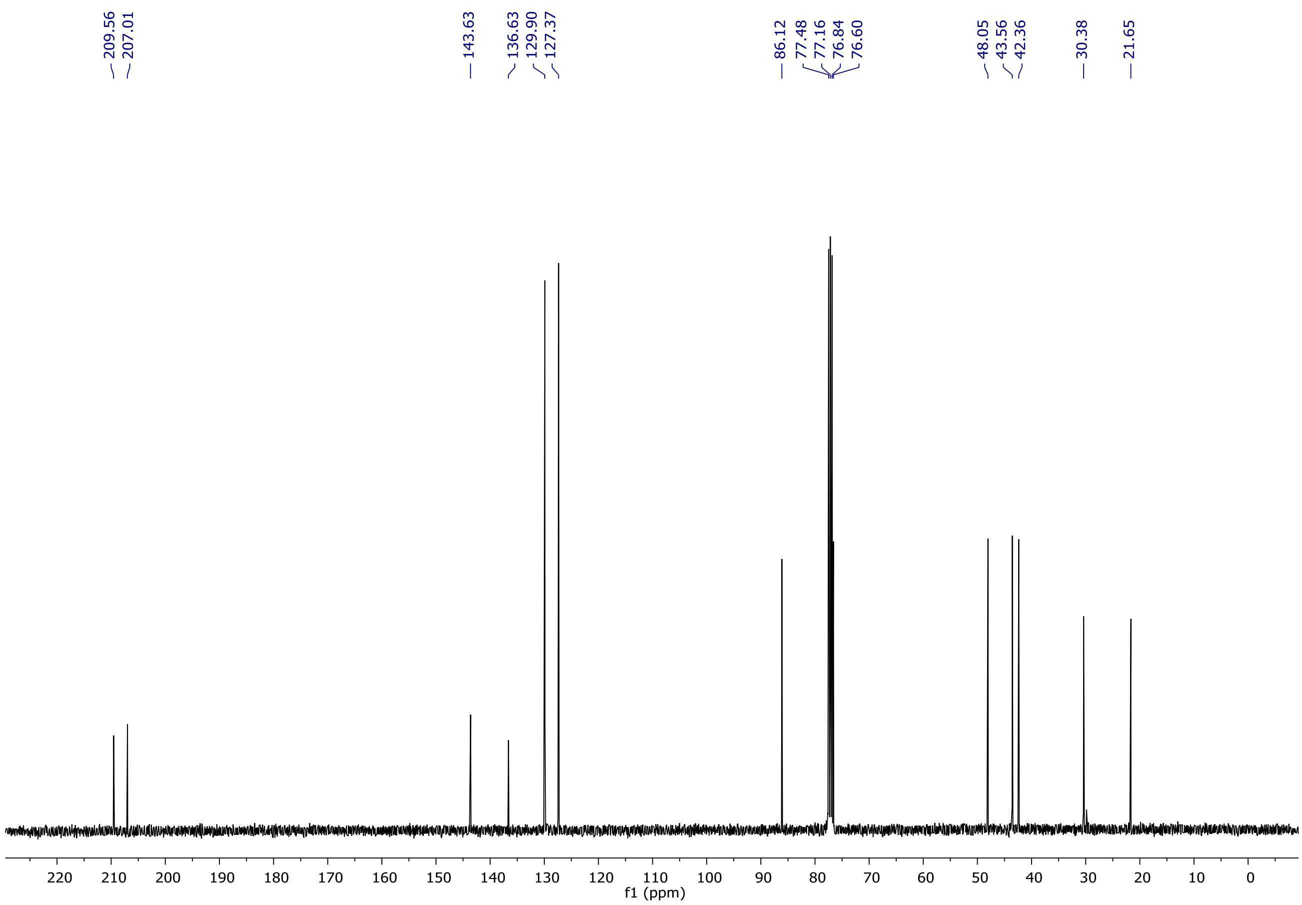

2.03
2.00
1.01
2.00
2.00
1.00
2.00
2.01
2.01
2.02
3.01
f1 (ppm)


209.61
198.47
143.61
136.71
136.62
133.55
129.92
128.83
128.20
127.39
86.28
77.48
77.16
76.84
76.67
48.31
43.21
38.99
21.68
f1 (ppm)


O
Me
N
Ts

4h


1.97
1.98
1.00
1.95
1.95
1.97
1.99
3.08
2.92
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1
f1 (ppm)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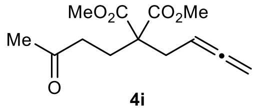
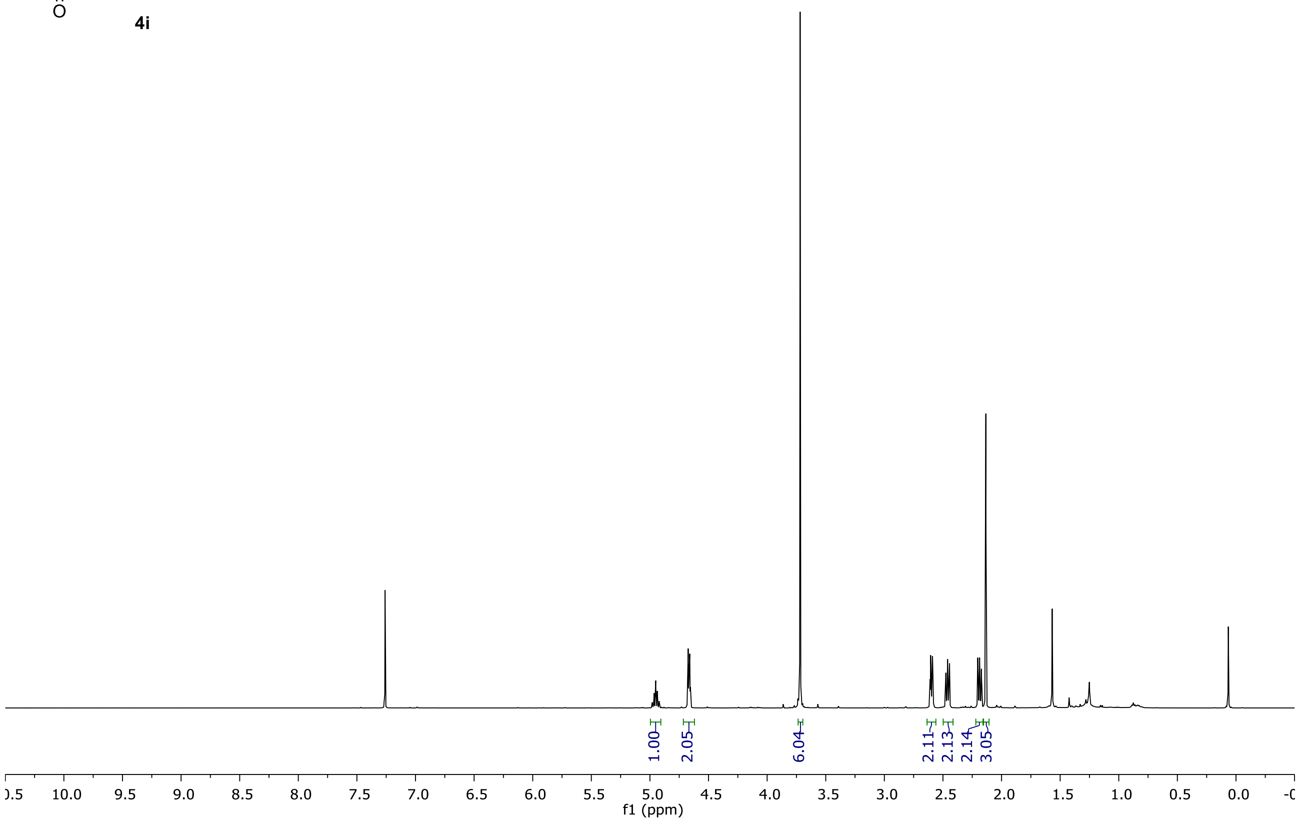
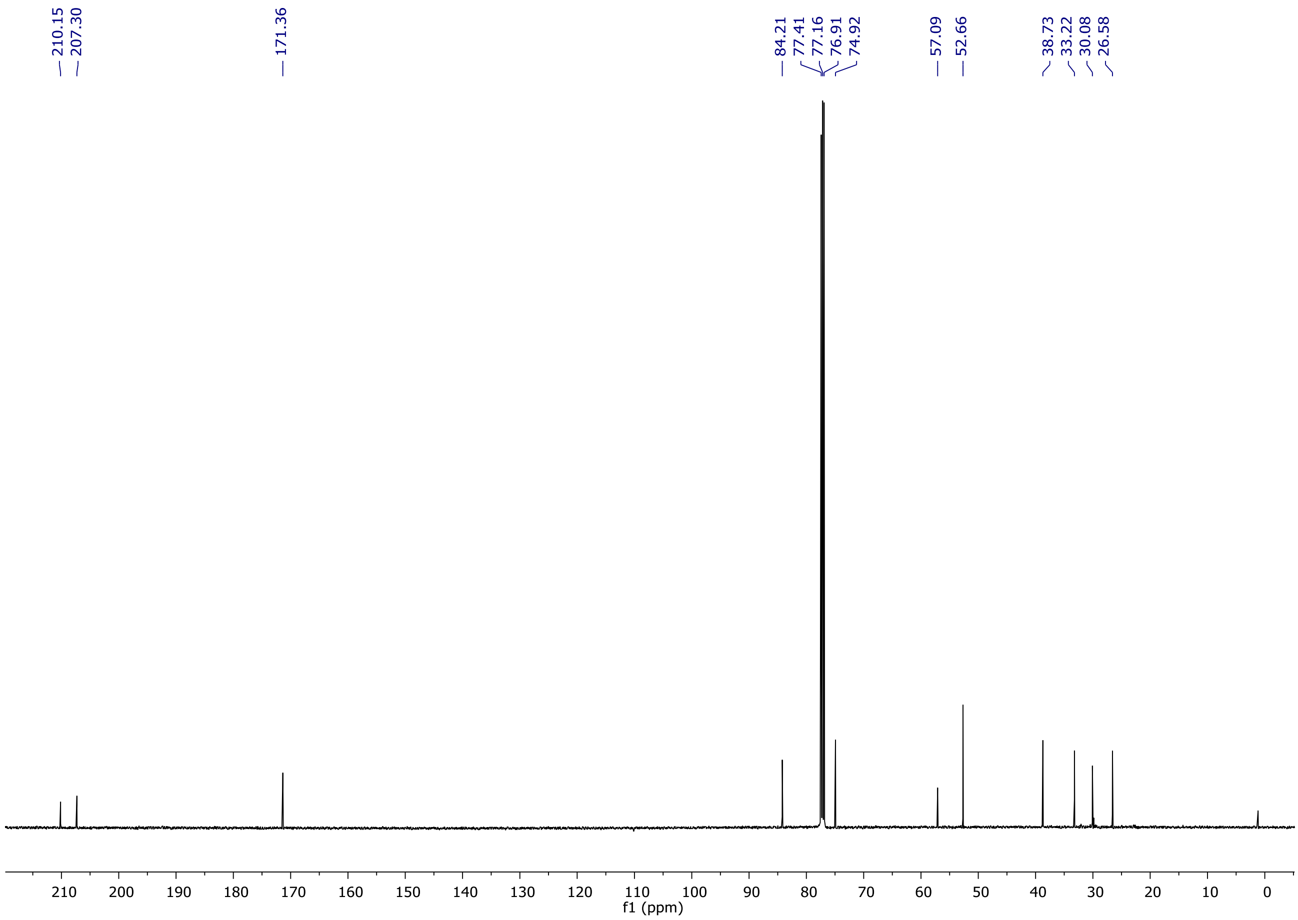
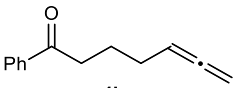
207.01
143.63
136.63
129.90
127.37
86.12
77.48
77.16
76.84
76.60
48.05
43.56
42.36
30.38
21.65
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


MeO2C
CO2Me
Me
O

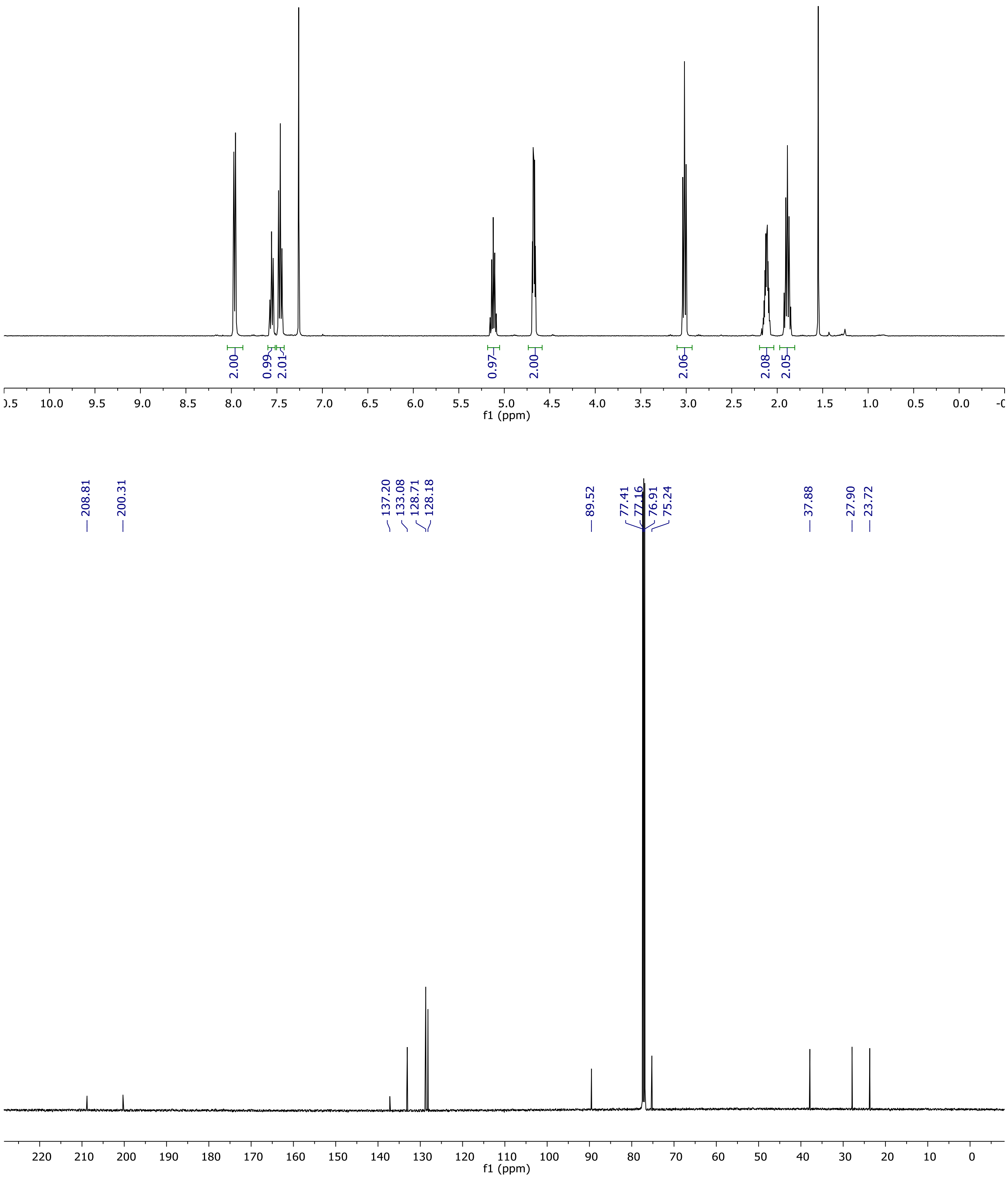
4i

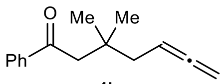

1.00
2.05
6.04
2.11
2.13
2.14
3.05
f1 (ppm)


210.15
207.30
171.36
84.21
77.41
77.16
76.91
74.92
57.09
52.66
38.73
33.22
30.08
26.58
f1 (ppm)

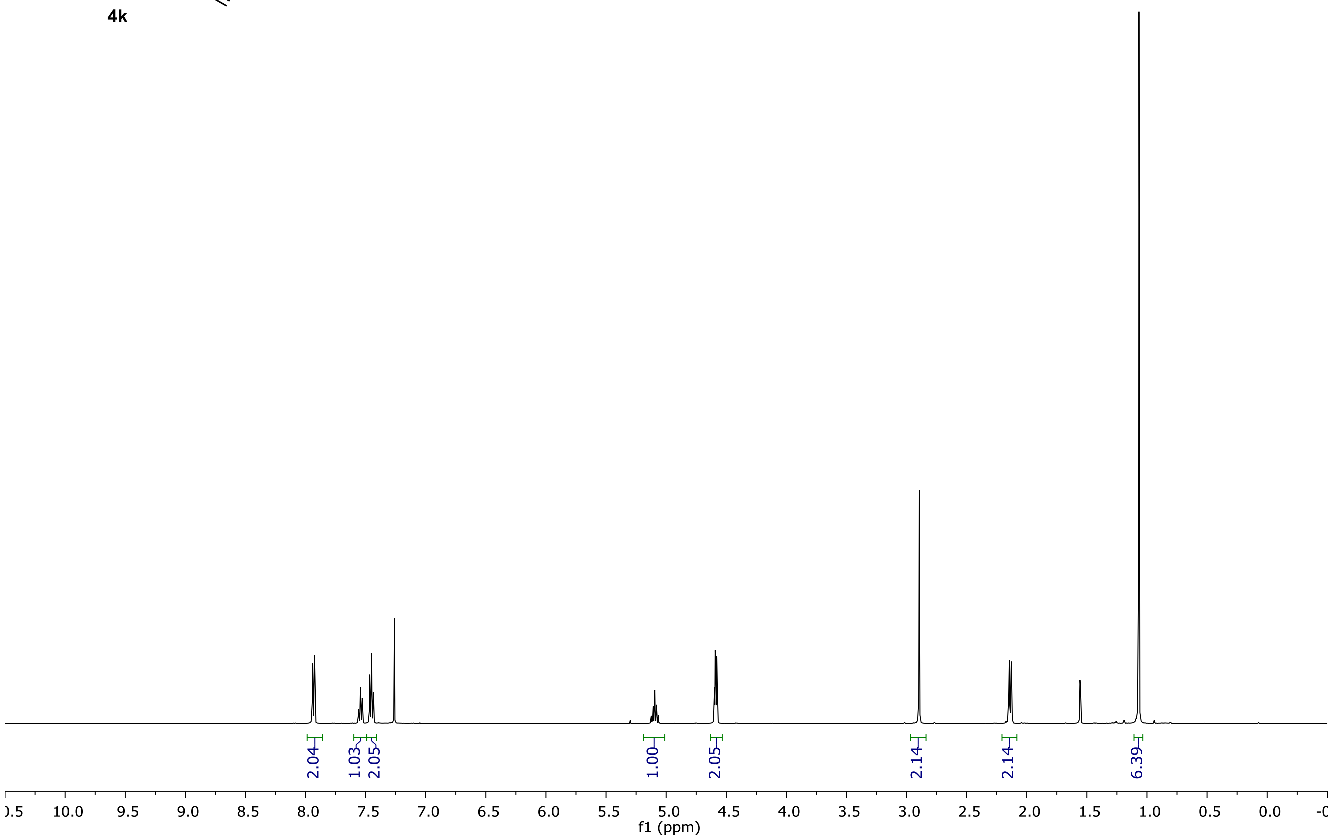


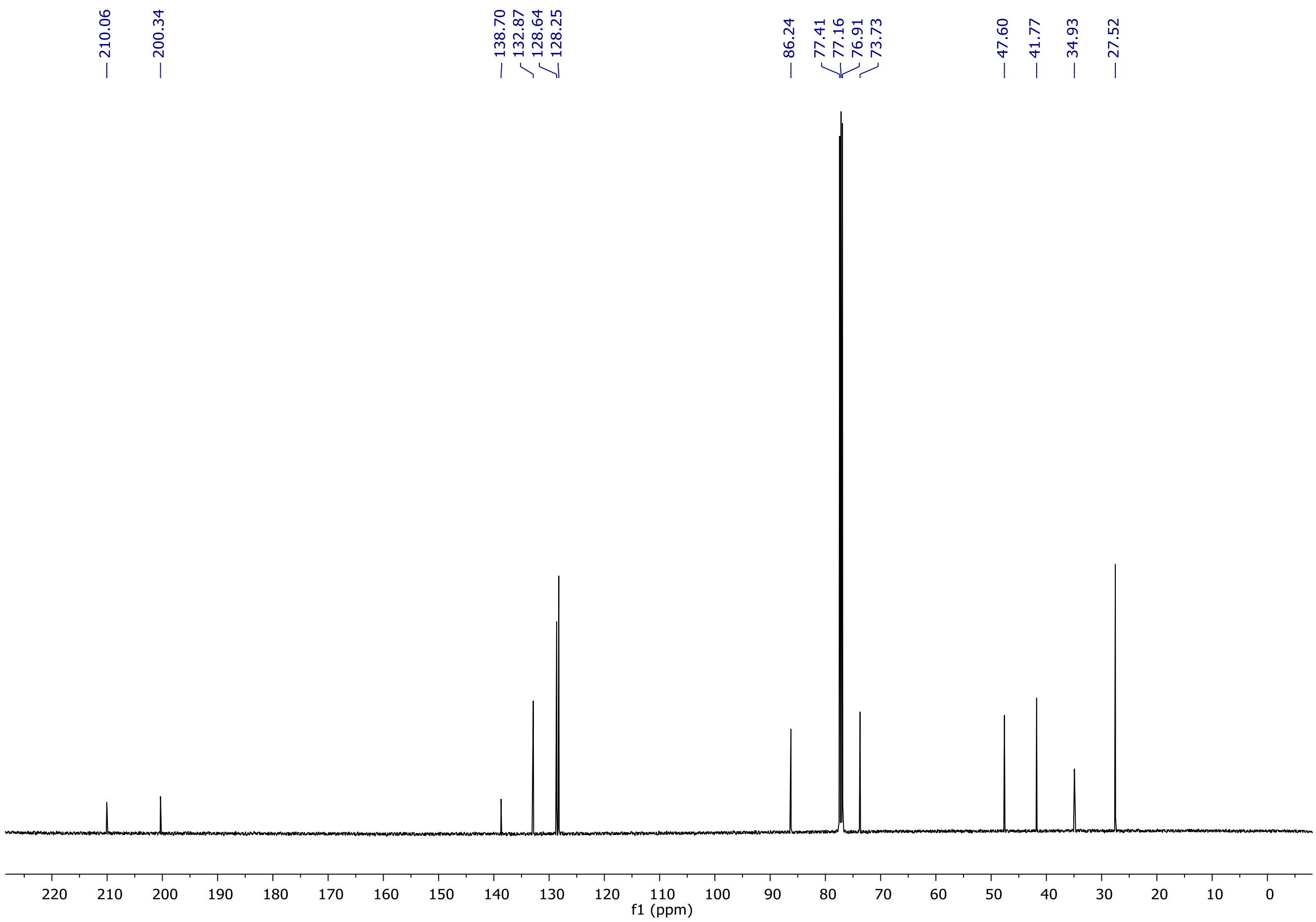
4j

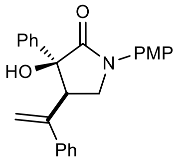

2.00
0.99
2.01
0.97
2.00
2.06
2.08
2.05
f1 (ppm)
208.81
200.31
137.20
133.08
128.71
128.18
89.52
77.41
77.16
76.91
75.24
37.88
27.90
23.72
f1 (ppm)


O
Me
Me
Ph

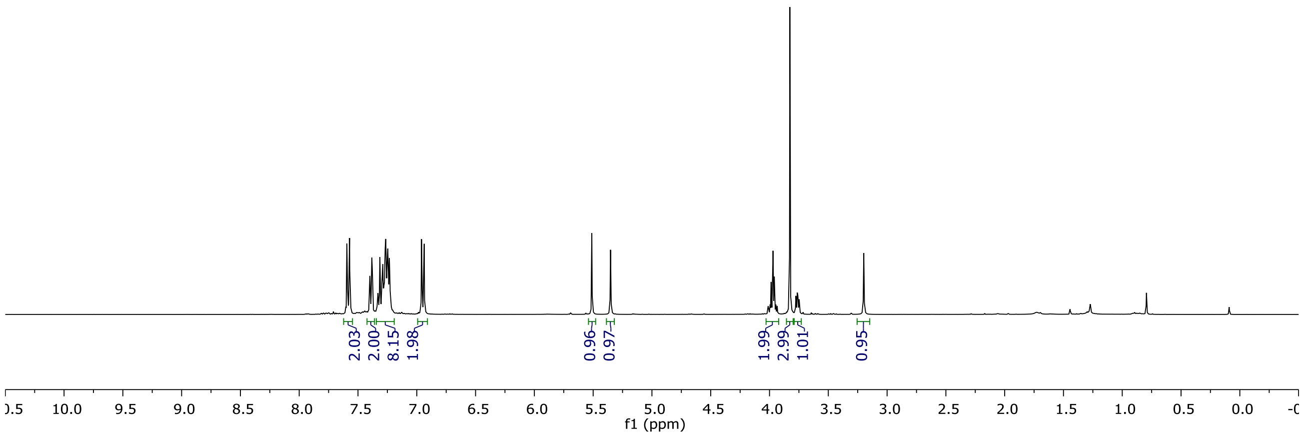
4k

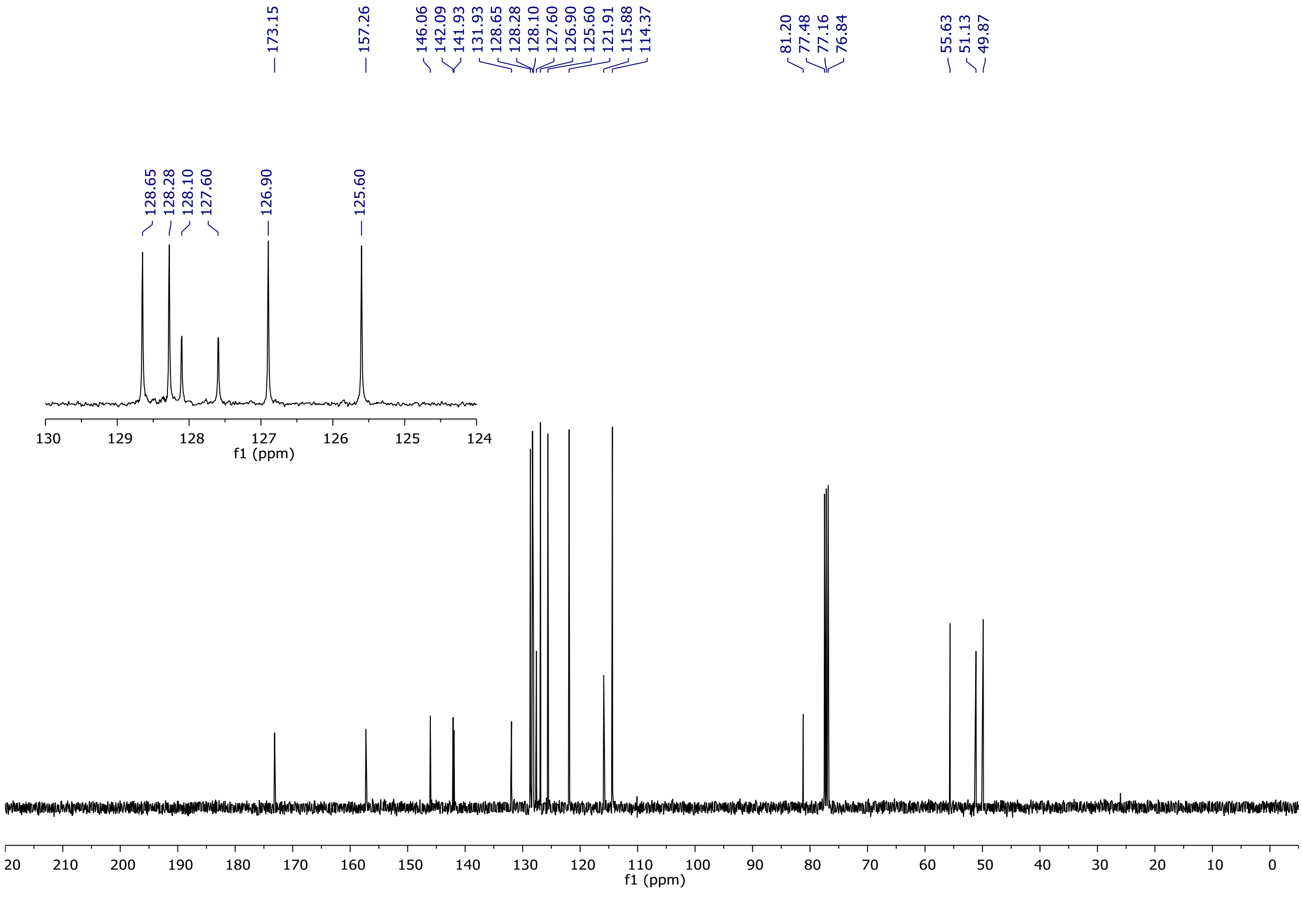

2.04
1.03
2.05
1.00
2.05
2.14
2.14
6.39
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

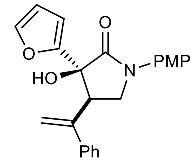

210.06
200.34
138.70
132.87
128.64
128.25
86.24
77.41
77.16
76.91
73.73
47.60
41.77
34.93
27.52
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Ph
HO
N
PMP
Ph

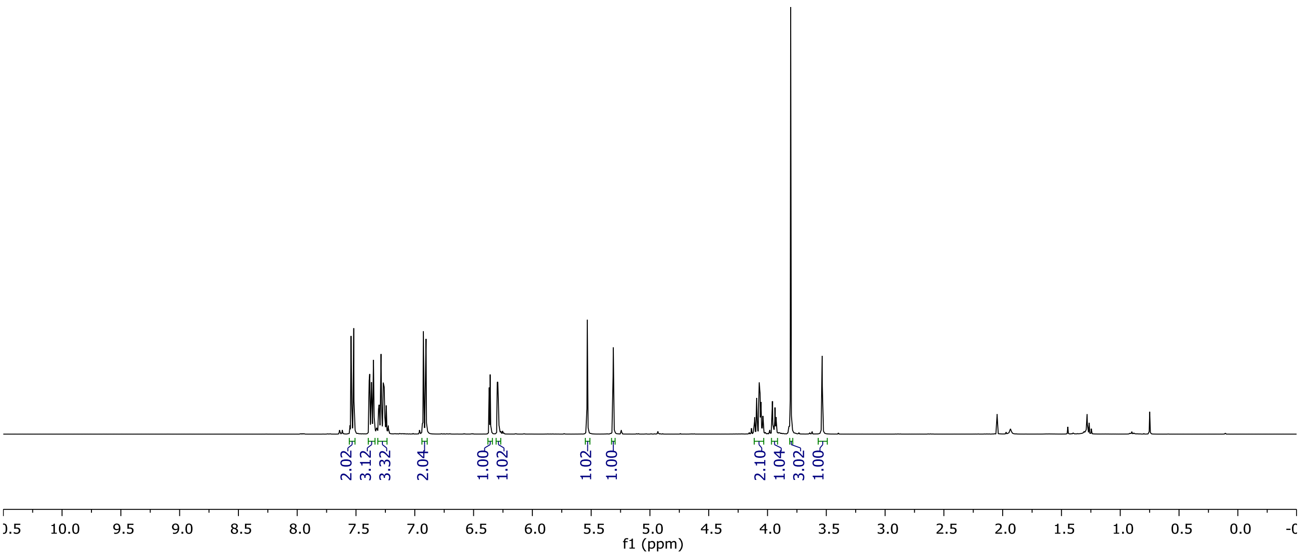
2a

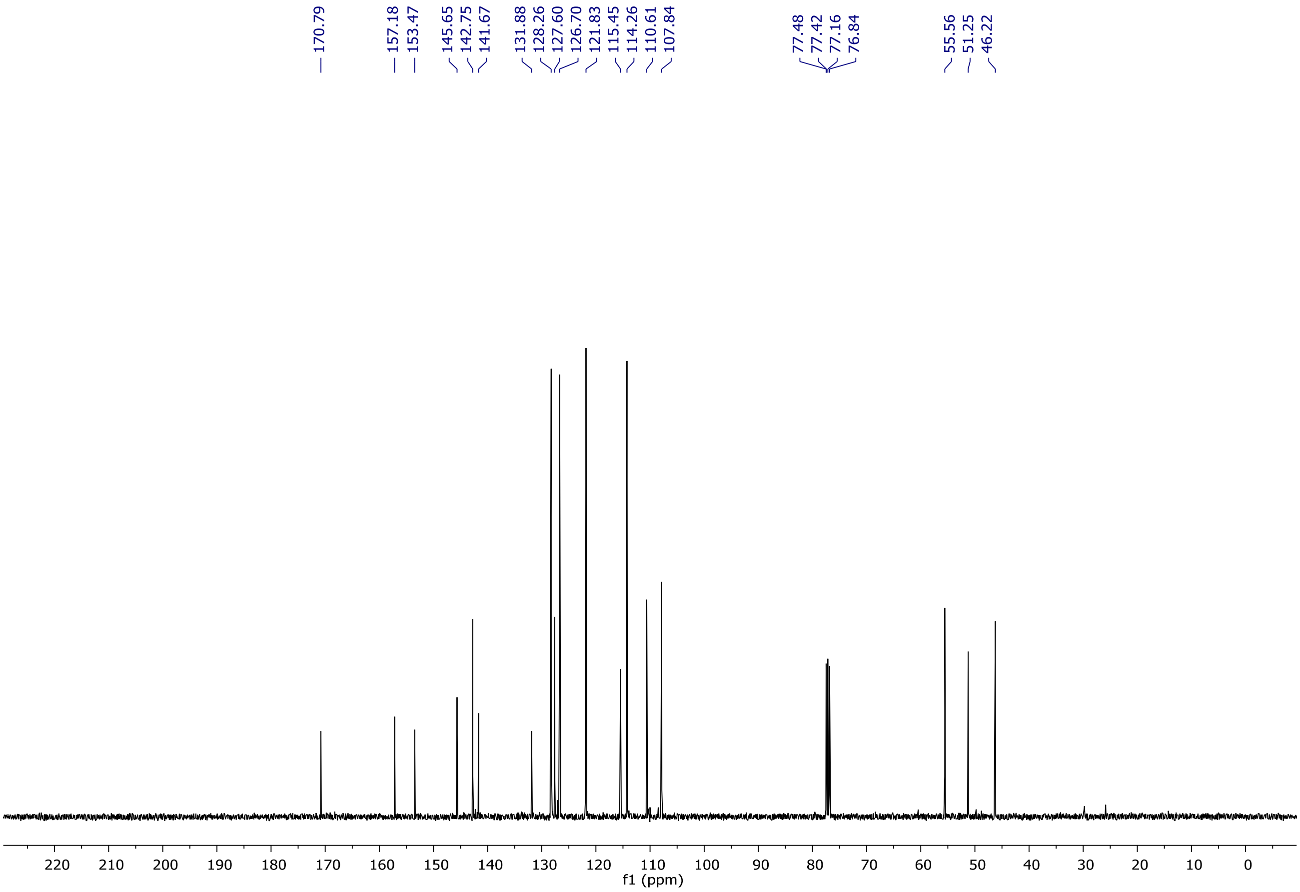

2.03
2.00
8.15
1.98
0.96
0.97
1.99
2.99
1.01
0.95
f1 (ppm)

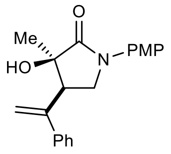

173.15
157.26
146.06
142.09
141.93
131.93
128.65
128.28
128.10
127.60
126.90
125.60
121.91
115.88
114.37
81.20
77.48
77.16
76.84
55.63
51.13
49.87
f1 (ppm)


O
O
N
PMP
HO
Ph

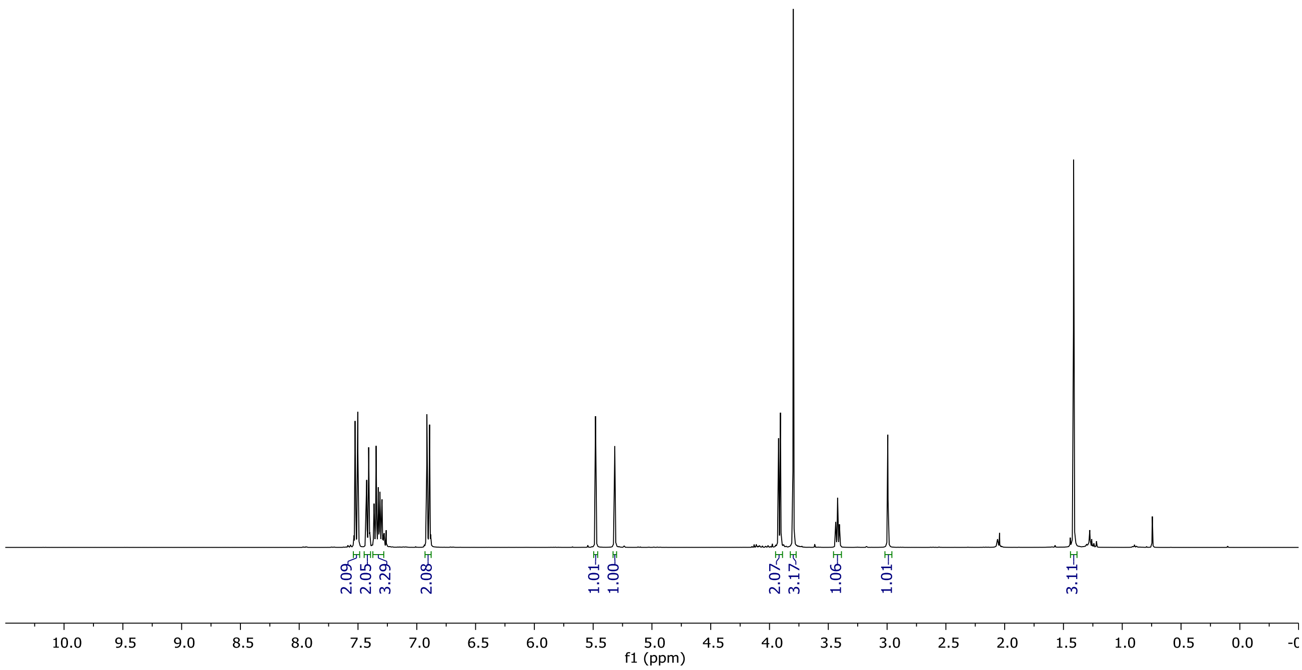
2b

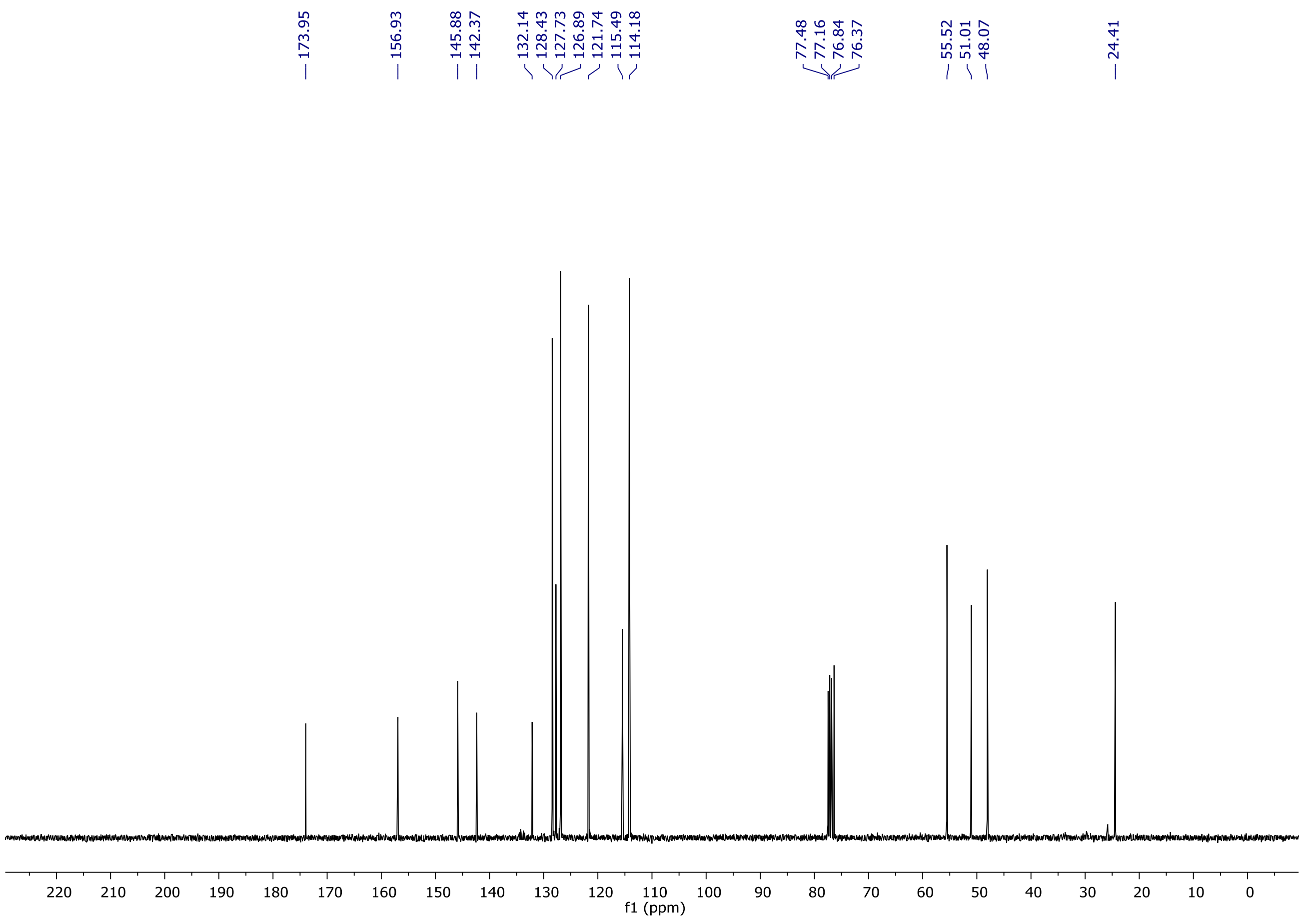

2.02
3.12
3.32
2.04
1.00
1.02
1.02
1.00
2.10
1.04
3.02
1.00
f1 (ppm)

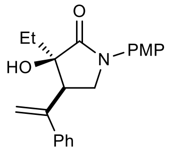

170.79
157.18
153.47
145.65
142.75
141.67
131.88
128.26
127.60
126.70
121.83
115.45
114.26
110.61
107.84
77.48
77.42
77.16
76.84
55.56
51.25
46.22
f1 (ppm)


Me
HO
O
N
PMP
Ph

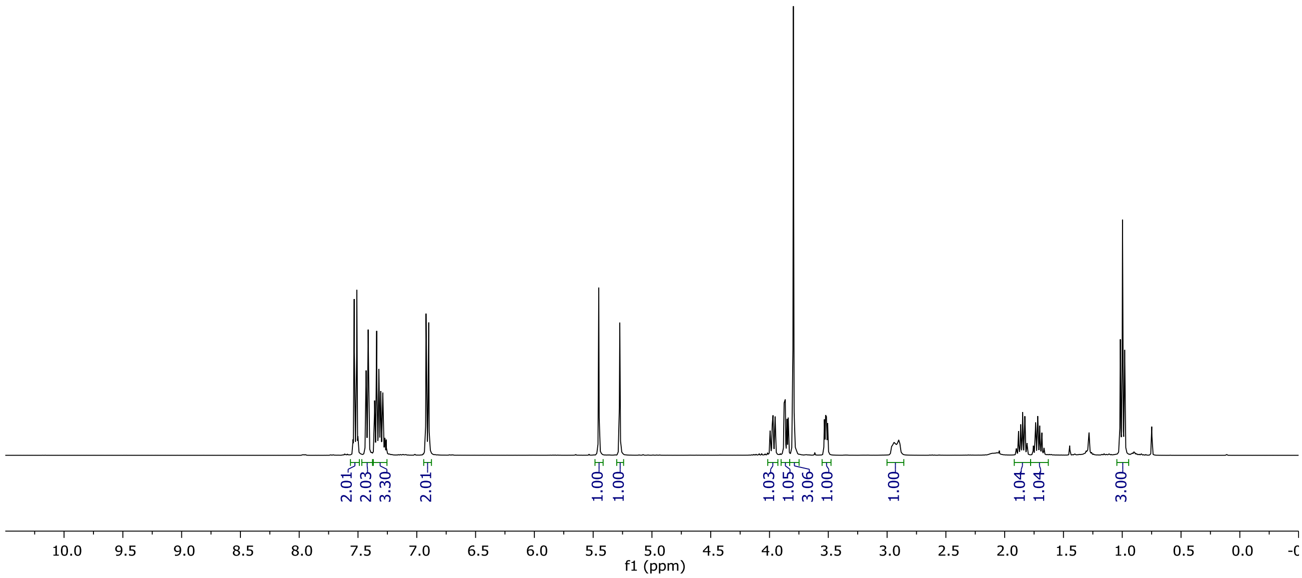
2c

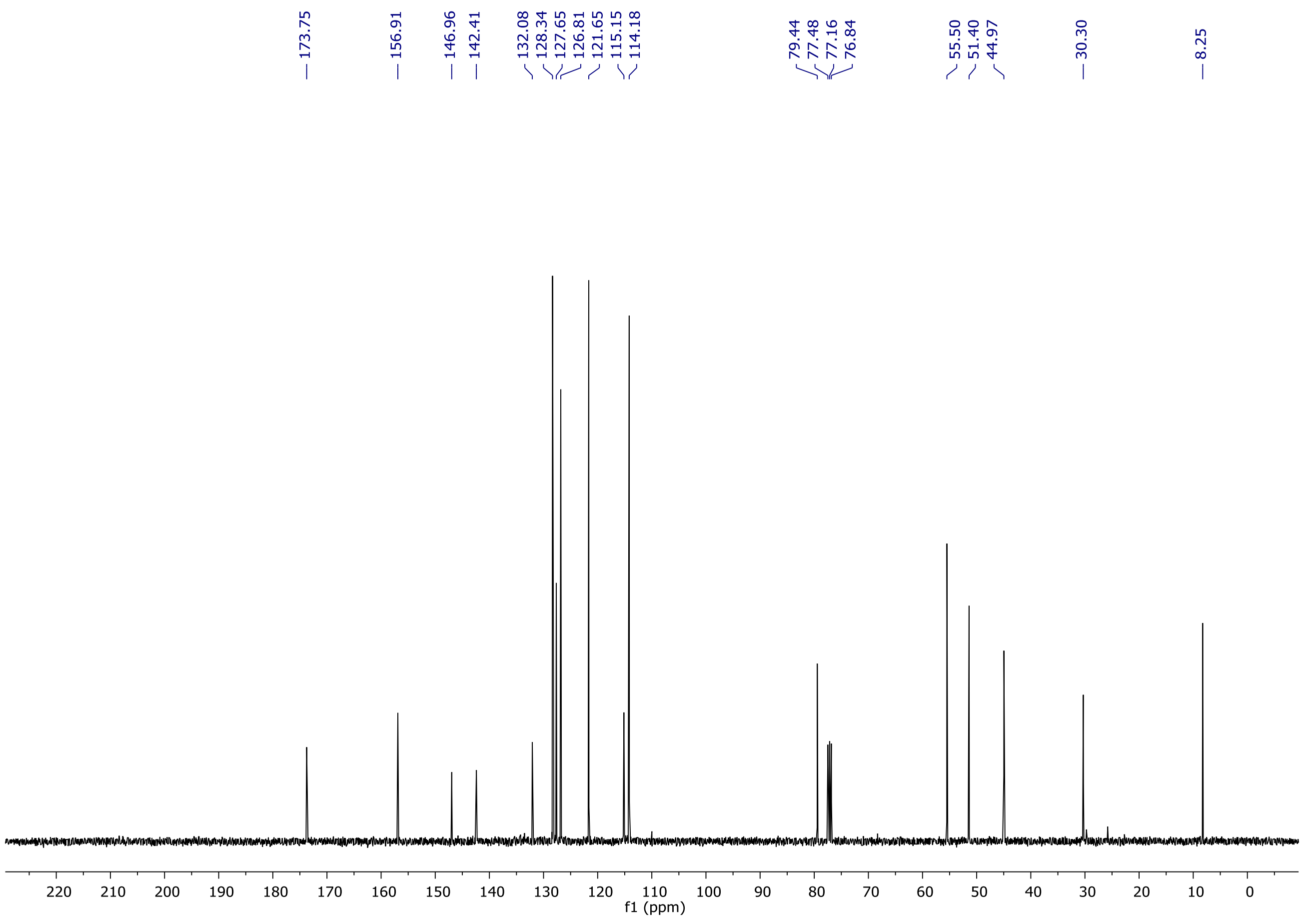

2.09
2.05
3.29
2.08
1.01
1.00
2.07
3.17
1.06
1.01
3.11
f1 (ppm)

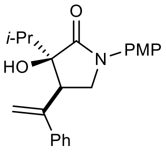

173.95
156.93
145.88
142.37
132.14
128.43
127.73
126.89
121.74
115.49
114.18
77.48
77.16
76.84
76.37
55.52
51.01
48.07
24.41
f1 (ppm)



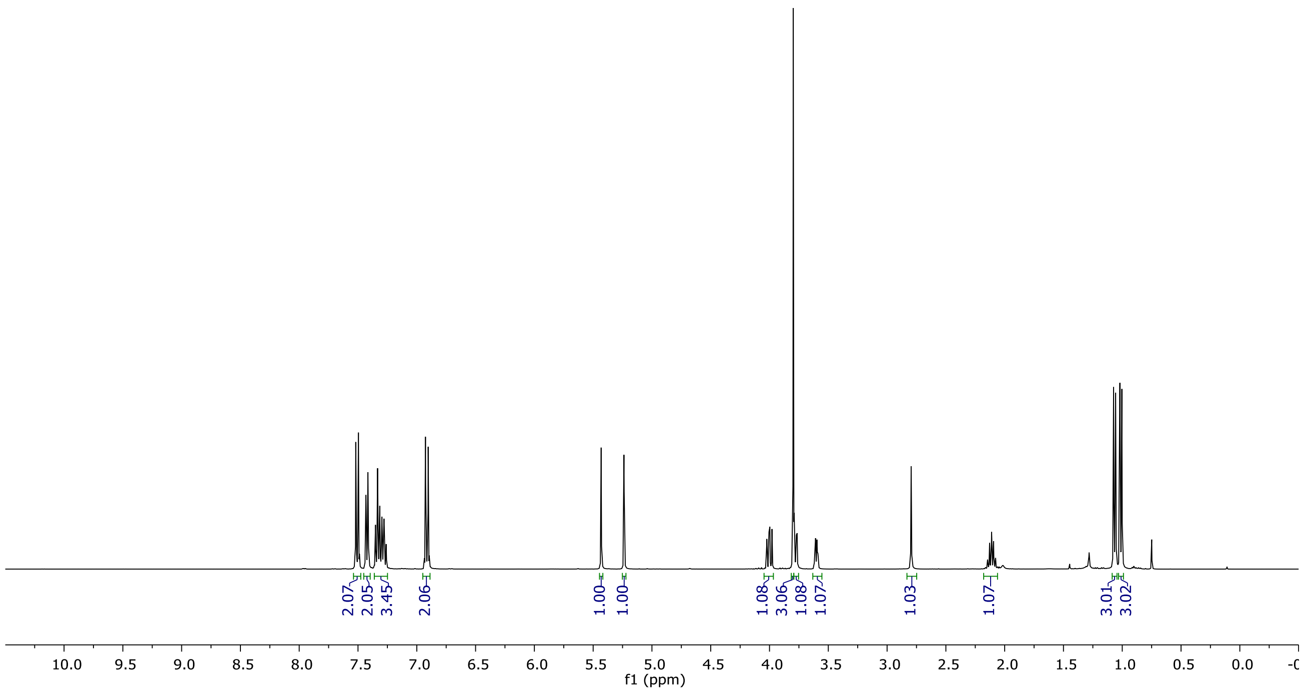
2d

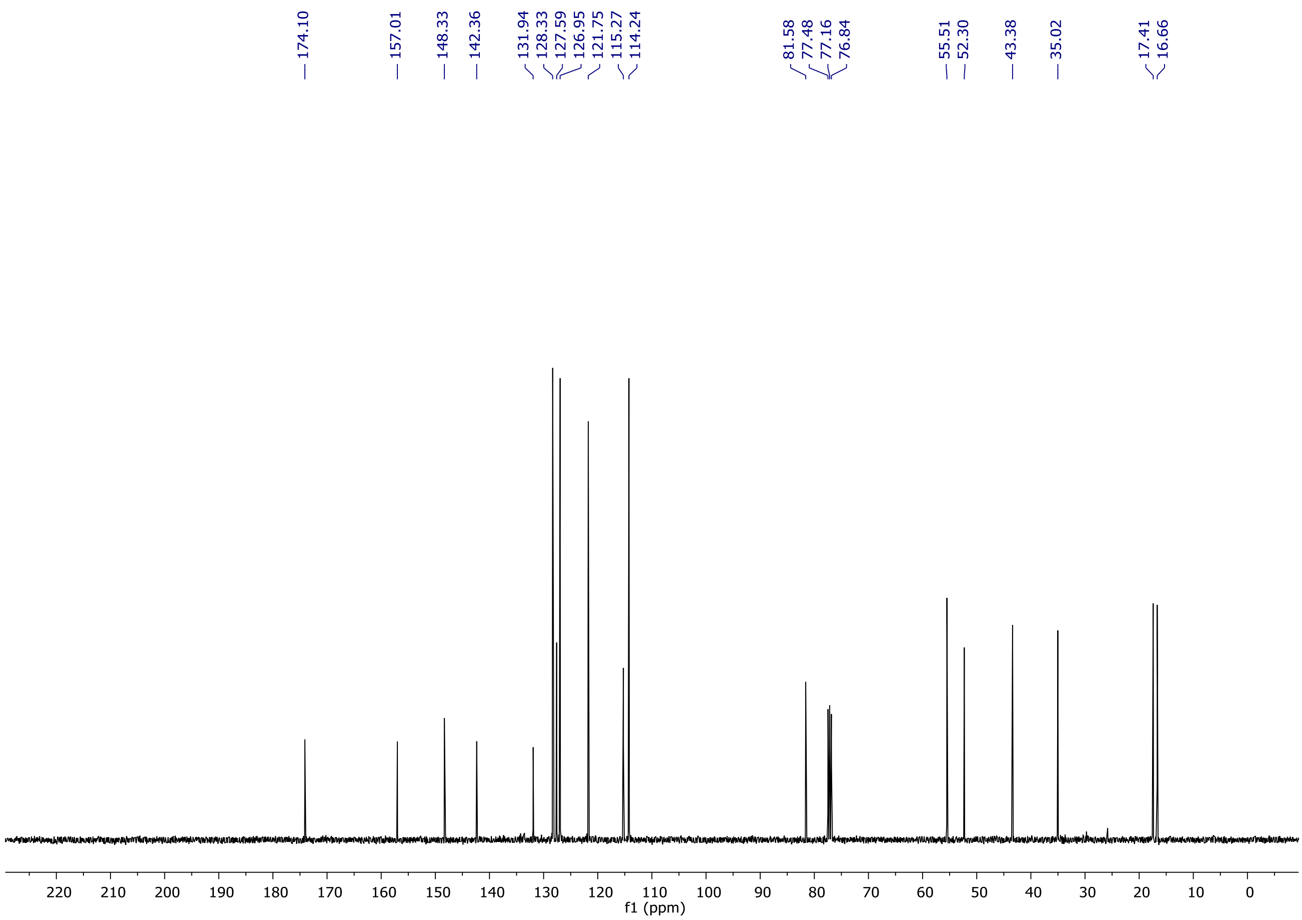


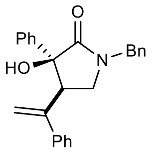



O
i-Pr
HO
N
PMP
Ph

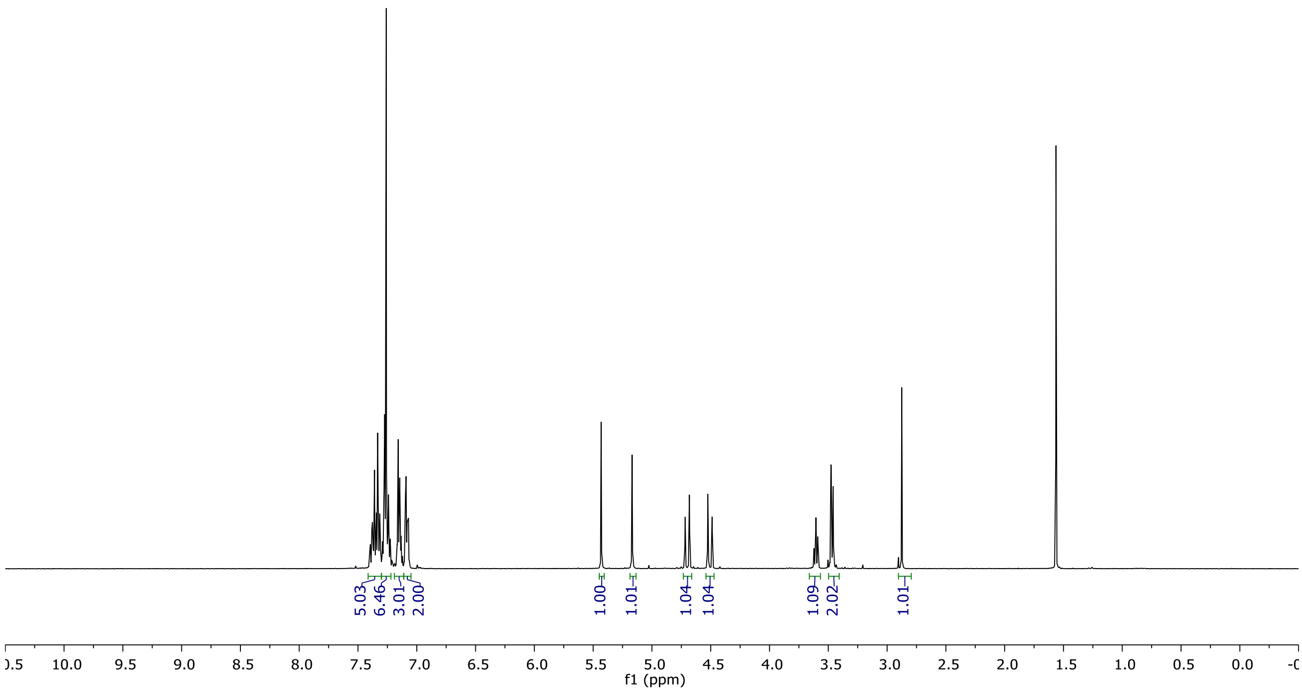
2e

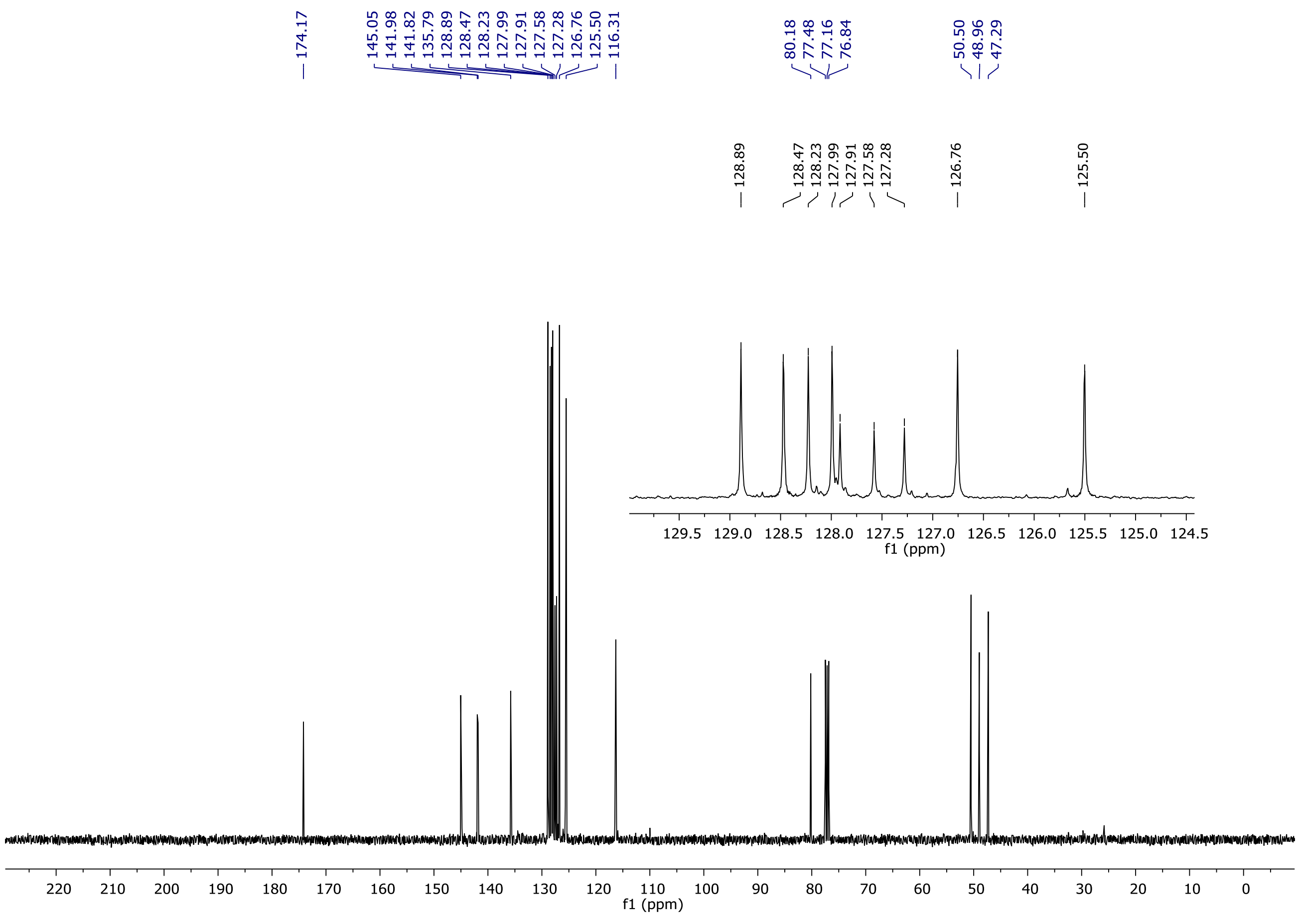

2.07
2.05
3.45
2.06
1.00
1.00
1.08
3.06
1.08
1.07
1.03
1.07
3.01
3.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

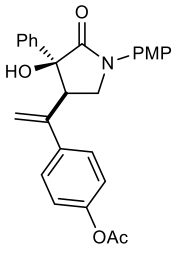

174.10
157.01
148.33
142.36
131.94
128.33
127.59
126.95
121.75
115.27
114.24
81.58
77.48
77.16
76.84
55.51
52.30
43.38
35.02
17.41
16.66
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Ph
N
Bn
HO
Ph

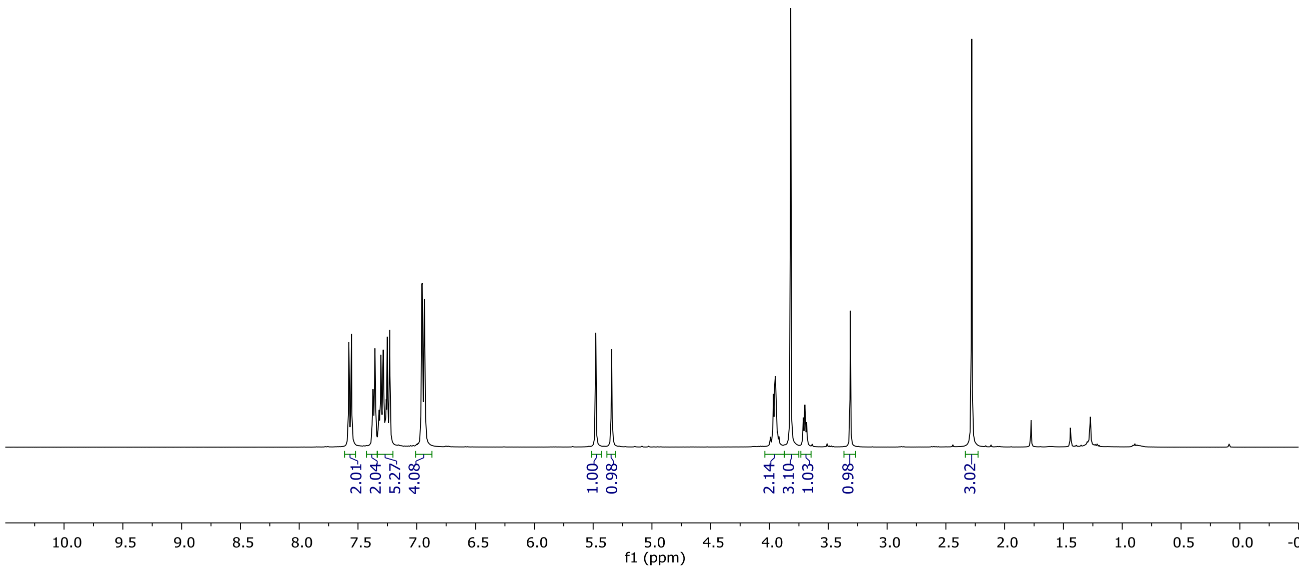
2f

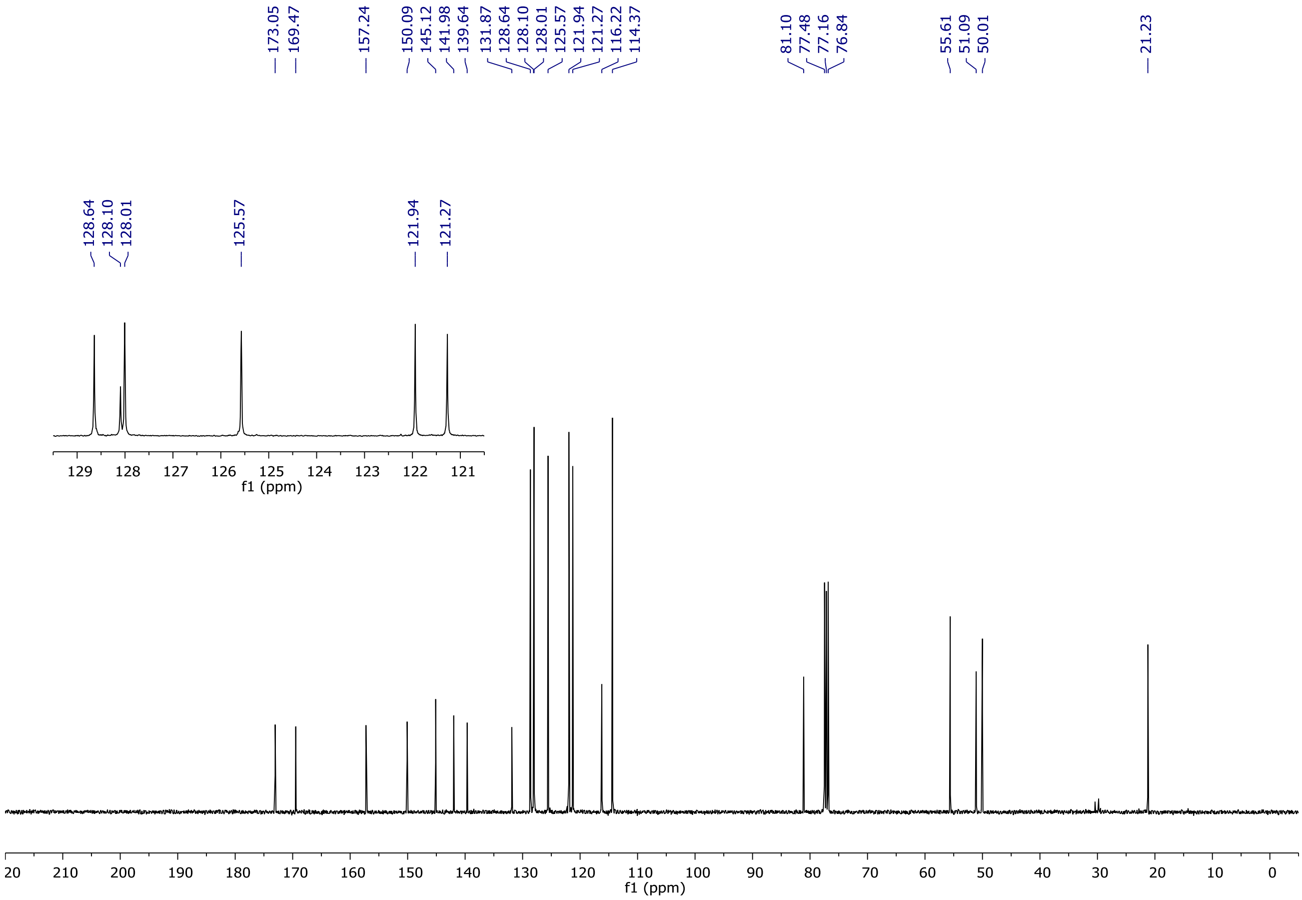

5.03
6.46
3.01
2.00
1.00
1.01
1.04
1.04
1.09
2.02
1.01
f1 (ppm)

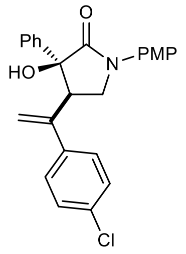

174.17
145.05
141.98
141.82
135.79
128.89
128.47
128.23
127.99
127.91
127.58
127.28
126.76
125.50
116.31
80.18
77.48
77.16
76.84
50.50
48.96
47.29
f1 (ppm)


O
Ph
HO
N
PMP
OAc

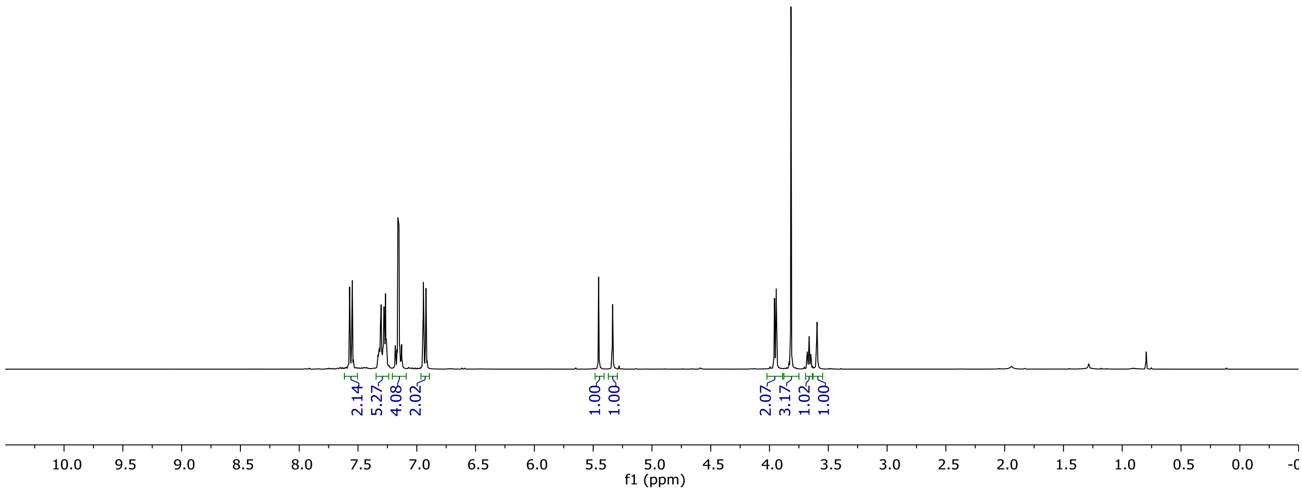
2g

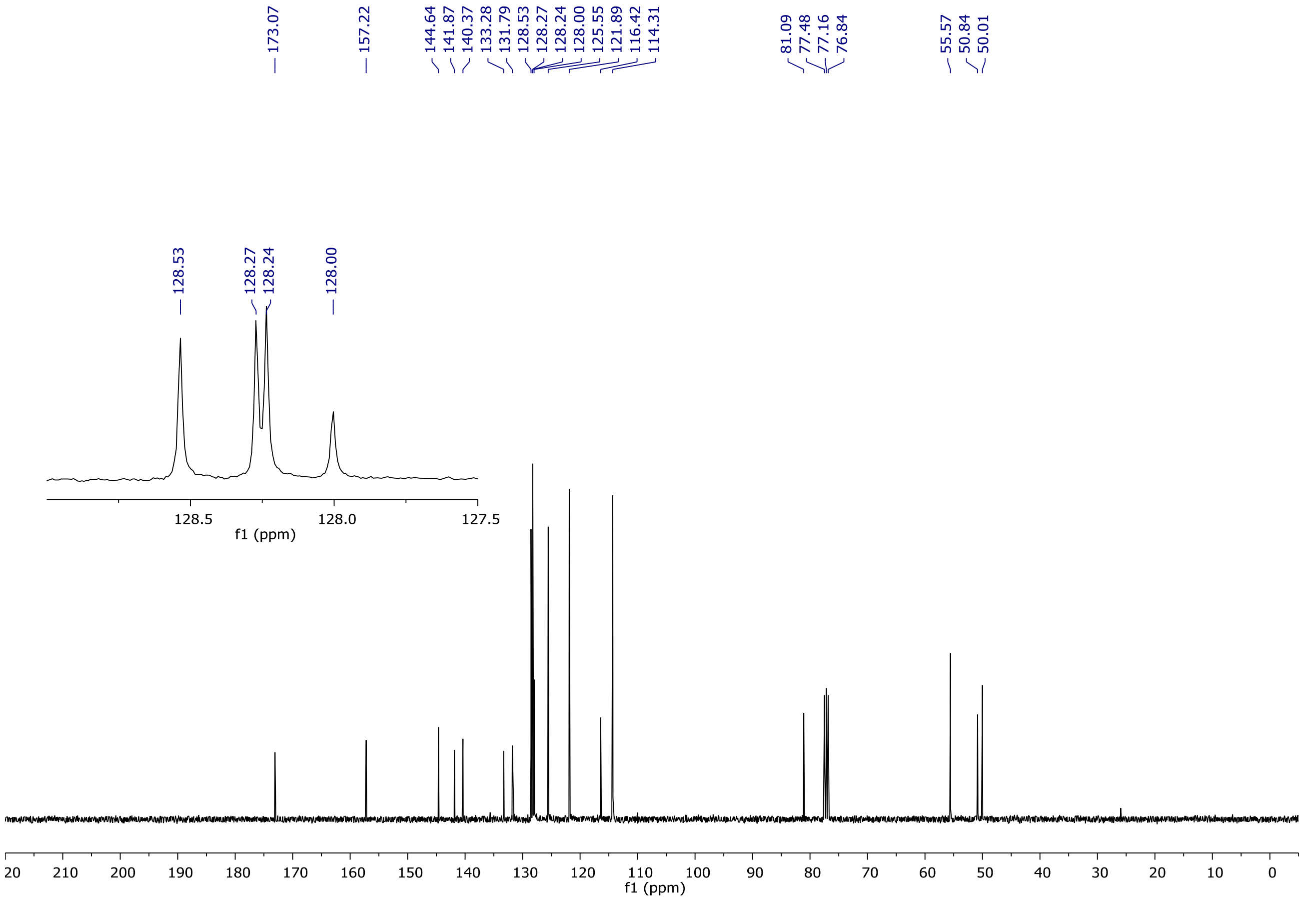

2.01
2.04
5.27
4.08
1.00
0.98
2.14
3.10
1.03
0.98
3.02
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

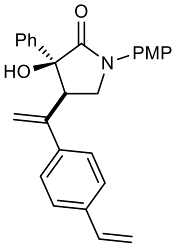

173.05
169.47
157.24
150.09
145.12
141.98
139.64
131.87
128.64
128.10
128.01
125.57
121.94
121.27
116.22
114.37
81.10
77.48
77.16
76.84
55.61
51.09
50.01
21.23
128.64
128.10
128.01
125.57
121.94
121.27
129 128 127 126 125 124 123 122 121
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Ph
HO
N
PMP
Cl

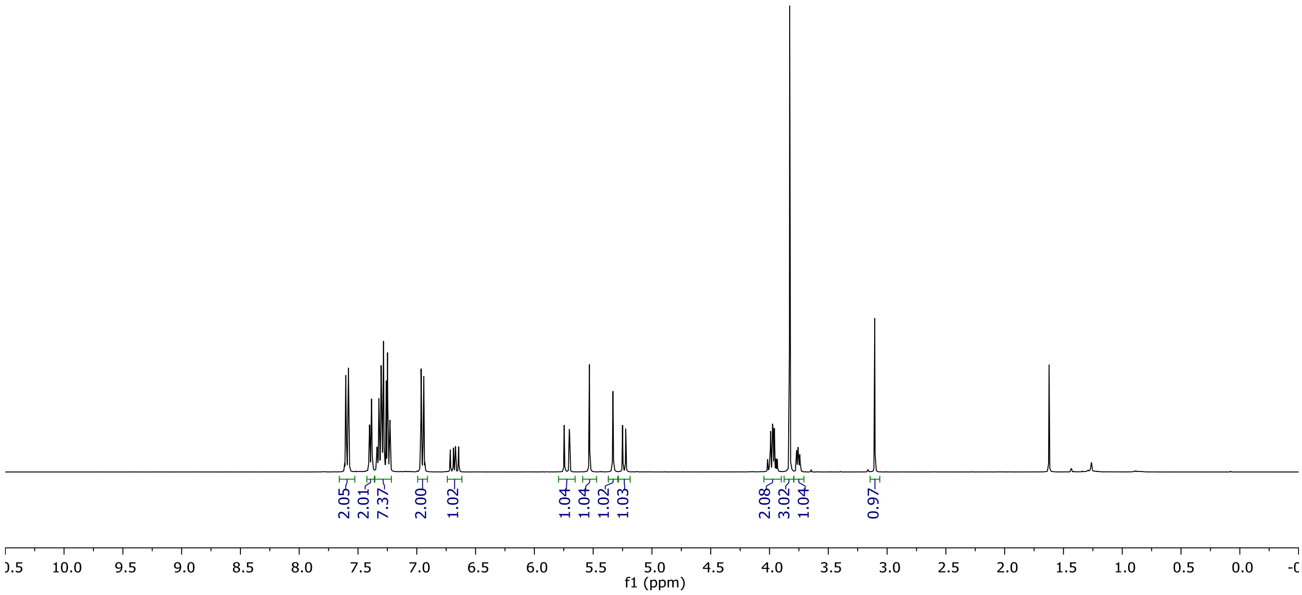
2h

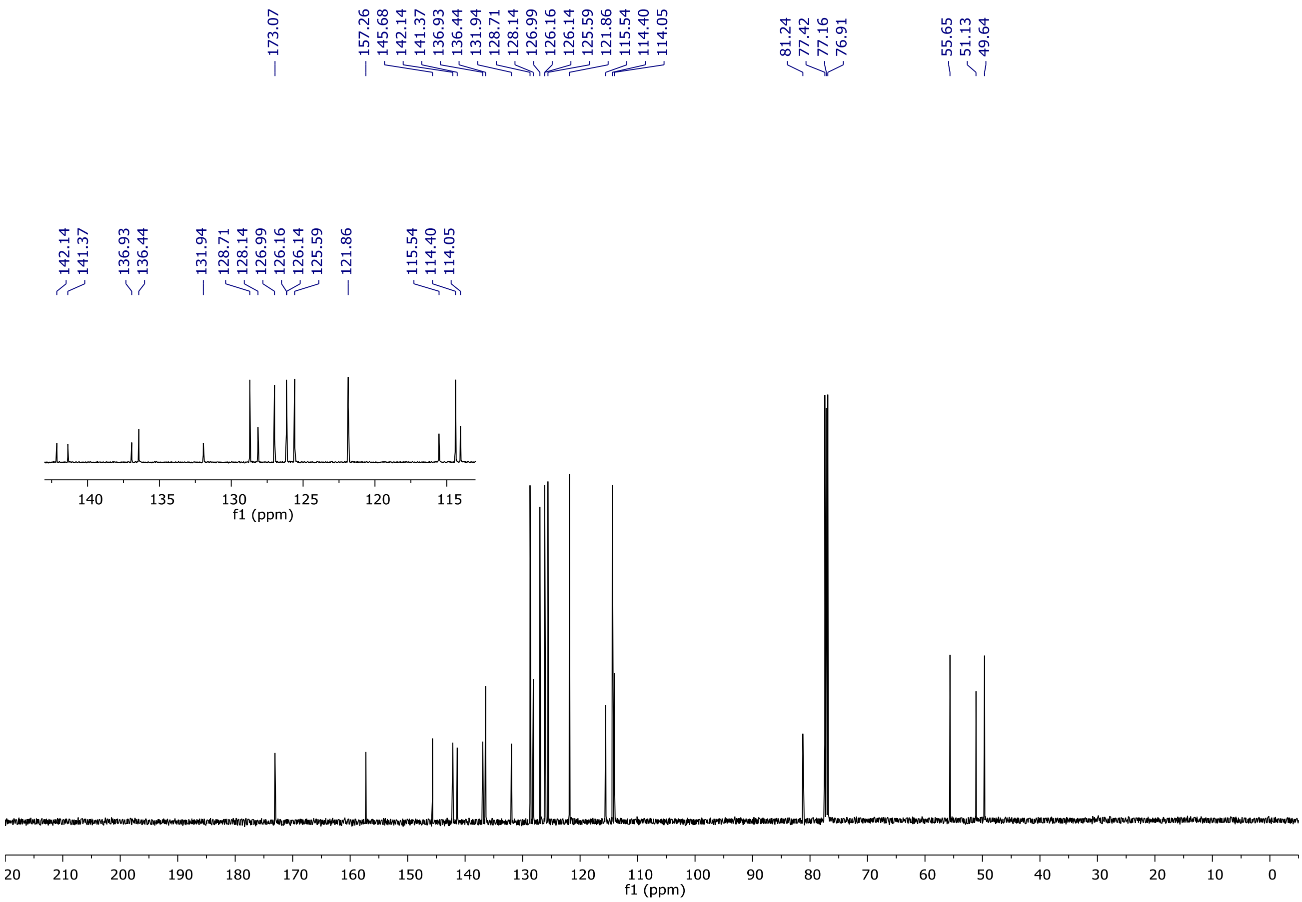

2.14
5.27
4.08
2.02
1.00
1.00
2.07
3.17
1.02
1.00
f1 (ppm)

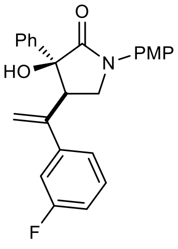

173.07
157.22
144.64
141.87
140.37
133.28
131.79
128.53
128.27
128.24
128.00
125.55
121.89
116.42
114.31
81.09
77.48
77.16
76.84
55.57
50.84
50.01
128.53
128.27
128.24
128.00
f1 (ppm)
f1 (ppm)


O
Ph
N
PMP
HO

2i

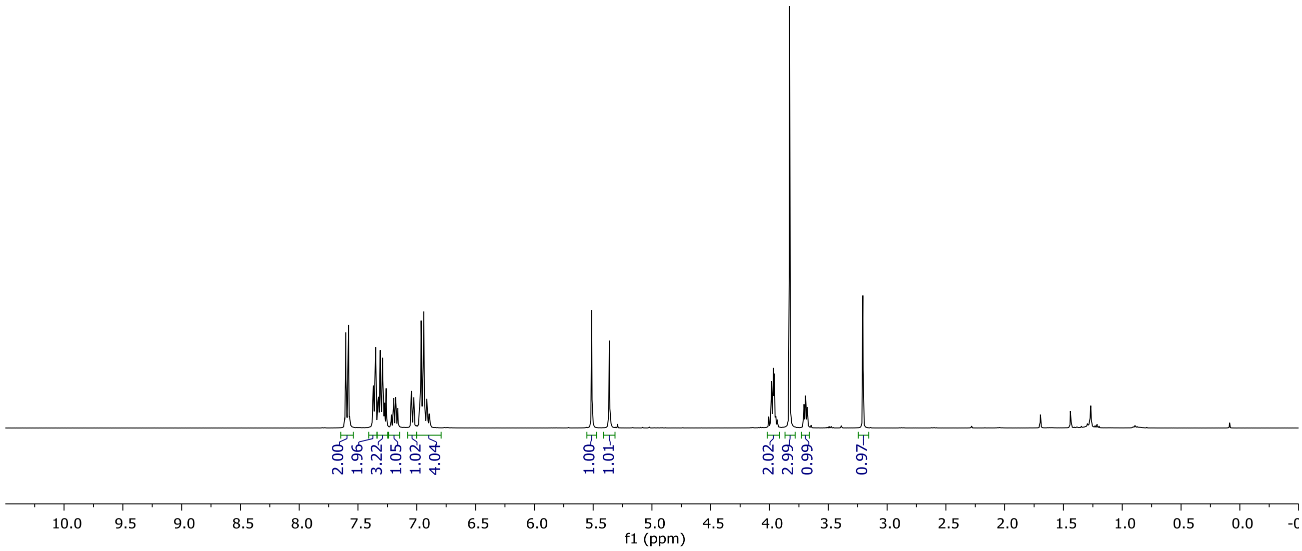

2.05
2.01
7.37
2.00
1.02
1.04
1.04
1.02
1.03
2.08
3.02
1.04
0.97
f1 (ppm)


173.07
157.26
145.68
142.14
141.37
136.93
136.44
131.94
128.71
128.14
126.99
126.16
126.14
125.59
121.86
115.54
114.40
114.05
81.24
77.42
77.16
76.91
55.65
51.13
49.64
f1 (ppm)

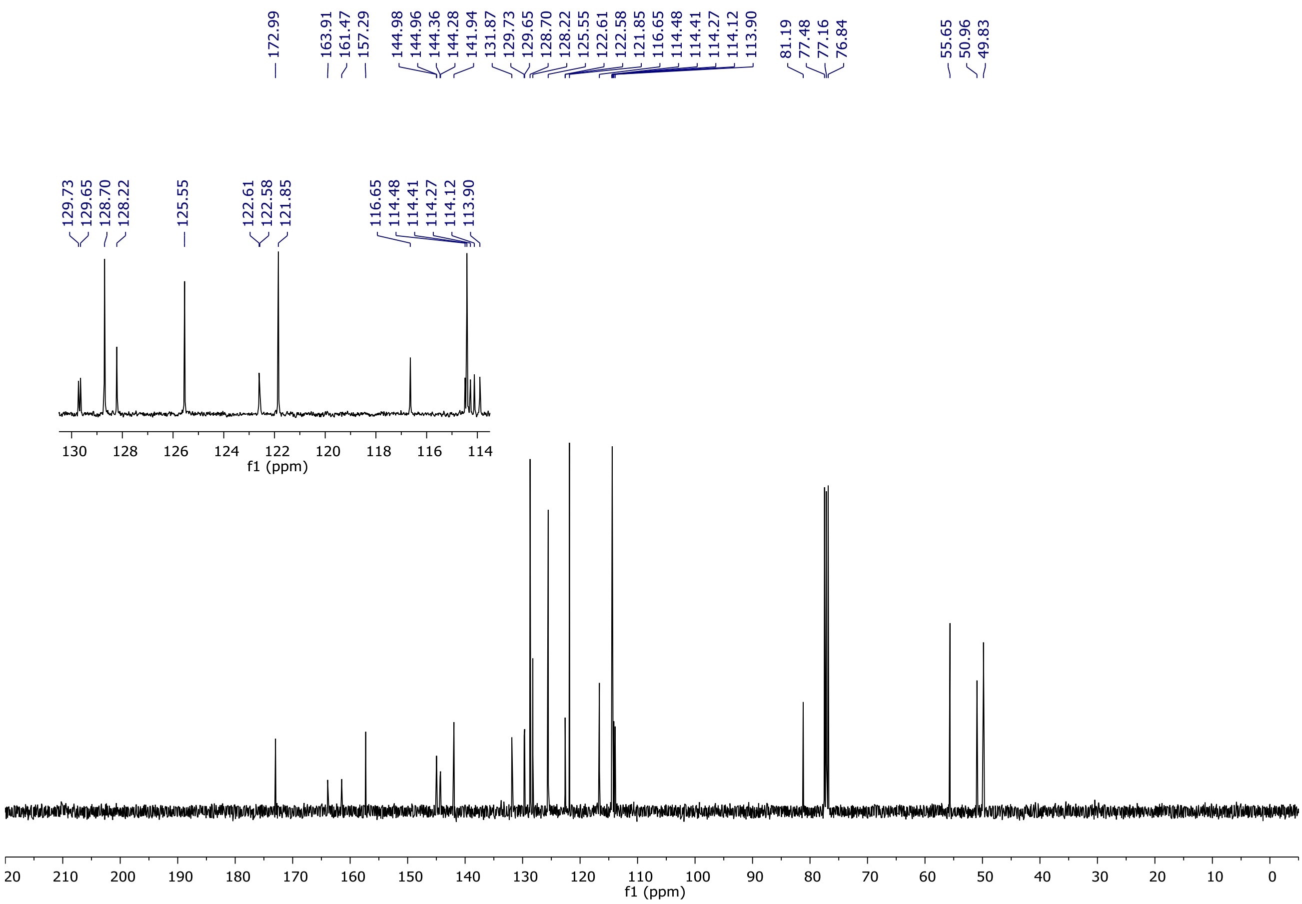


O
Ph
HO
N
PMP
F

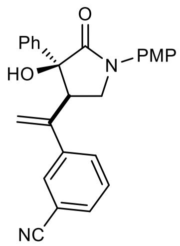
2j



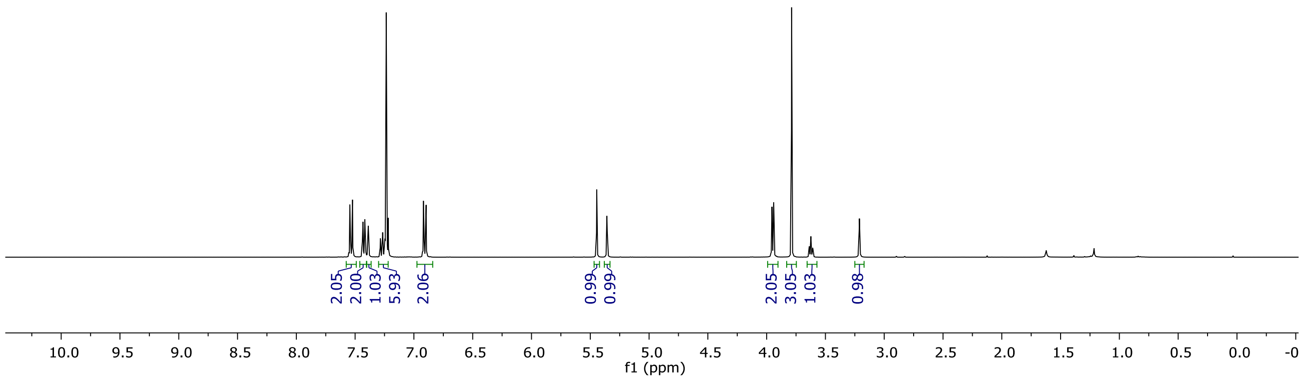
2.00
1.96
3.22
1.05
1.02
4.04
1.00
1.01
2.02
2.99
0.99
0.97
f1 (ppm)

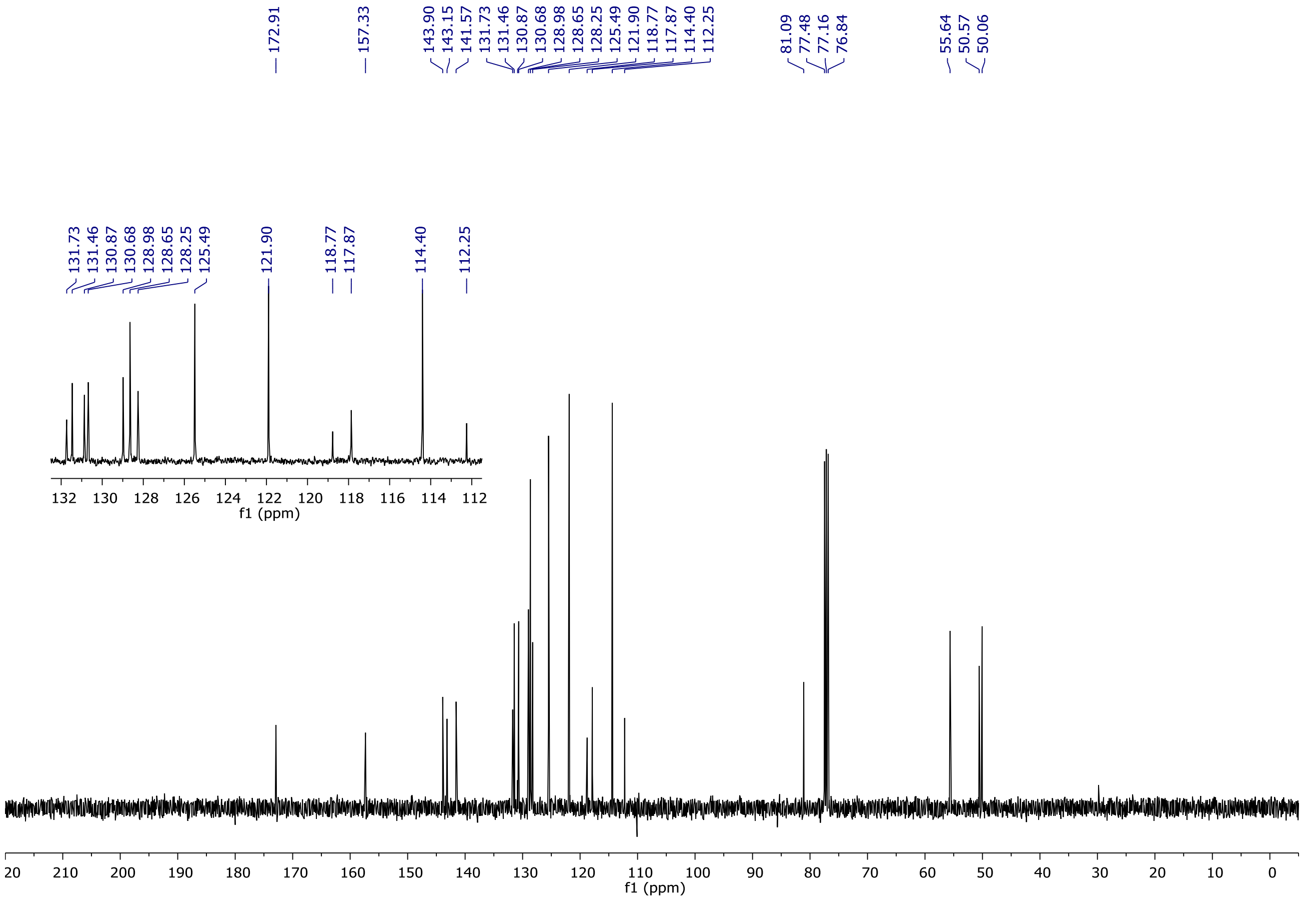


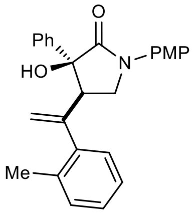
172.99
163.91
161.47
157.29
144.98
144.96
144.36
144.28
141.94
131.87
129.73
129.65
128.70
128.22
125.55
122.61
122.58
121.85
116.65
114.48
114.41
114.27
114.12
113.90
81.19
77.48
77.16
76.84
55.65
50.96
49.83
f1 (ppm)


O
Ph
HO
N
PMP
NC

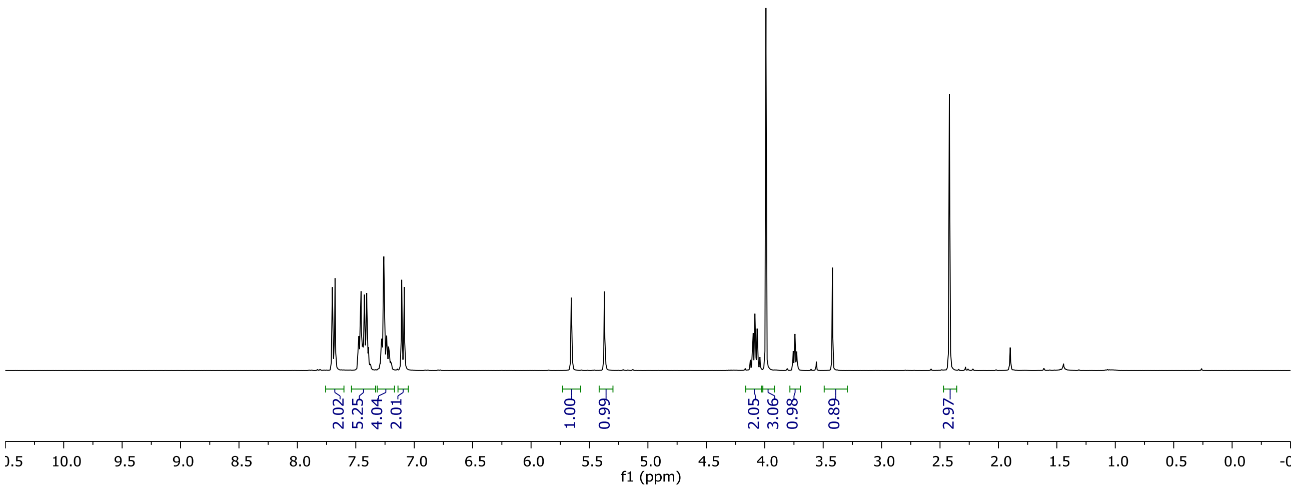
2k


2.05
2.00
1.03
5.93
2.06
0.99
0.99
2.05
3.05
1.03
0.98
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)


172.91
157.33
143.90
143.15
141.57
131.73
131.46
130.87
130.68
128.98
128.65
128.25
125.49
121.90
118.77
117.87
114.40
112.25
81.09
77.48
77.16
76.84
55.64
50.57
50.06
132 130 128 126 124 122 120 118 116 114 112
f1 (ppm)
20 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Ph
HO
N
PMP
Me

2l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5.25
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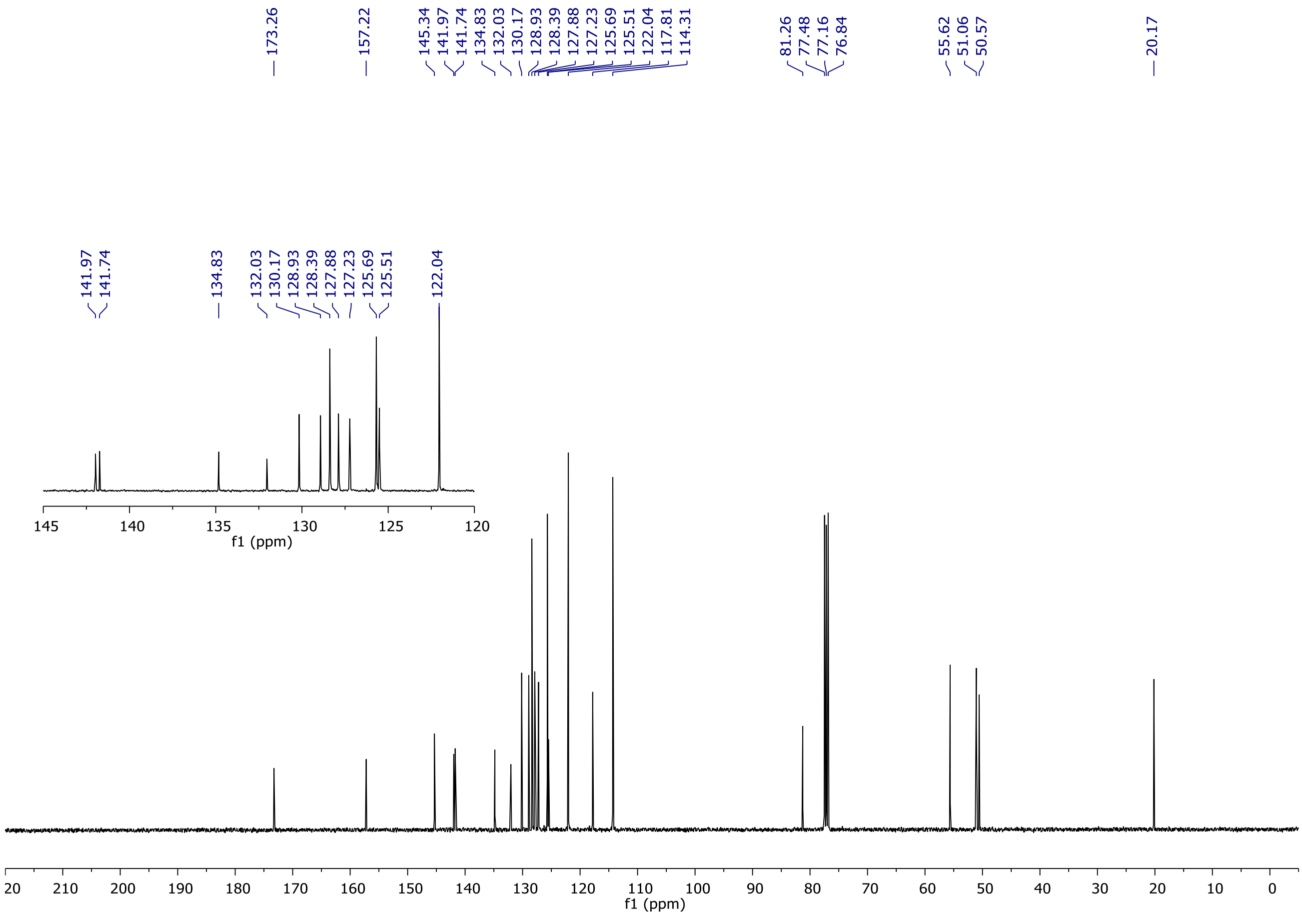
2.01
1.00
0.99
2.05
3.06
0.98
0.89
2.97
f1 (ppm)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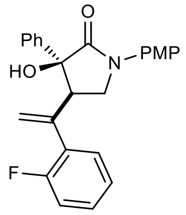
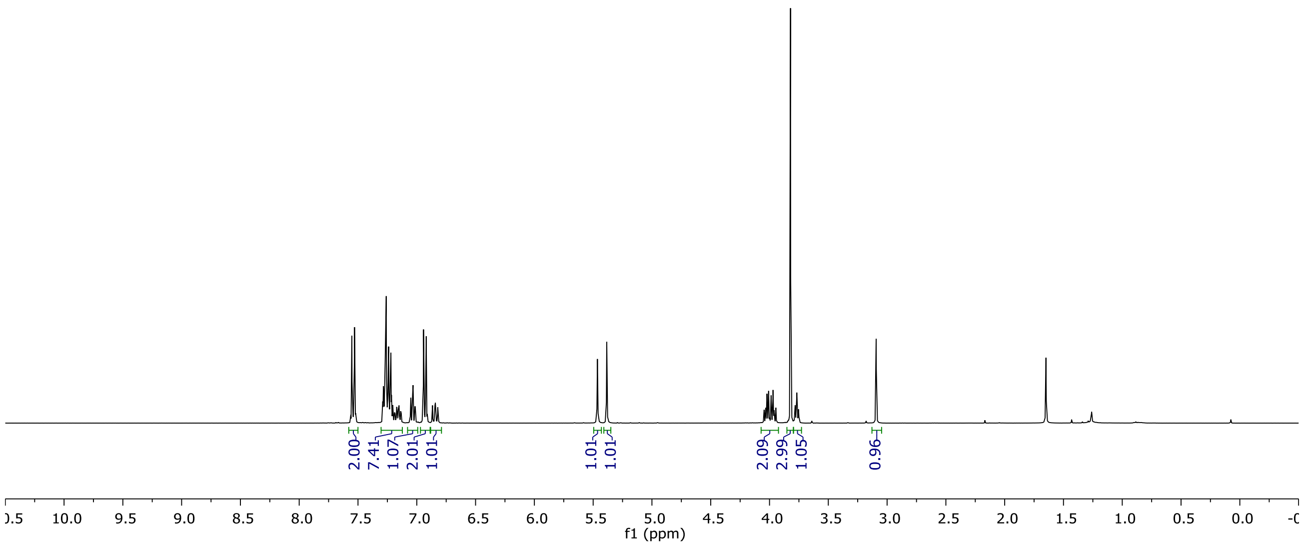
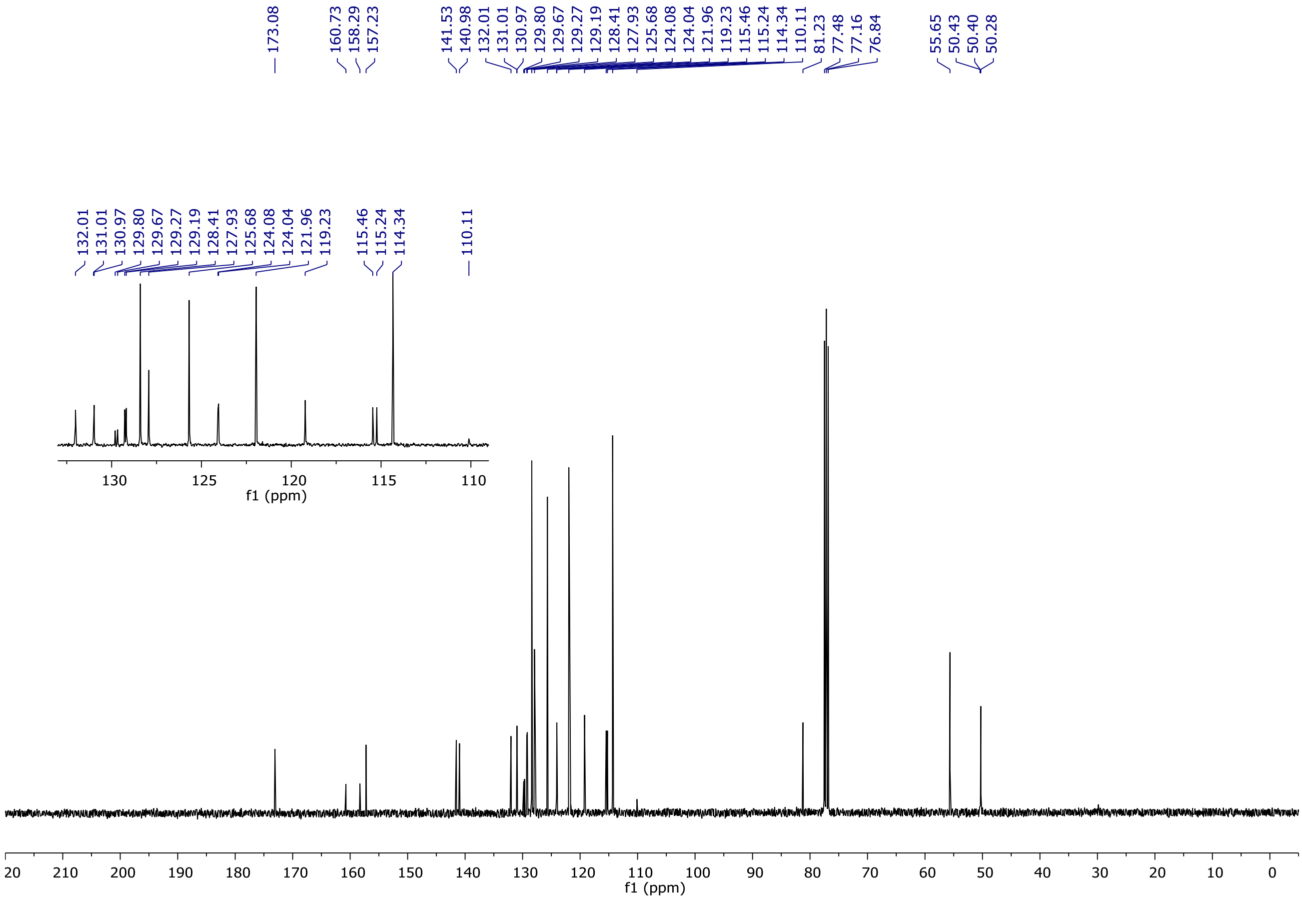
157.22
145.34
141.97
141.74
134.83
132.03
130.17
128.93
128.39
127.88
127.23
125.69
125.51
122.04
117.81
114.31
81.26
77.48
77.16
76.84
55.62
51.06
50.57
20.17
f1 (ppm)


O
Ph
HO
N
PMP
F

2m


2.00
7.41
1.07
2.01
1.01
1.01
1.01
2.09
2.99
1.05
0.96
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0
f1 (ppm)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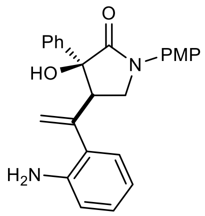
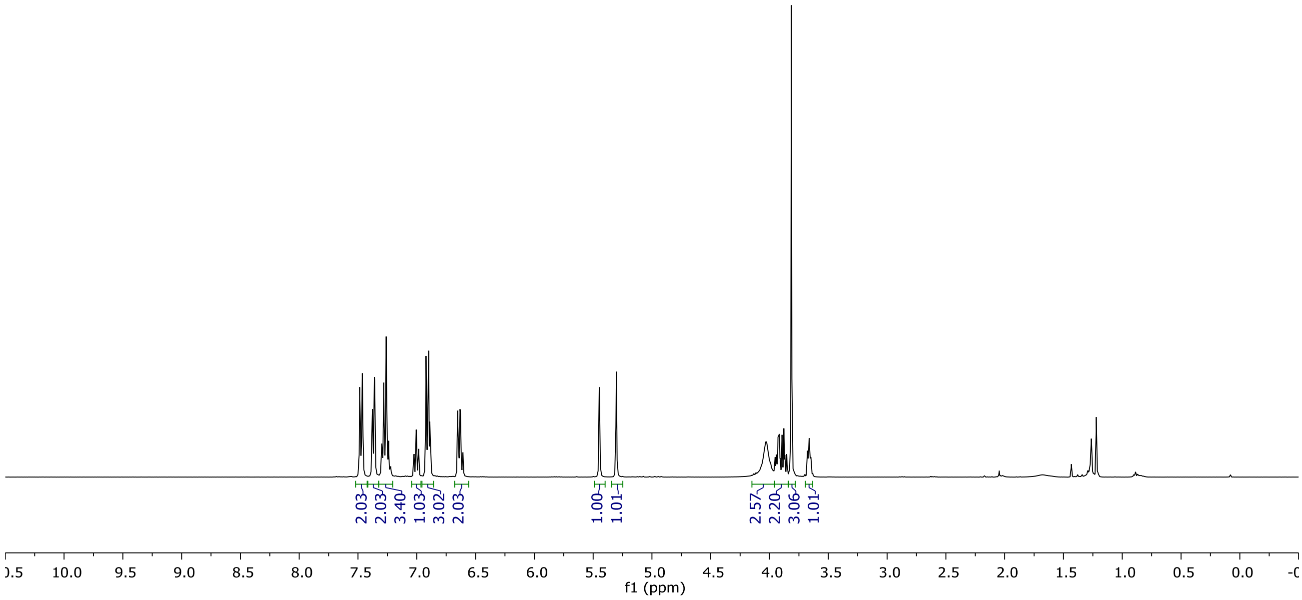
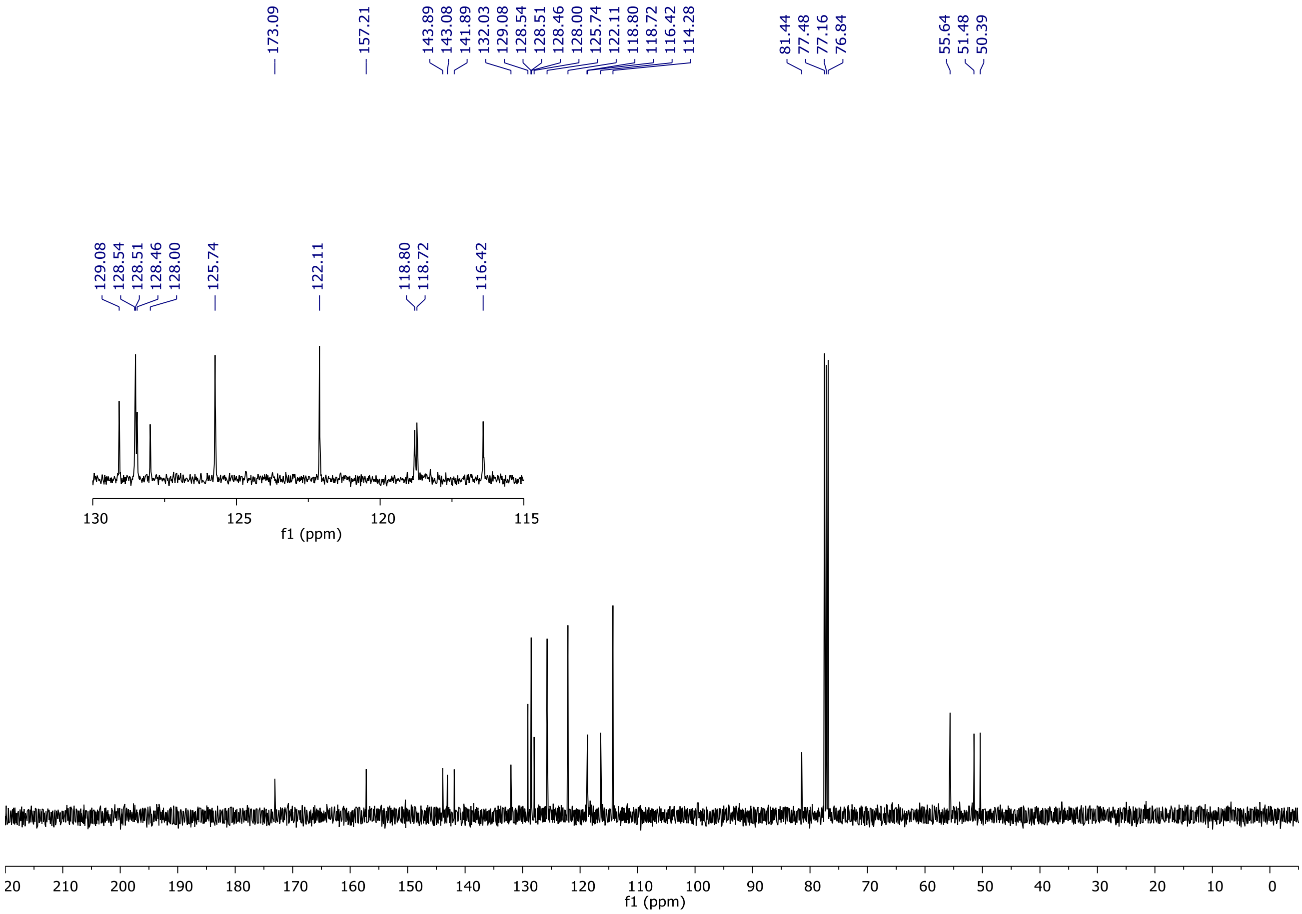
140.98
132.01
131.01
130.97
129.80
129.67
129.27
129.19
128.41
127.93
125.68
124.08
124.04
121.96
119.23
115.46
115.24
114.34
110.11
81.23
77.48
77.16
76.84
55.65
50.43
50.40
50.28
132.01
131.01
130.97
129.80
129.67
129.27
129.19
128.41
127.93
125.68
124.08
124.04
121.96
119.23
115.46
115.24
114.34
110.11
130 125 120 115 110
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


O
Ph
HO
N
PMP
H_2N

2n


2.03
2.03
3.40
1.03
3.02
2.03
1.00
1.01
2.57
2.20
3.06
1.01
f1 (ppm)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157.21
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143.08
141.89
132.03
129.08
128.54
128.51
128.46
128.00
125.74
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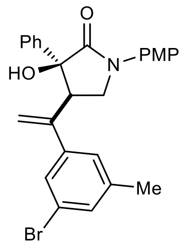
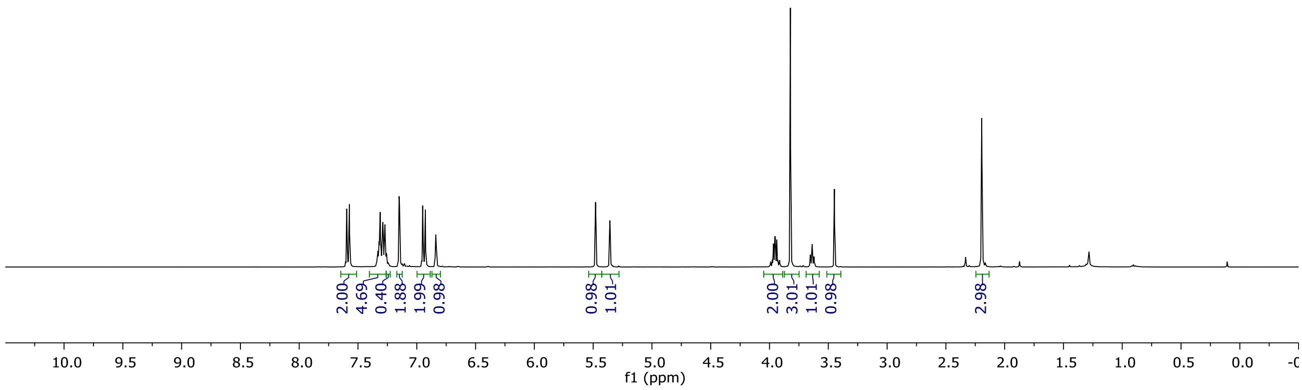
51.48
50.39
f1 (ppm)


O
Ph
HO
N
PMP
Me
Br

2o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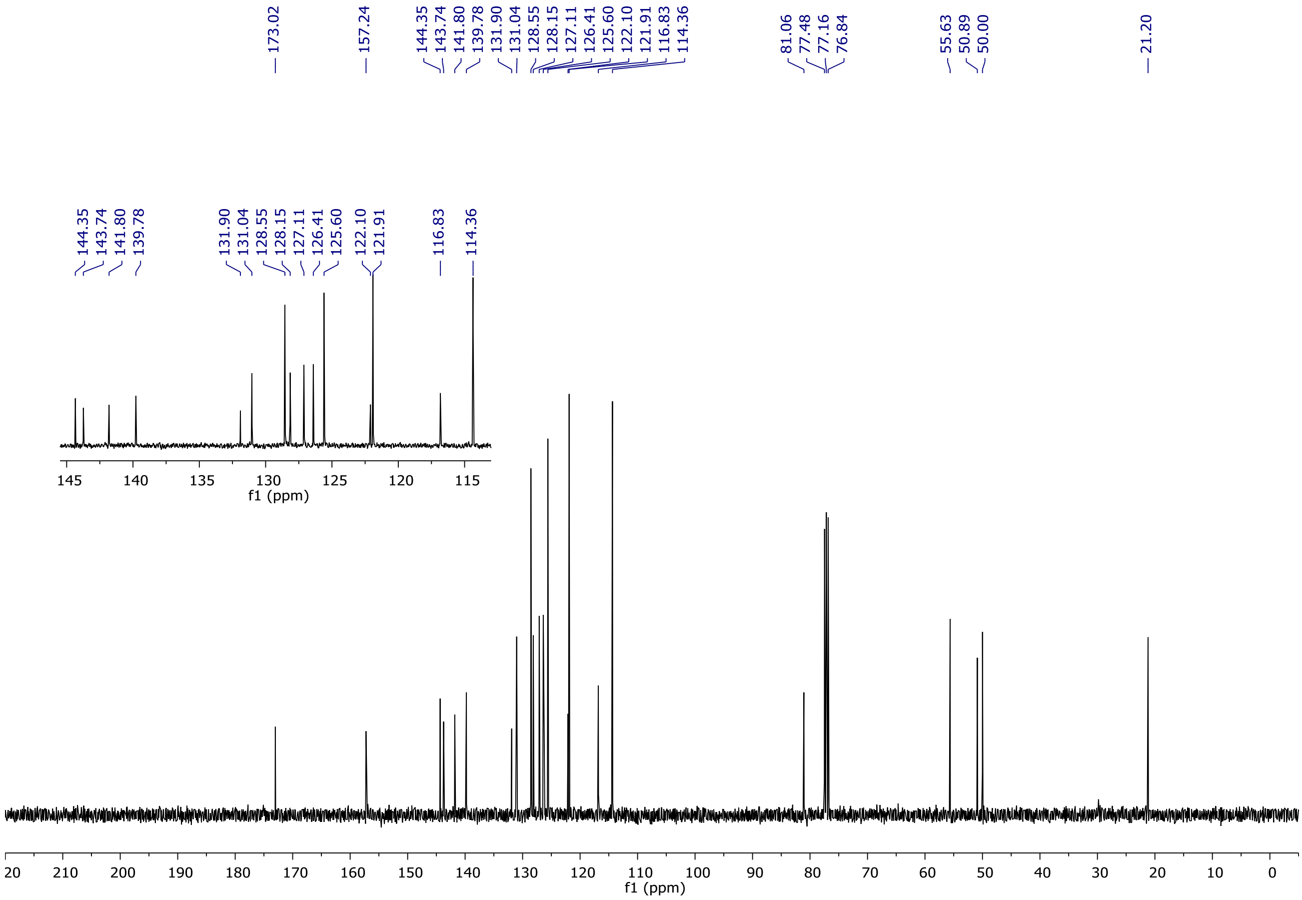
4.69
0.40
1.88
1.99
0.98
0.98
1.01
2.00
3.01
1.01
0.98
2.98
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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143.74
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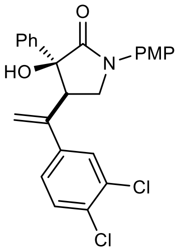
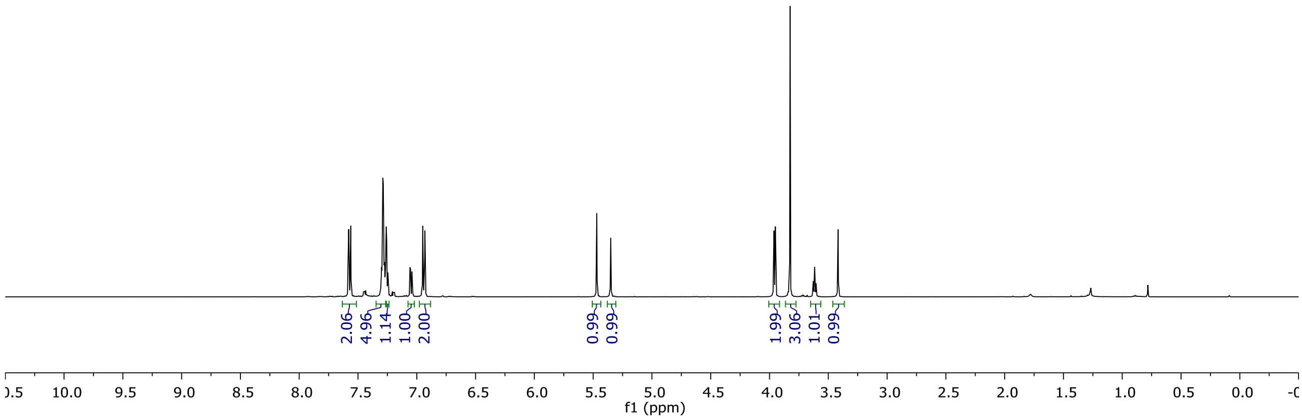
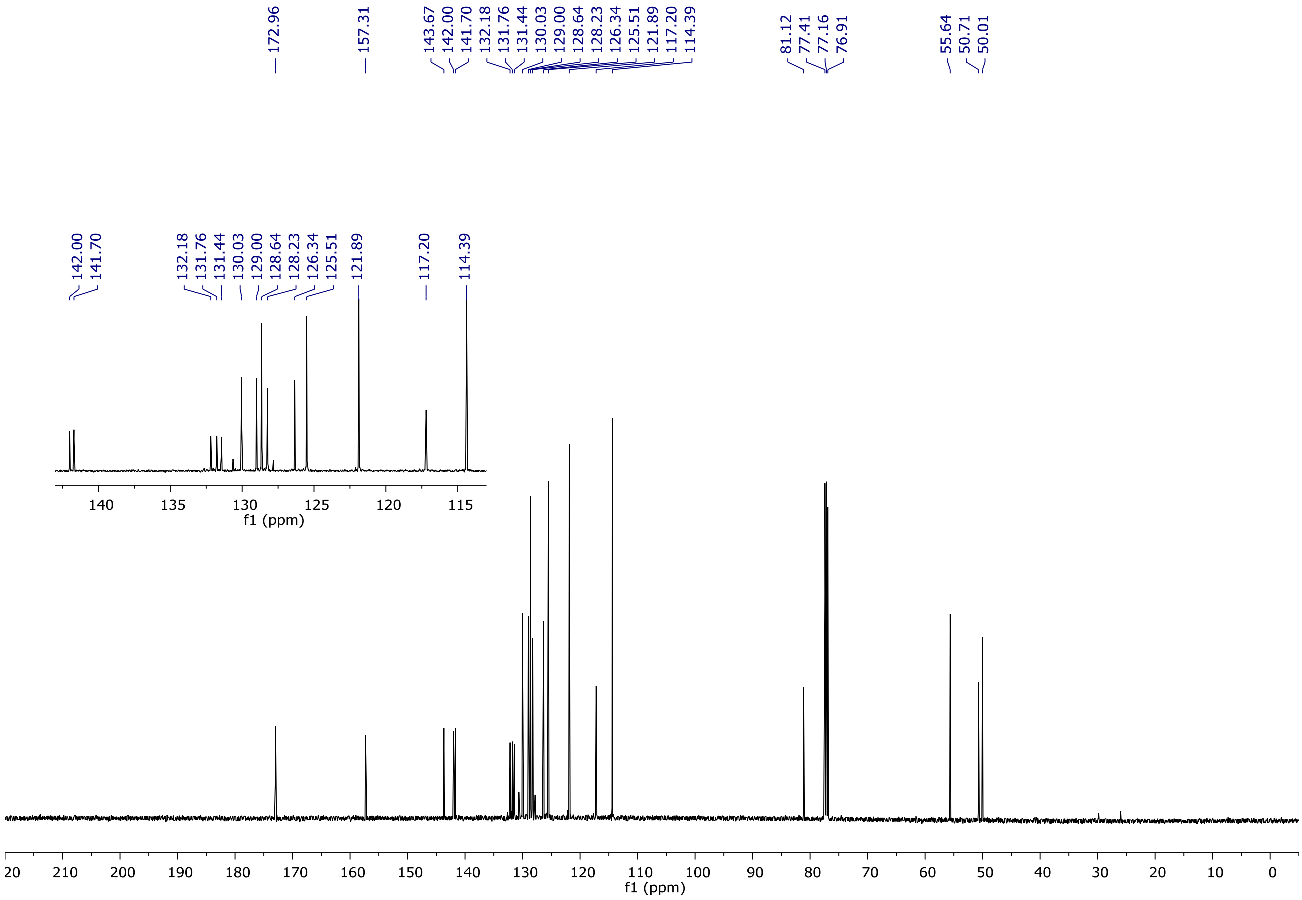
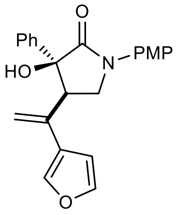
139.78
131.90
131.04
128.55
128.15
127.11
126.41
125.60
122.10
121.91
116.83
114.36
81.06
77.48
77.16
76.84
55.63
50.89
50.00
21.20
145 140 135 130 125 120 115
f1 (ppm)
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)



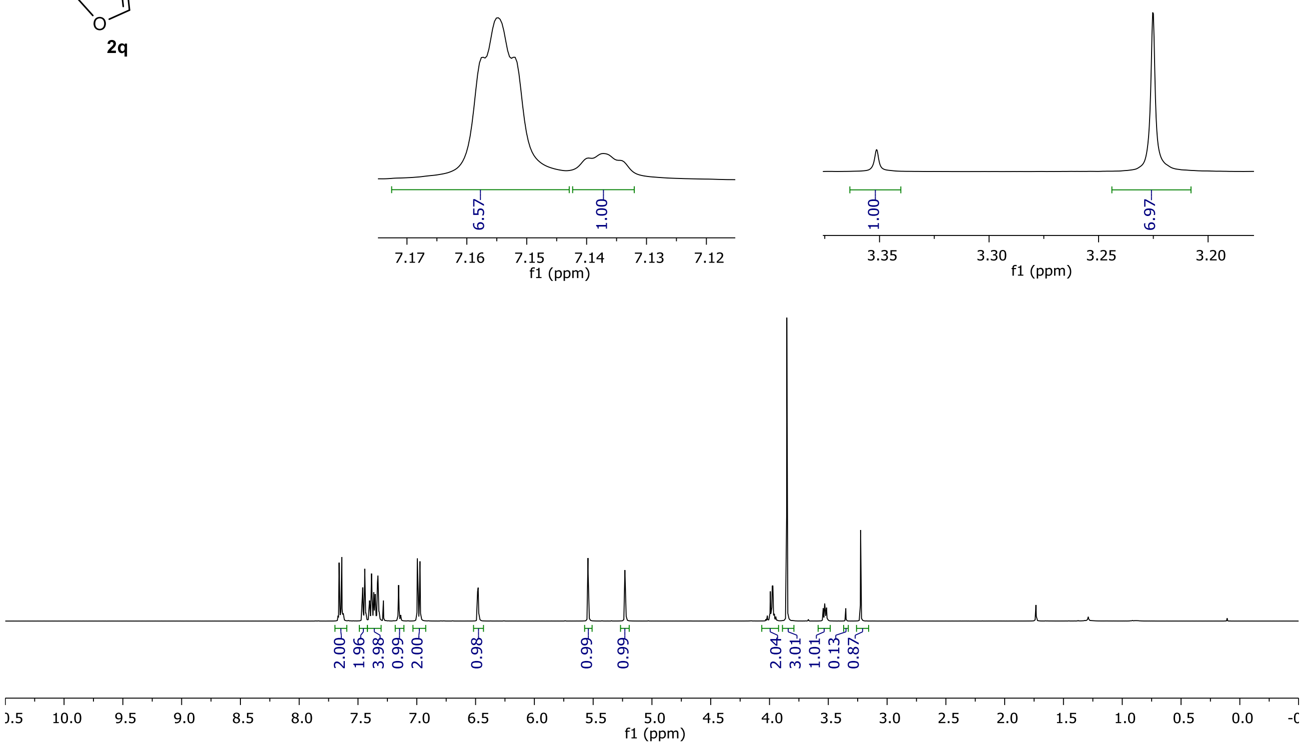
2p

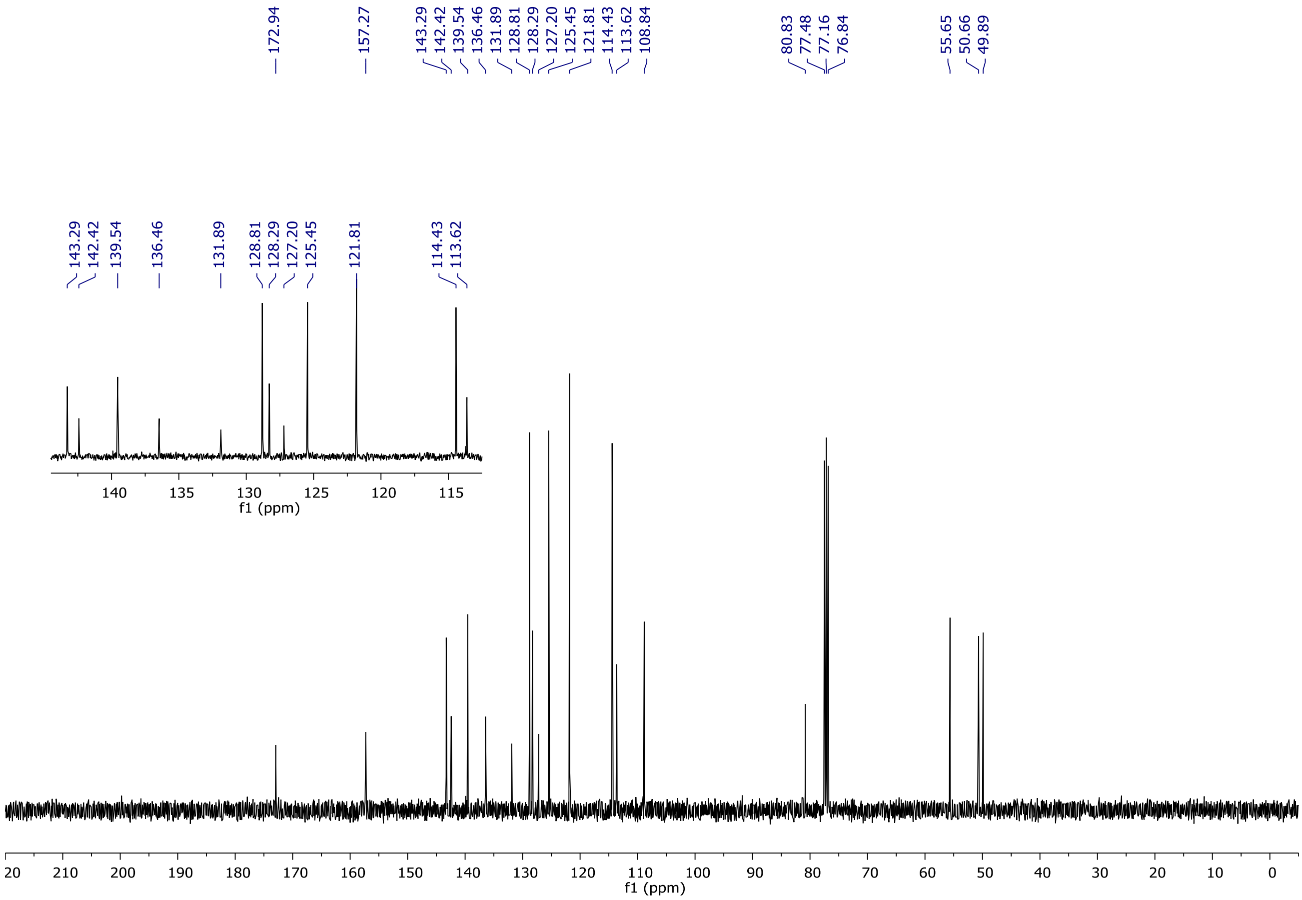


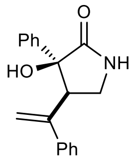



Ph
HO
O
N
PMP
O

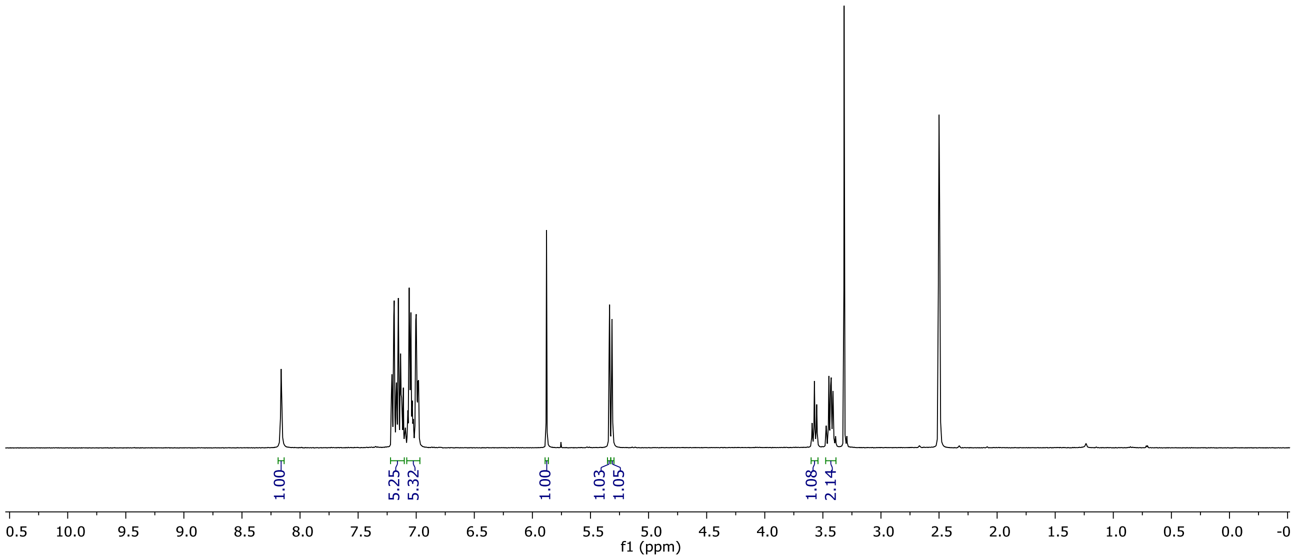
2q

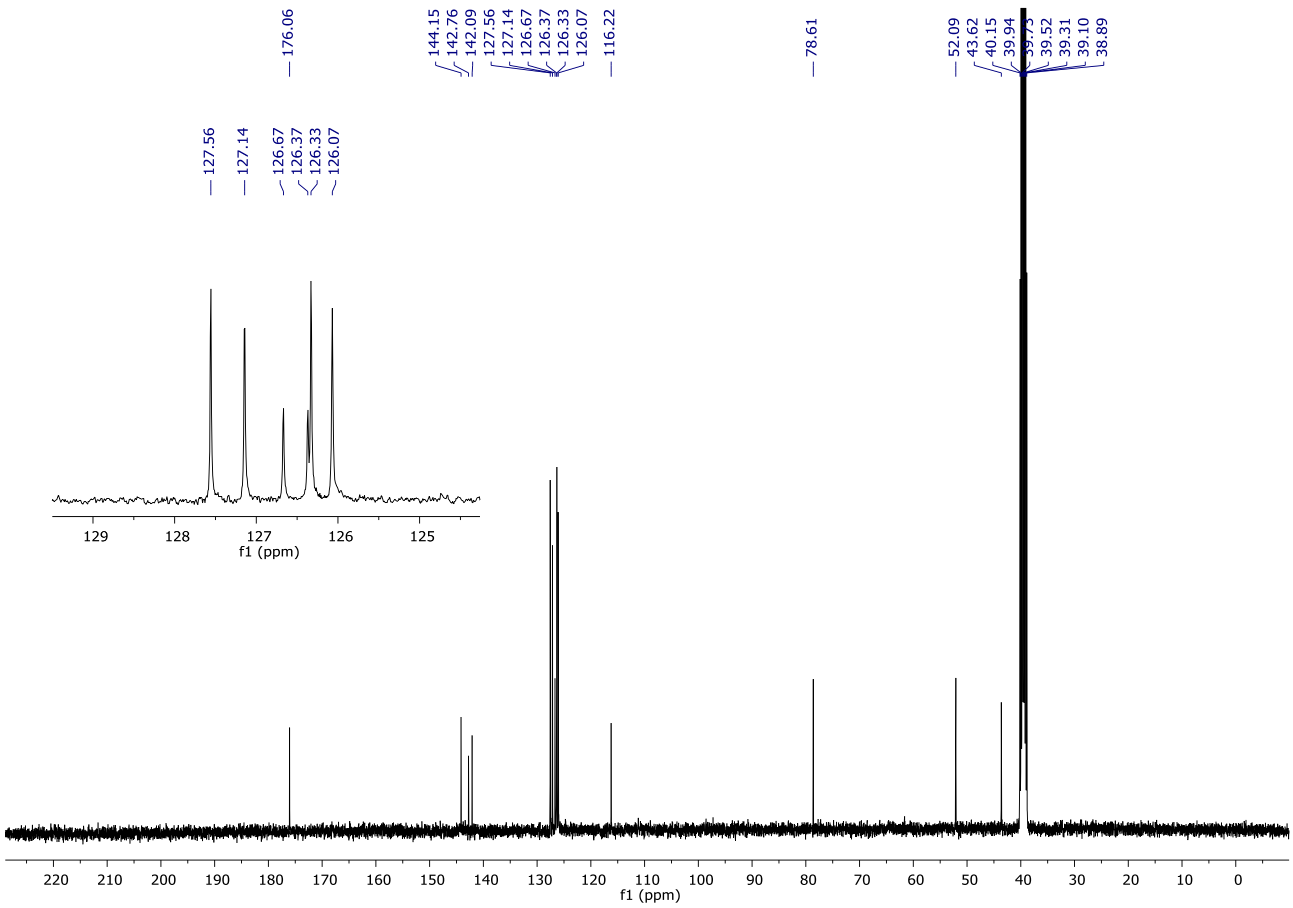

6.57
1.00
7.17 7.16 7.15 7.14 7.13 7.12
f1 (ppm)
1.00
6.97
3.35 3.30 3.25 3.20
f1 (ppm)
2.00
1.96
3.98
0.99
2.00
0.98
0.99
0.99
2.04
3.01
1.01
0.13
0.87
f1 (ppm)

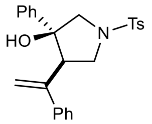

172.94
157.27
143.29
142.42
139.54
136.46
131.89
128.81
128.29
127.20
125.45
121.81
114.43
113.62
108.84
80.83
77.48
77.16
76.84
55.65
50.66
49.89
f1 (ppm)
f1 (ppm)


O
Ph
HO
NH
Ph

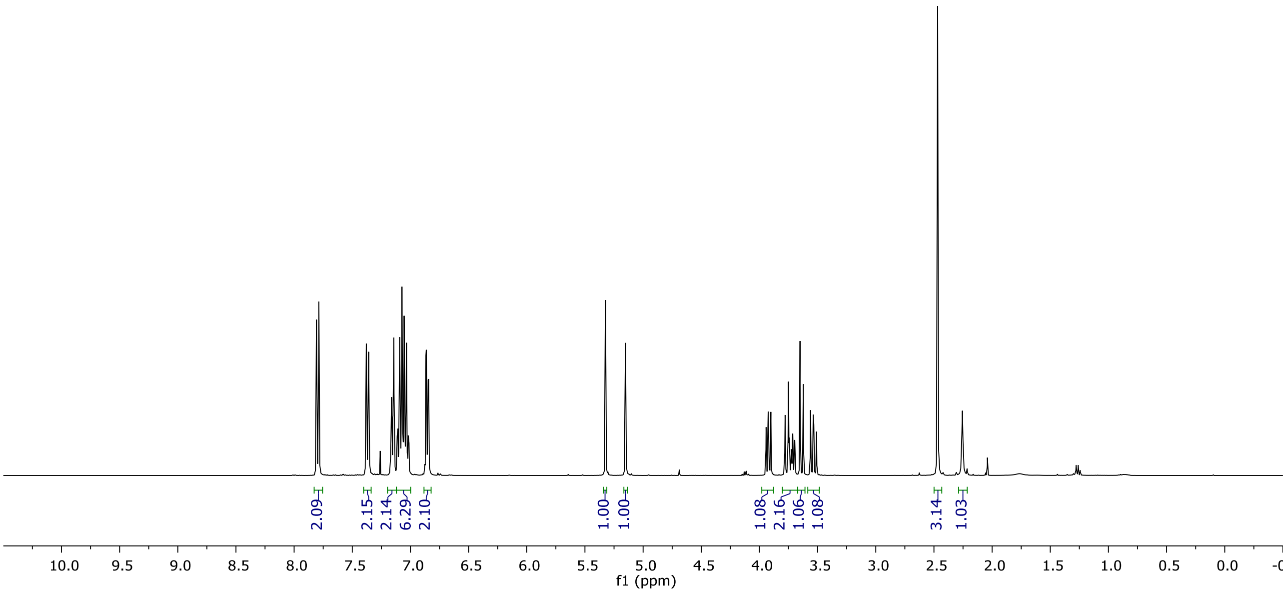
2r

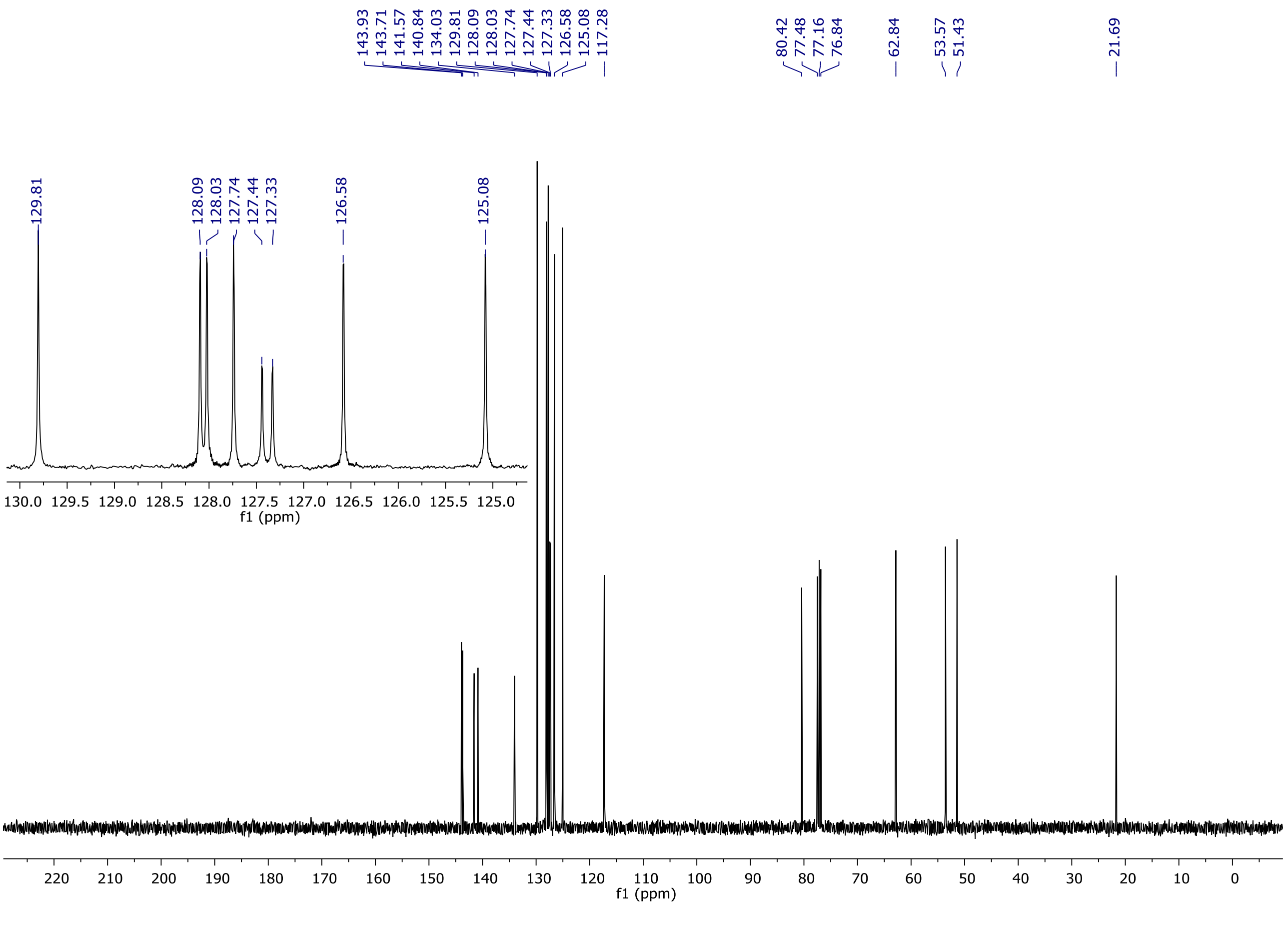

1.00
5.25
5.32
1.00
1.03
1.05
1.08
2.14
f1 (ppm)

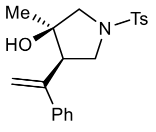

176.06
144.15
142.76
142.09
127.56
127.14
126.67
126.37
126.33
126.07
116.22
78.61
52.09
43.62
40.15
39.94
39.73
39.52
39.31
39.10
38.89
f1 (ppm)


Ph
HO
N
Ts
Ph

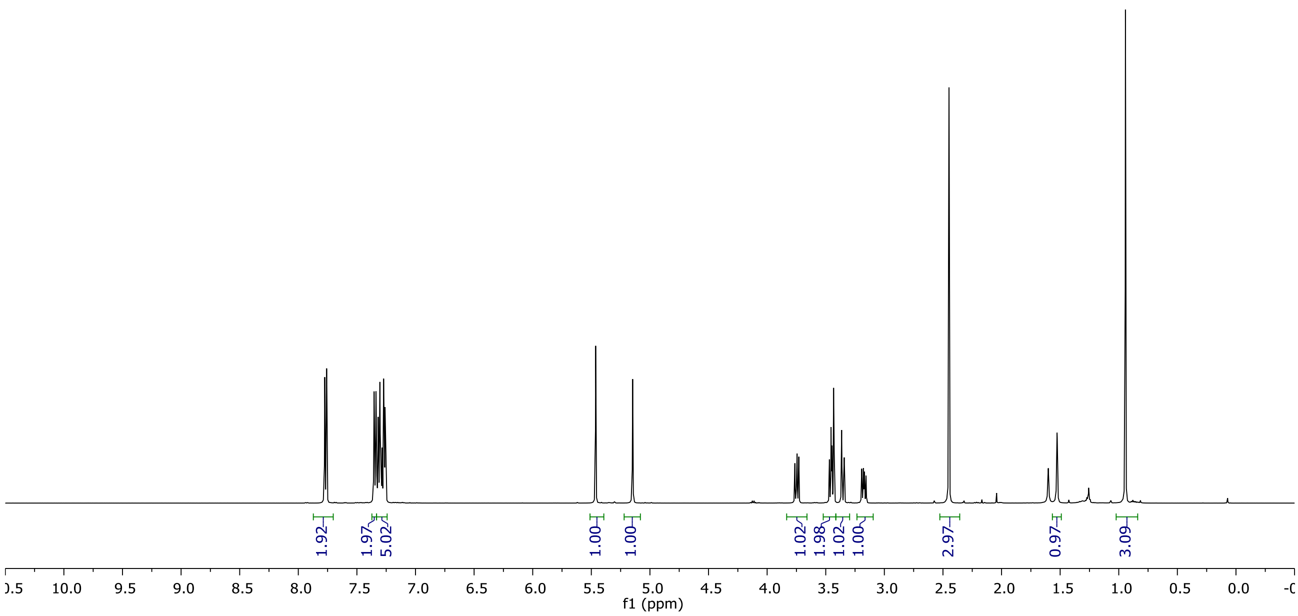
5a

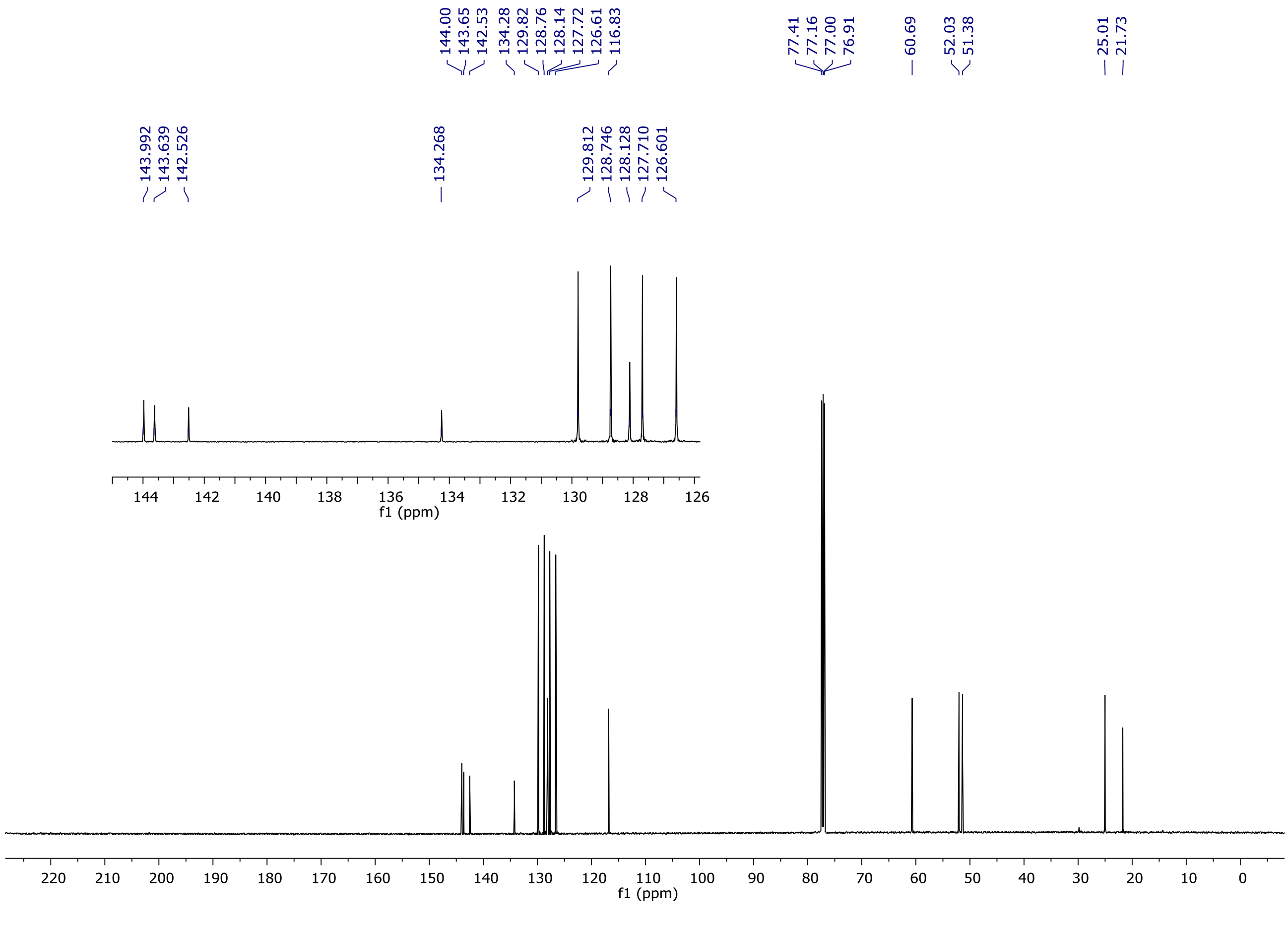

2.09
2.15
2.14
6.29
2.10
1.00
1.00
1.08
2.16
1.06
1.08
3.14
1.03
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

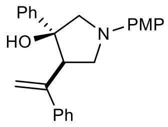

143.93
143.71
141.57
140.84
134.03
129.81
128.09
128.03
127.74
127.44
127.33
126.58
125.08
117.28
80.42
77.48
77.16
76.84
62.84
53.57
51.43
21.69
129.81
128.09
128.03
127.74
127.44
127.33
126.58
125.08
130.0 129.5 129.0 128.5 128.0 127.5 127.0 126.5 126.0 125.5 125.0
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


Me
HO
N
Ts
Ph

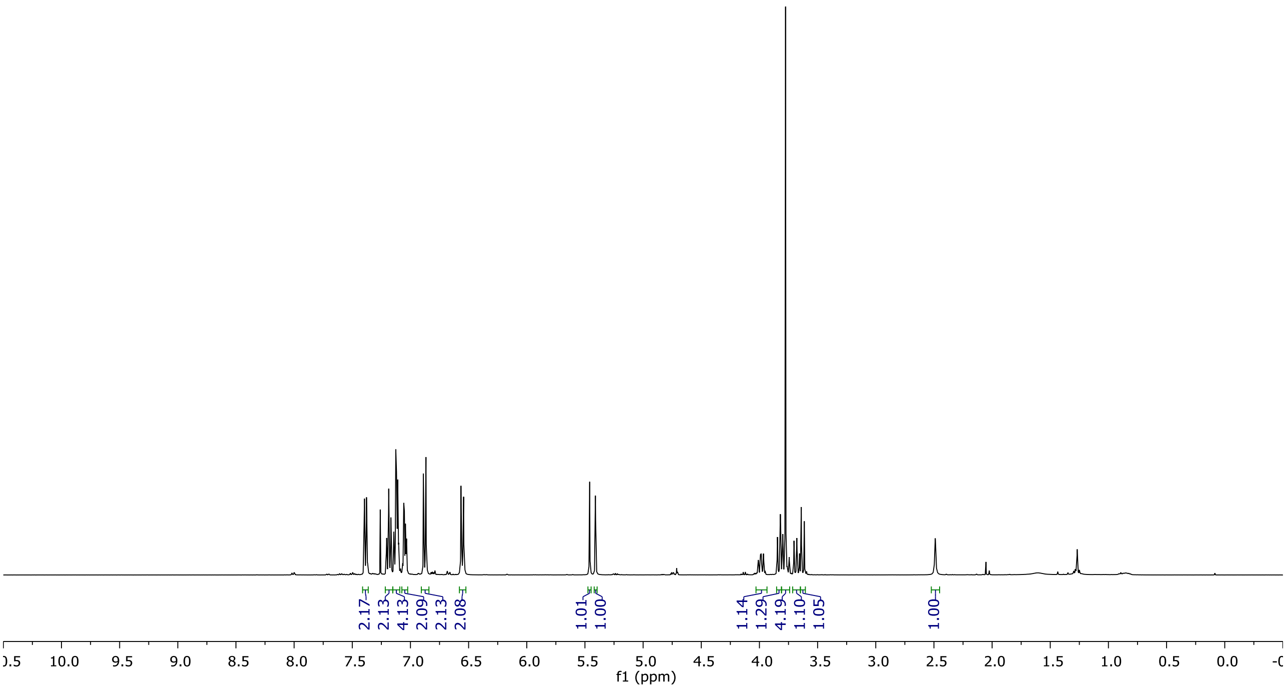
5b

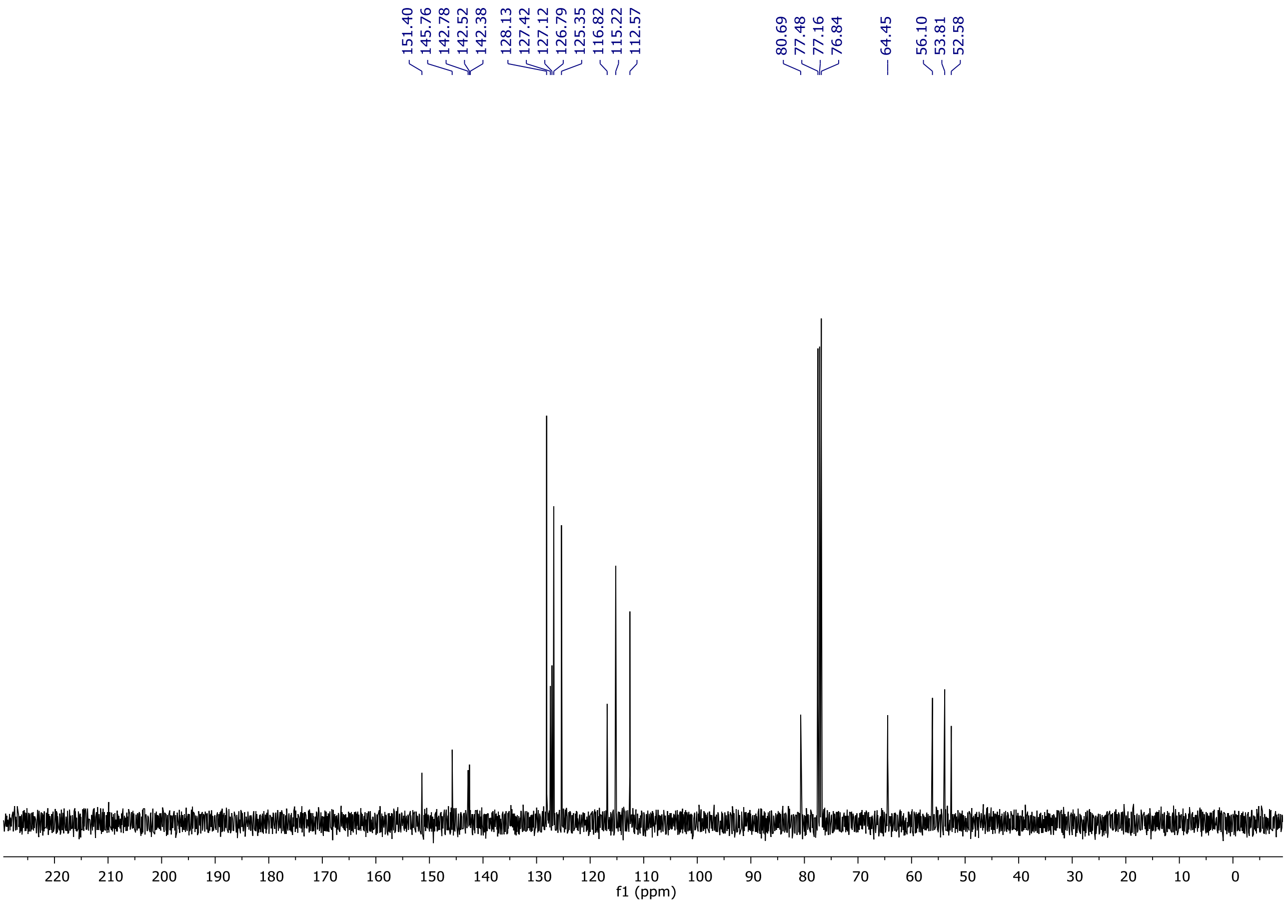

1.92
1.97
5.02
1.00
1.00
1.02
1.98
1.02
1.00
2.97
0.97
3.09
f1 (ppm)

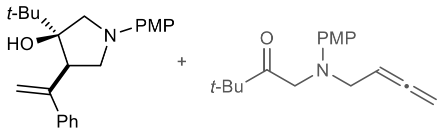

144.00
143.65
142.53
134.28
129.82
128.76
128.14
127.72
126.61
116.83
77.41
77.16
77.00
76.91
60.69
52.03
51.38
25.01
21.73
143.992
143.639
142.526
134.268
129.812
128.746
128.128
127.710
126.601
f1 (ppm)
f1 (ppm)


Ph
HO
N
PMP
Ph

5c

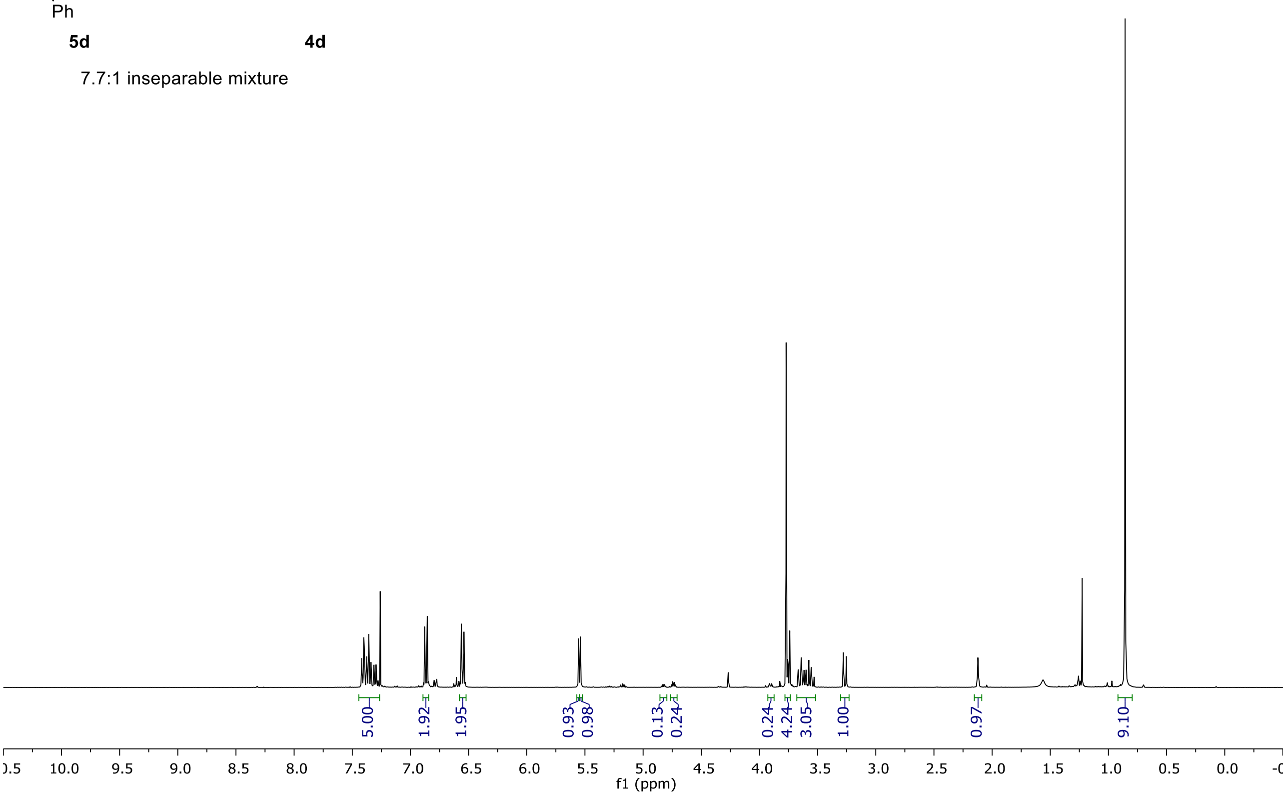

2.17
2.13
4.13
2.09
2.13
2.08
1.01
1.00
1.14
1.29
4.19
1.10
1.05
1.00
f1 (ppm)

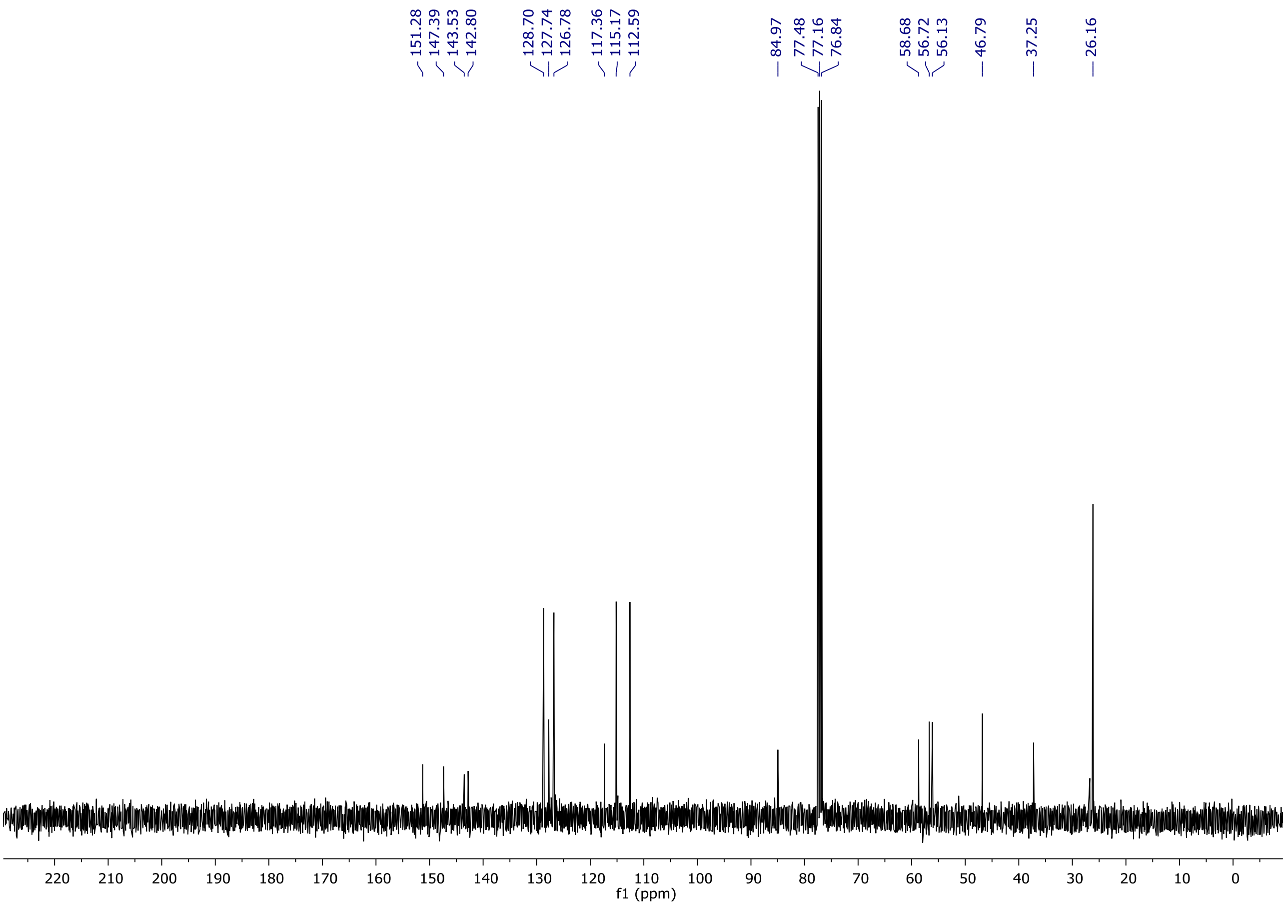

151.40
145.76
142.78
142.52
142.38
128.13
127.42
127.12
126.79
125.35
116.82
115.22
112.57
80.69
77.48
77.16
76.84
64.45
56.10
53.81
52.58
f1 (ppm)

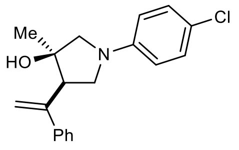


5d **4d**

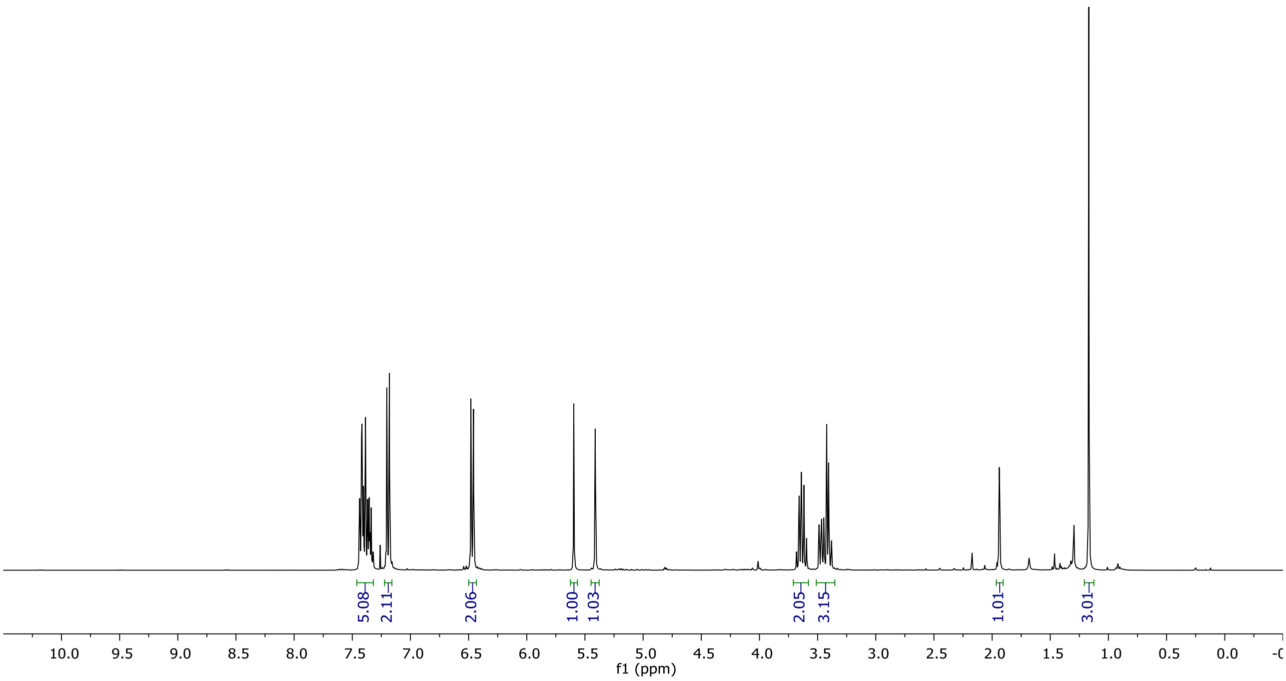
7.7:1 inseparable mixture

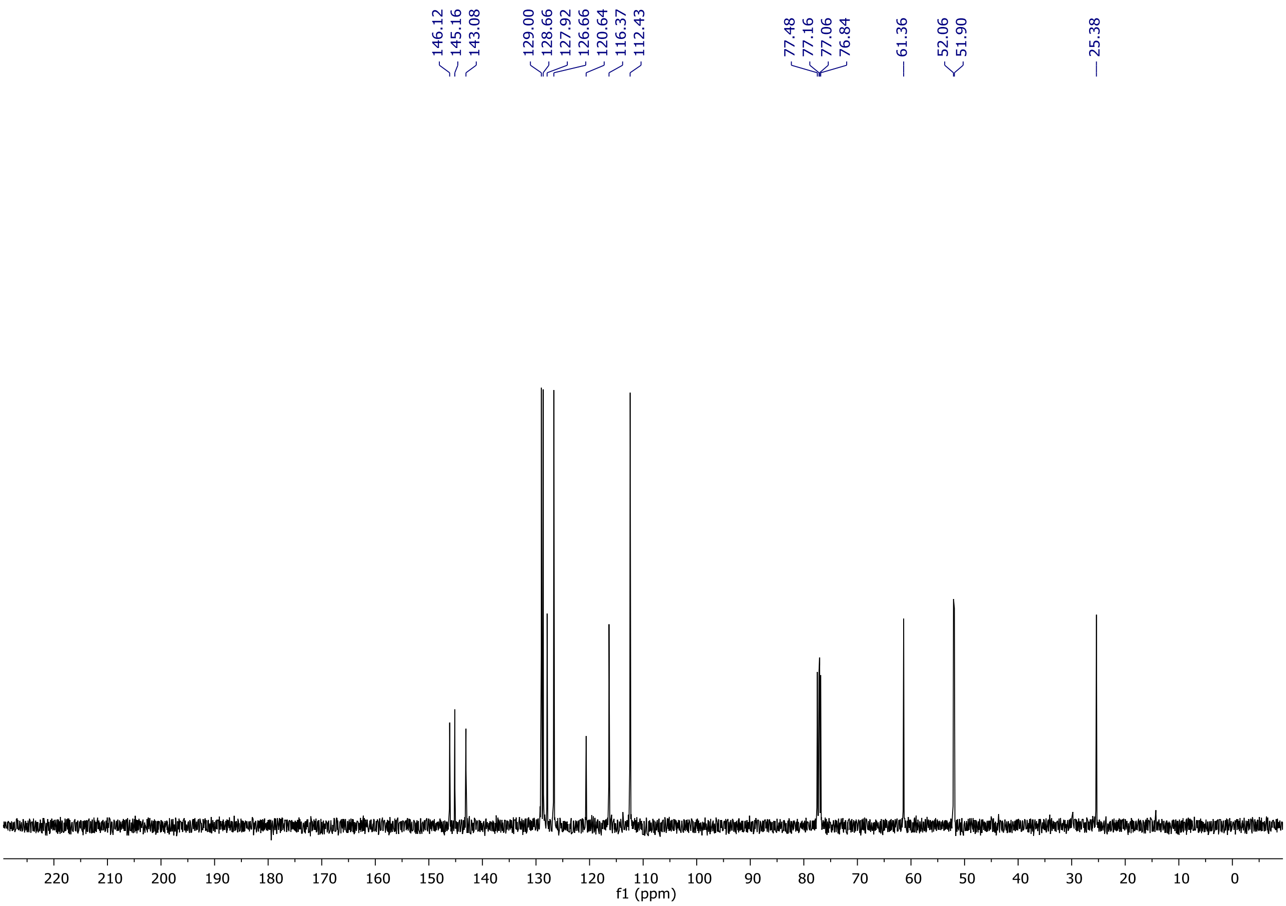


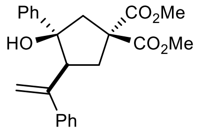



Me
HO
N
Cl
Ph

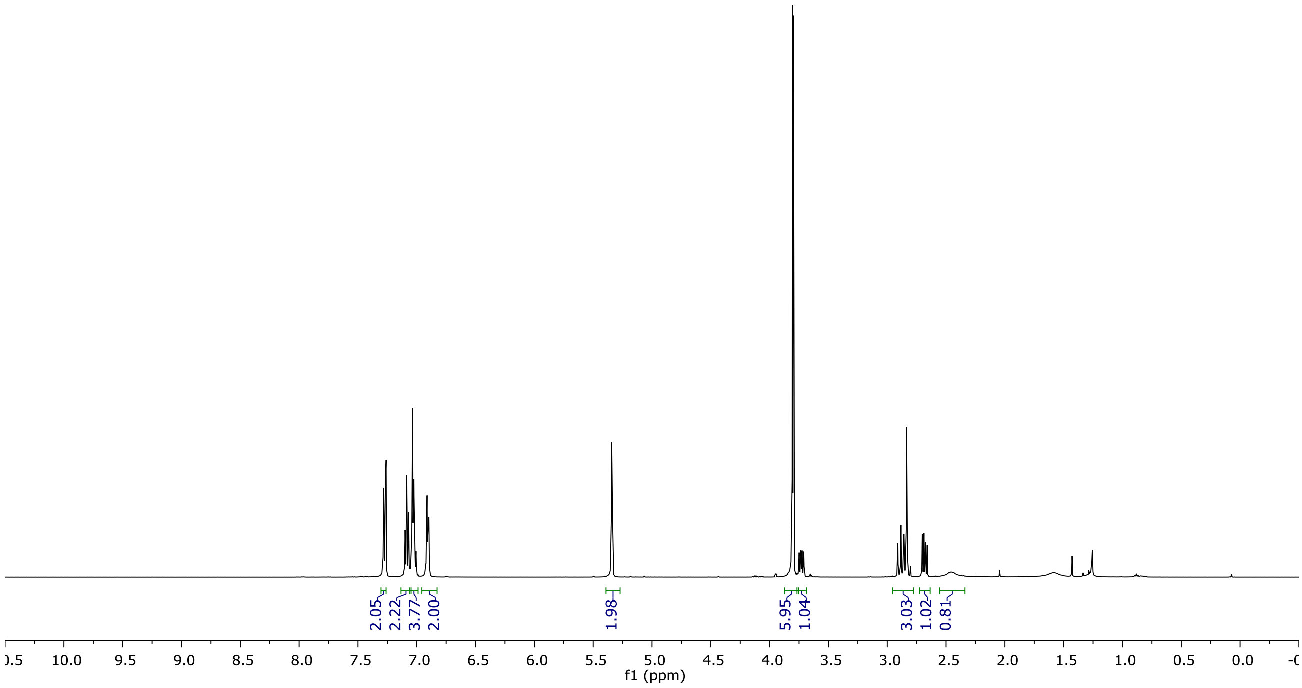
5e

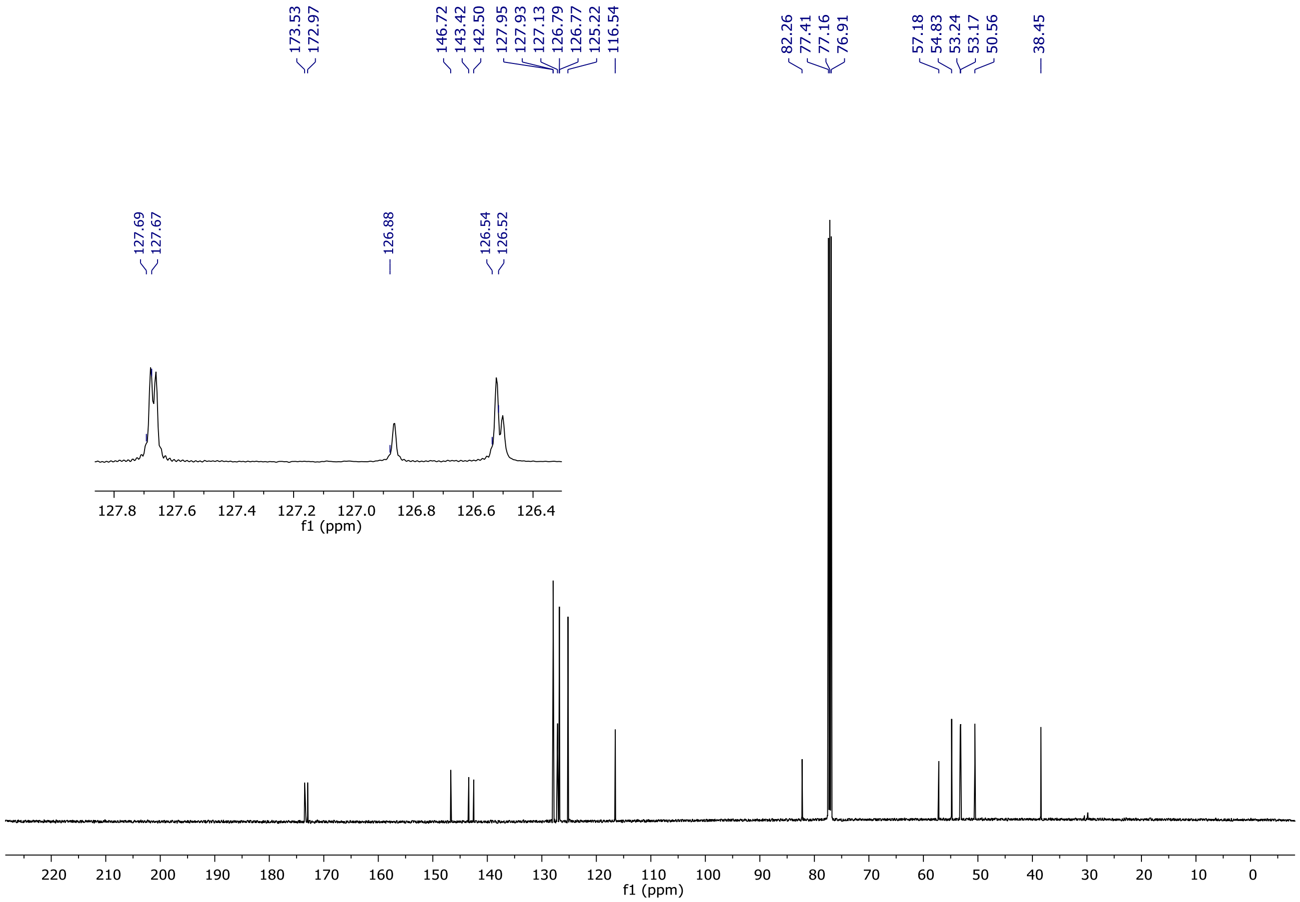

5.08
2.11
2.06
1.00
1.03
2.05
3.15
1.01
3.01
f1 (ppm)

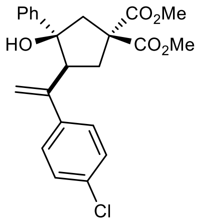

146.12
145.16
143.08
129.00
128.66
127.92
126.66
120.64
116.37
112.43
77.48
77.16
77.06
76.84
61.36
52.06
51.90
25.38
f1 (ppm)


Ph
CO2Me
HO
CO2Me
Ph

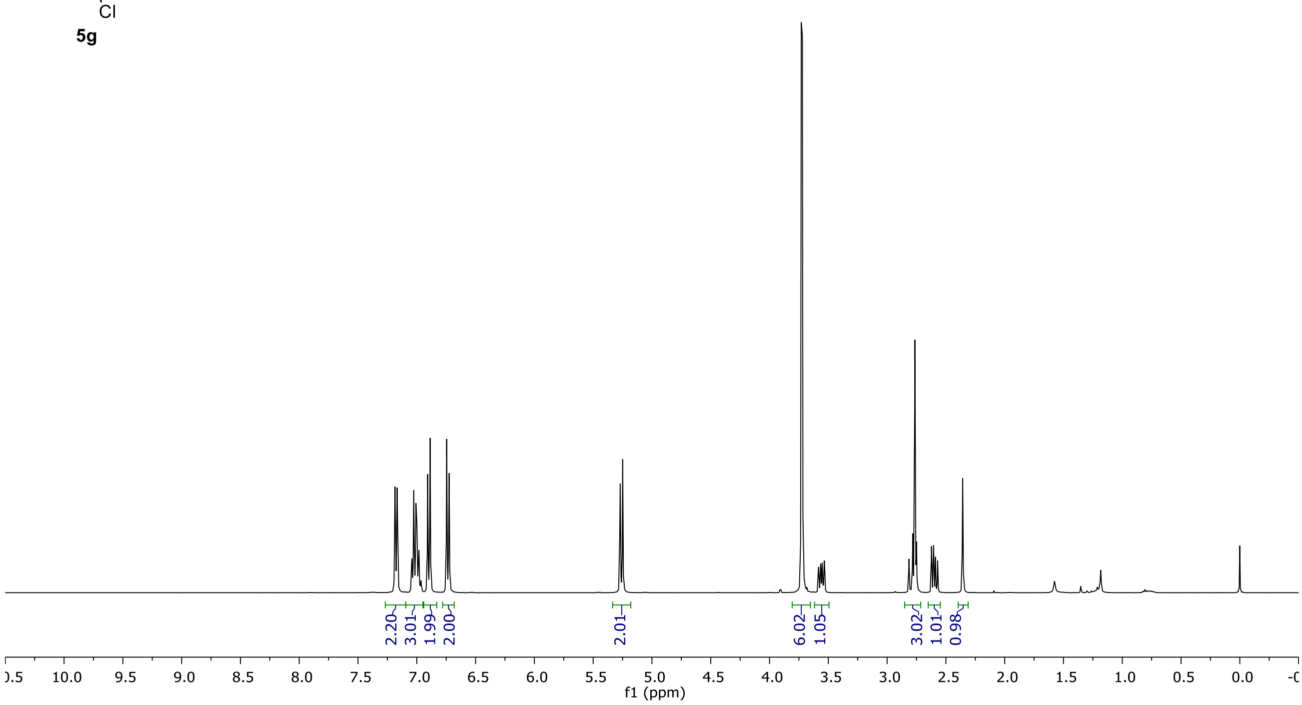
5f

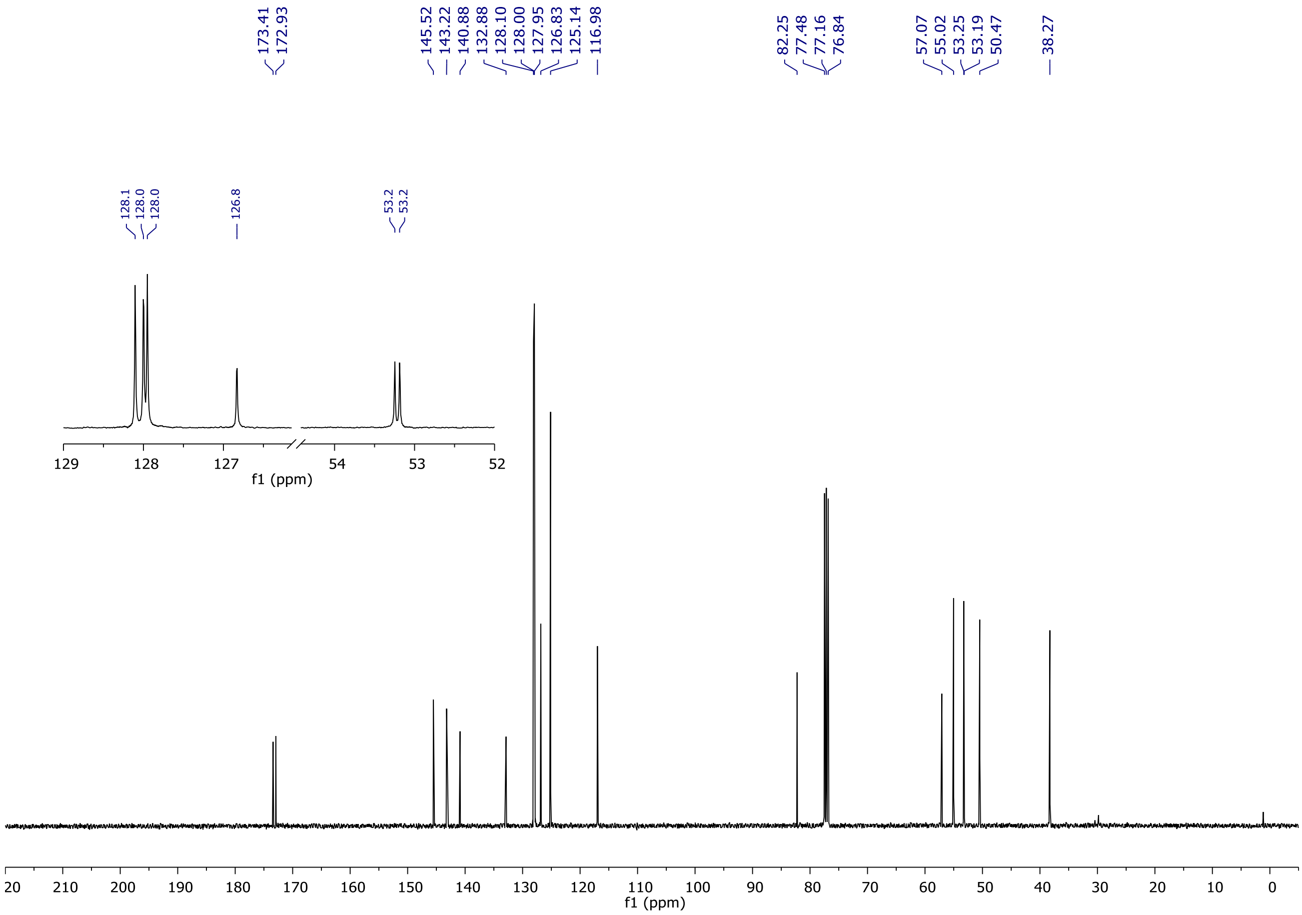

2.05
2.22
3.77
2.00
1.98
5.95
1.04
3.03
1.02
0.81
f1 (ppm)

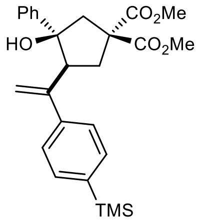

173.53
172.97
146.72
143.42
142.50
127.95
127.93
127.13
126.79
126.77
125.22
116.54
82.26
77.41
77.16
76.91
57.18
54.83
53.24
53.17
50.56
38.45
127.69
127.67
126.88
126.54
126.52
f1 (ppm)
f1 (ppm)


Ph
HO
CO2Me
CO2Me
Cl

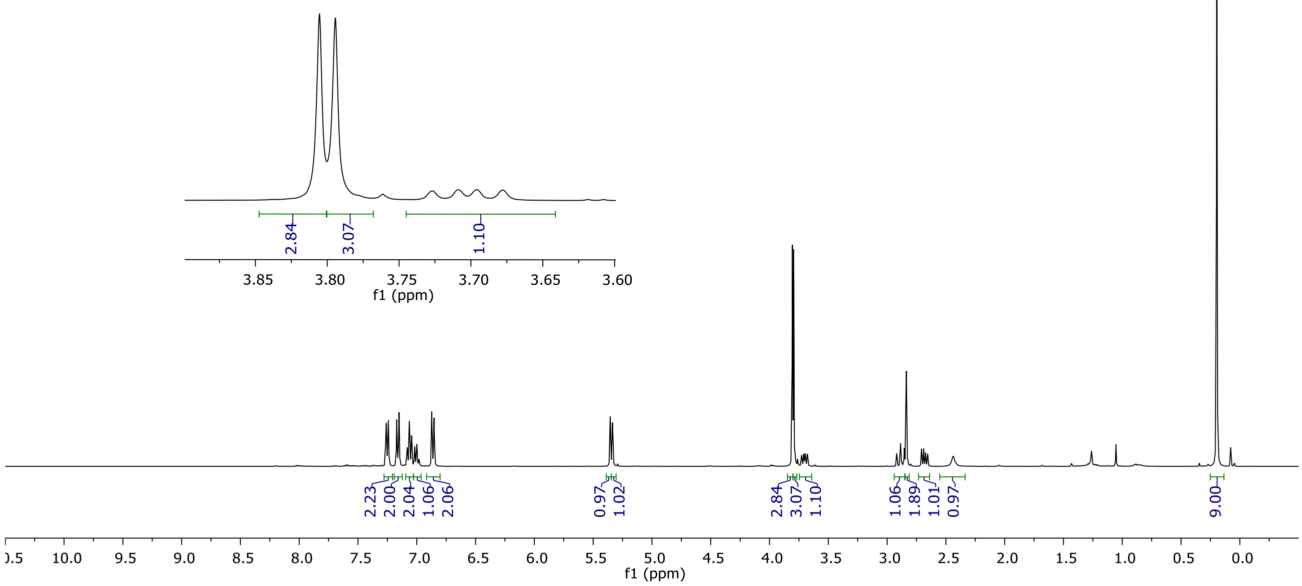
5g

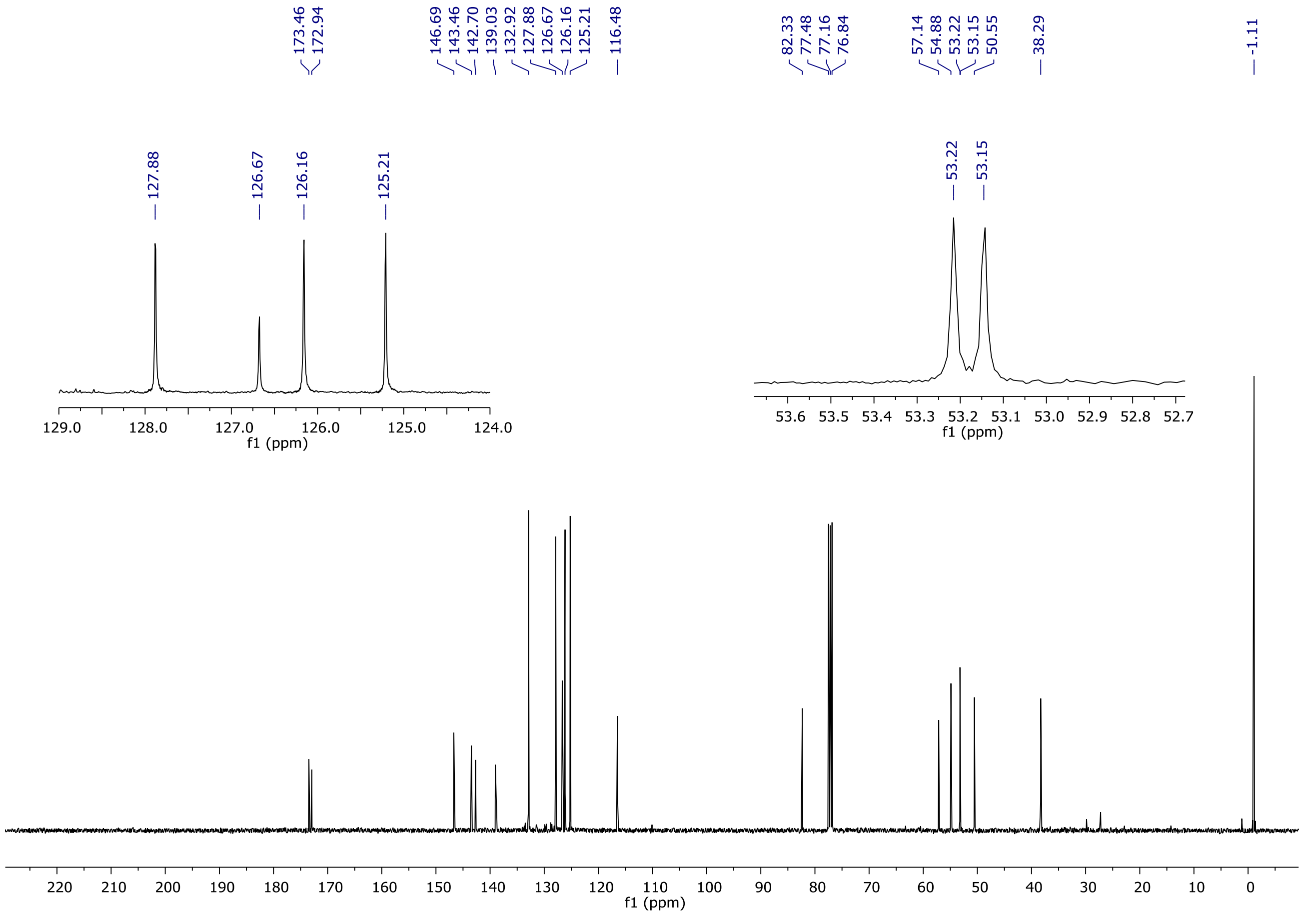

2.20
3.01
1.99
2.00
2.01
6.02
1.05
3.02
1.01
0.98
f1 (ppm)

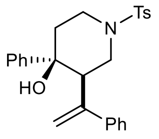

173.41
172.93
145.52
143.22
140.88
132.88
128.10
128.00
127.95
126.83
125.14
116.98
82.25
77.48
77.16
76.84
57.07
55.02
53.25
53.19
50.47
38.27
128.1
128.0
128.0
126.8
53.2
53.2
f1 (ppm)


Ph
HO
CO2Me
CO2Me
TMS

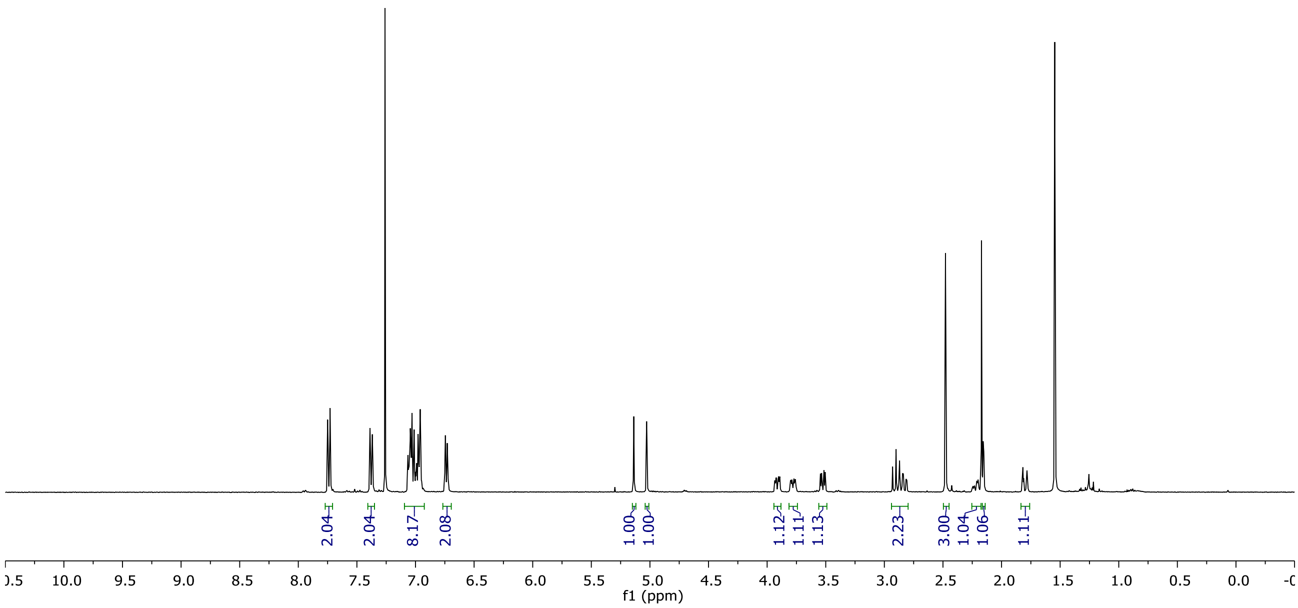
5h

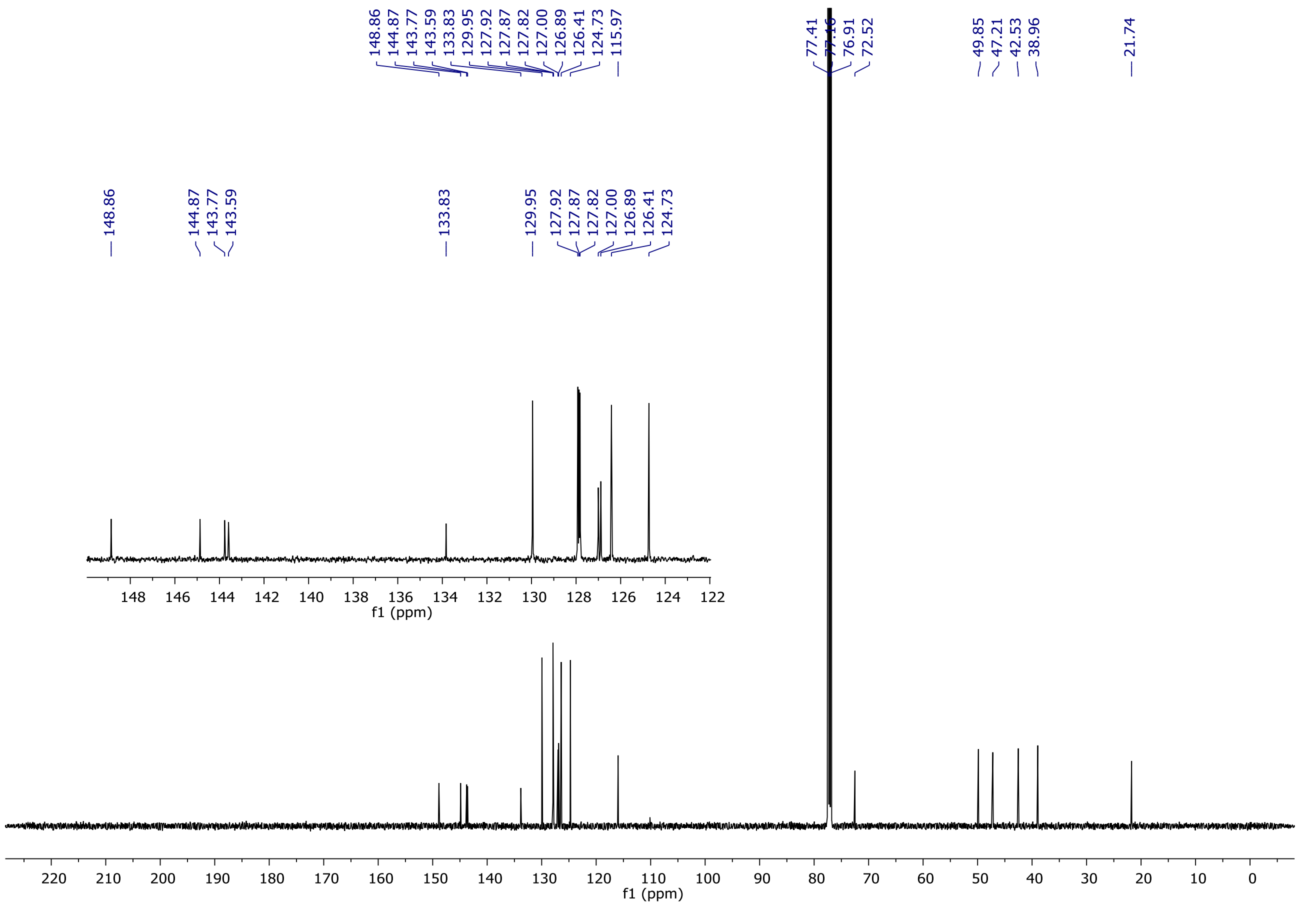

2.84
3.07
1.10
3.85 3.80 3.75 3.70 3.65 3.60
f1 (ppm)
2.23
2.00
2.04
1.06
2.06
0.97
1.02
2.84
3.07
1.10
1.06
1.89
1.01
0.97
9.00
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

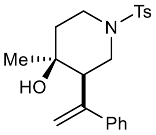

173.46
172.94
146.69
143.46
142.70
139.03
132.92
127.88
126.67
126.16
125.21
116.48
82.33
77.48
77.16
76.84
57.14
54.88
53.22
53.15
50.55
38.29
-1.11
127.88
126.67
126.16
125.21
129.0 128.0 127.0 126.0 125.0 124.0
f1 (ppm)
53.22
53.15
53.6 53.5 53.4 53.3 53.2 53.1 53.0 52.9 52.8 52.7
f1 (ppm)
220 210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


Ts
N
Ph
HO
Ph

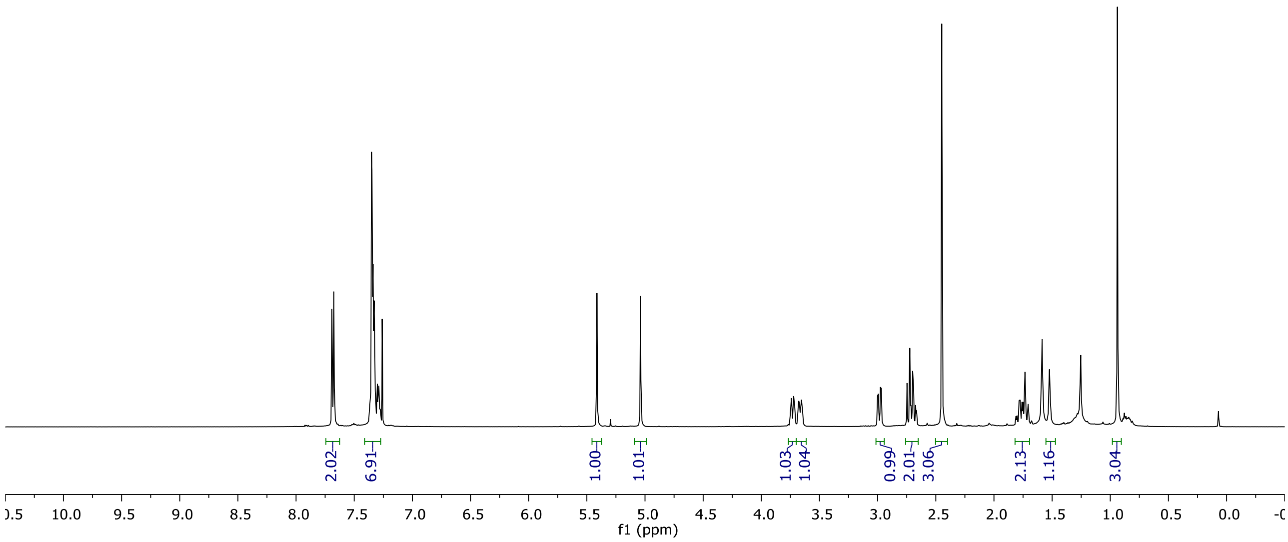
5i

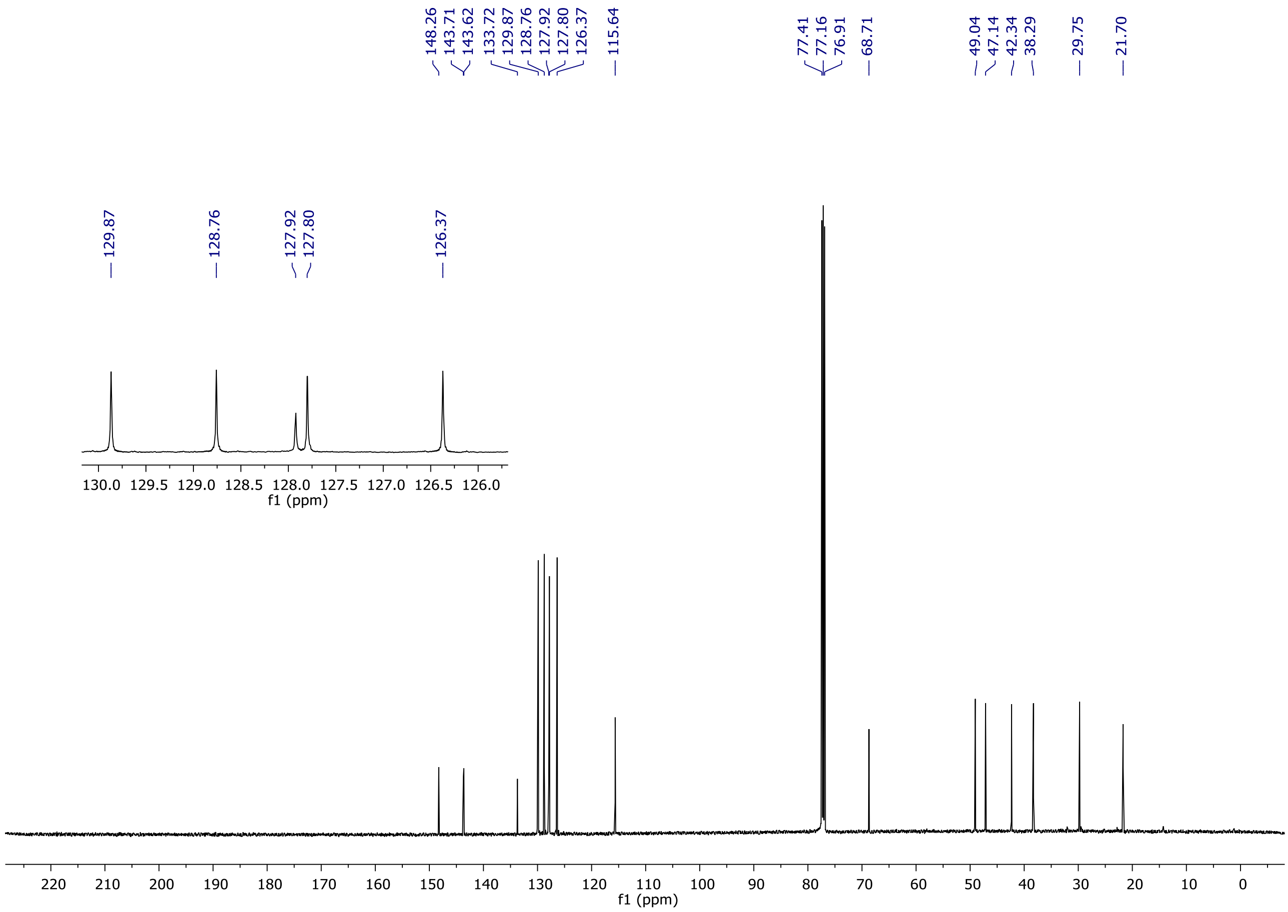

2.04
2.04
8.17
2.08
1.00
1.00
1.12
1.11
1.13
2.23
3.00
1.04
1.06
1.11
f1 (ppm)

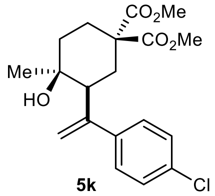

148.86
144.87
143.77
143.59
133.83
129.95
127.92
127.87
127.82
127.00
126.89
126.41
124.73
115.97
77.41
77.16
76.91
72.52
49.85
47.21
42.53
38.96
21.74
f1 (ppm)
f1 (ppm)


Ts
N
Me
HO
Ph

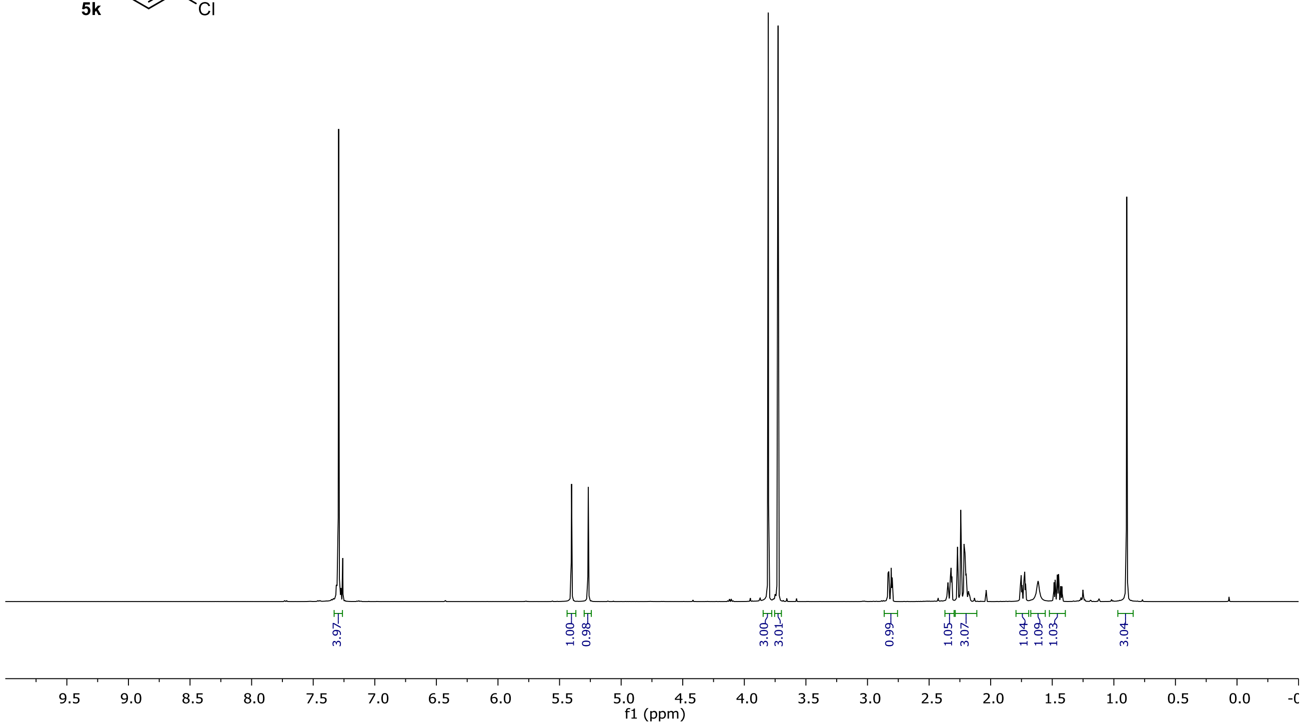
5j

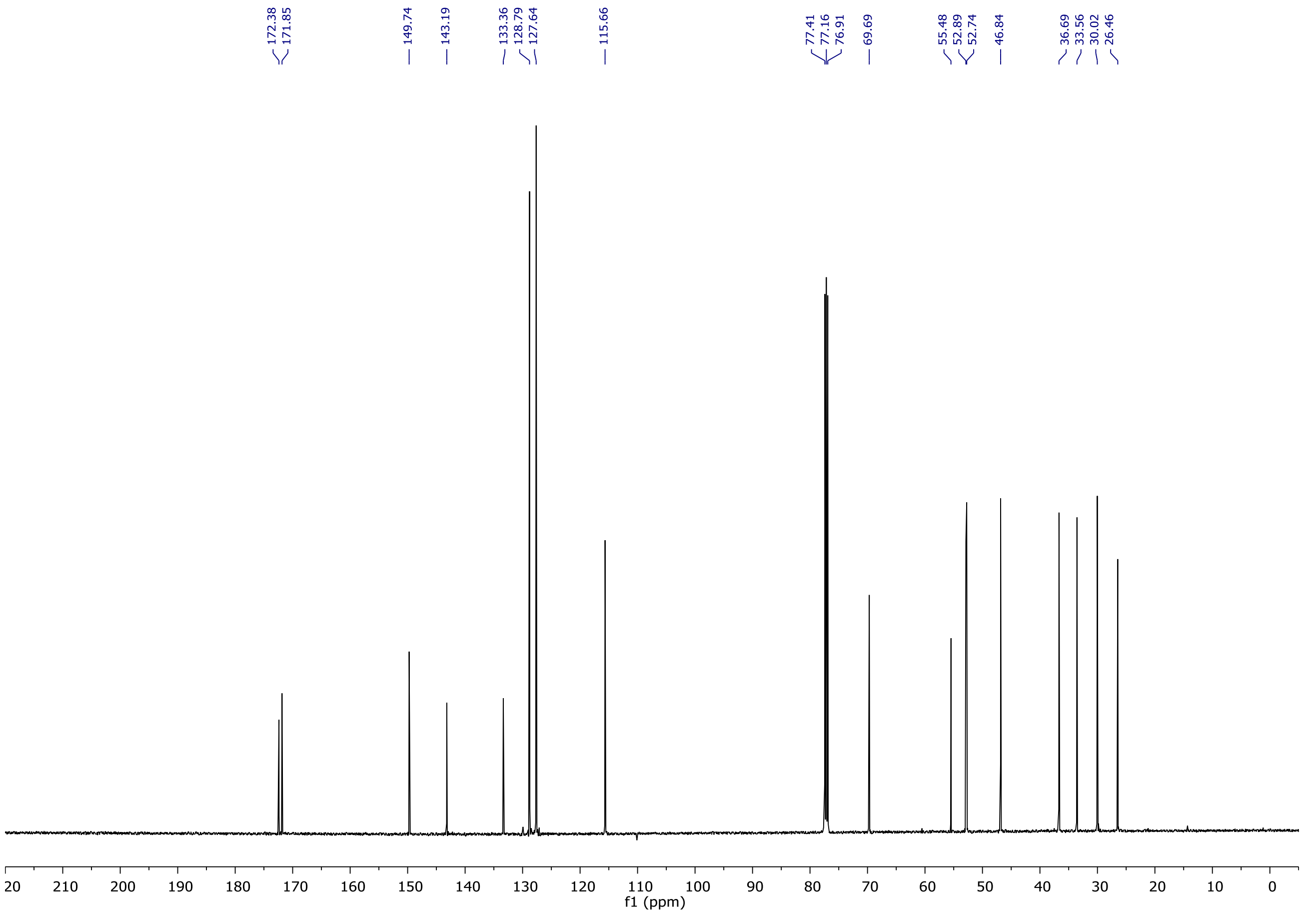

2.02
6.91
1.00
1.01
1.03
1.04
0.99
2.01
3.06
2.13
1.16
3.04
f1 (ppm)

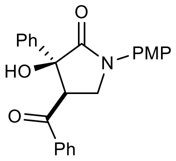

148.26
143.71
143.62
133.72
129.87
128.76
127.92
127.80
126.37
115.64
77.41
77.16
76.91
68.71
49.04
47.14
42.34
38.29
29.75
21.70
f1 (ppm)


CO2Me
CO2Me
Me
HO
Cl

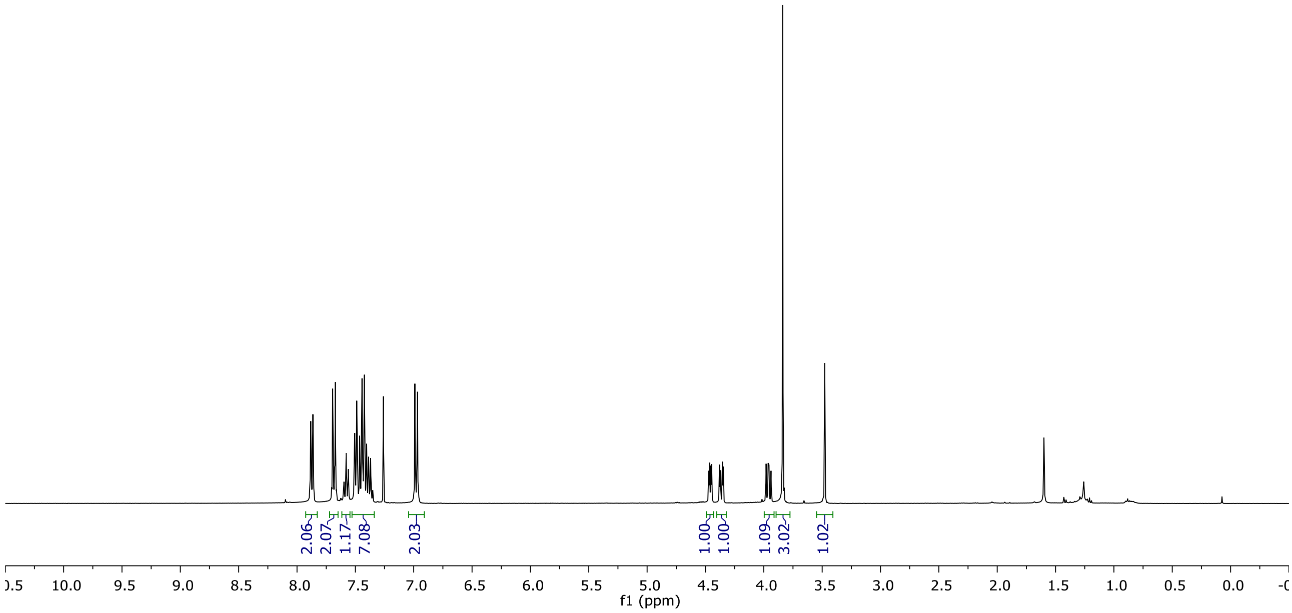
5k

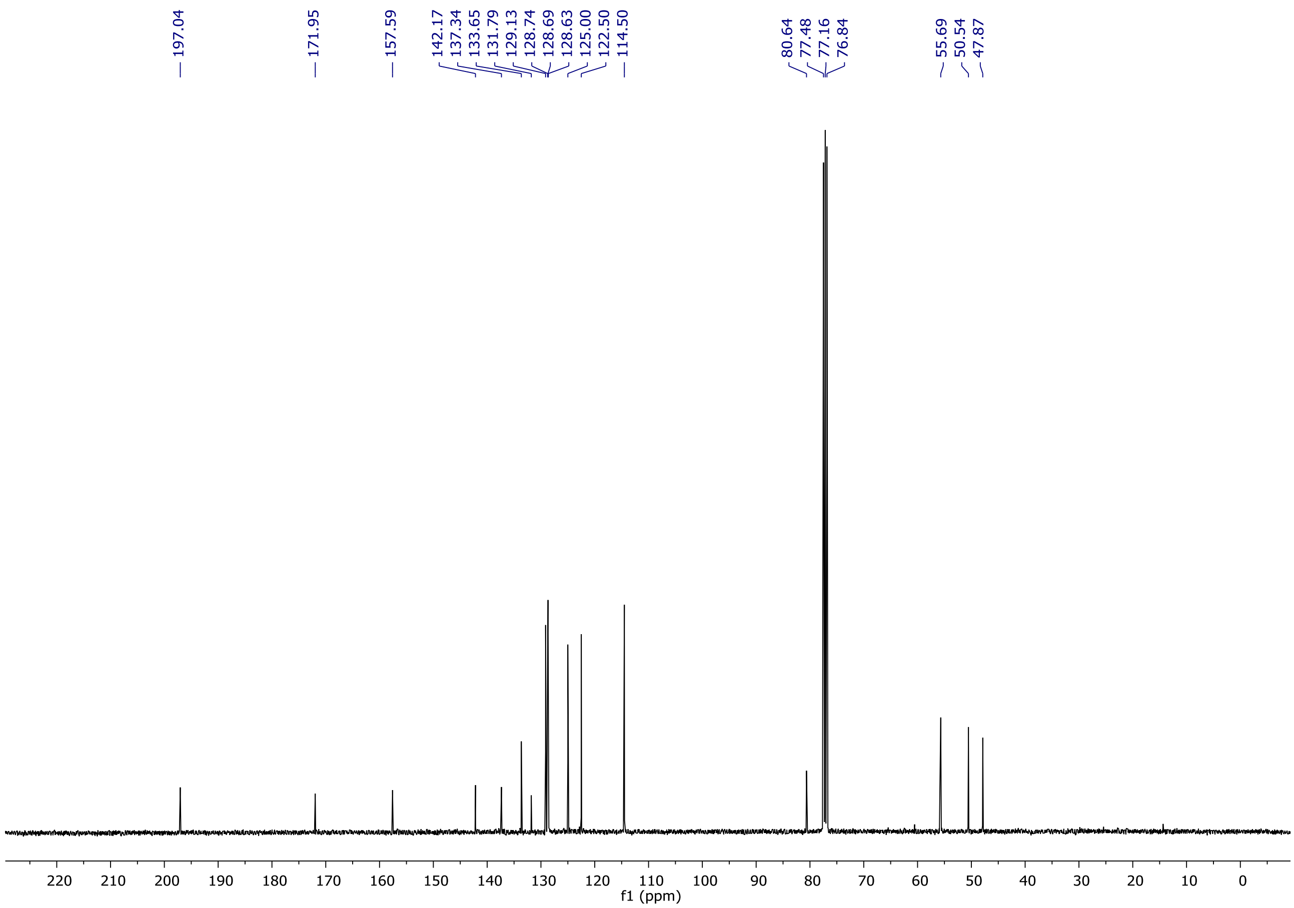

3.97
1.00
0.98
3.00
3.01
0.99
1.05
3.07
1.04
1.09
1.03
3.04
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)


172.38
171.85
149.74
143.19
133.36
128.79
127.64
115.66
77.41
77.16
76.91
69.69
55.48
52.89
52.74
46.84
36.69
33.56
30.02
26.46
210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

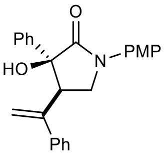

O
Ph
HO
N
PMP
O
Ph

12

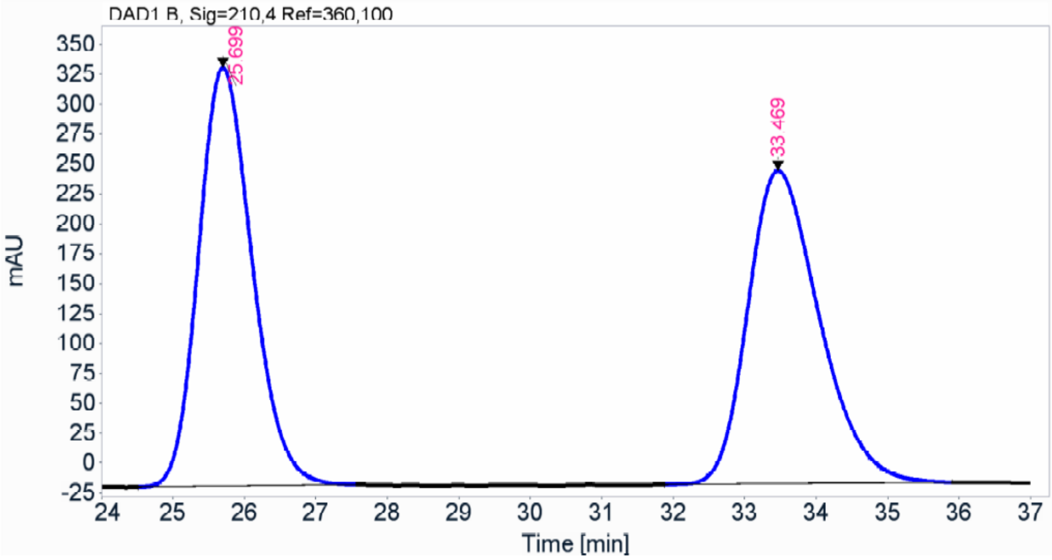

2.06
2.07
1.17
7.08
2.03
1.00
1.00
1.09
3.02
1.02
f1 (ppm)


197.04
171.95
157.59
142.17
137.34
133.65
131.79
129.13
128.74
128.69
128.63
125.00
122.50
114.50
80.64
77.48
77.16
76.84
55.69
50.54
47.87
f1 (ppm)

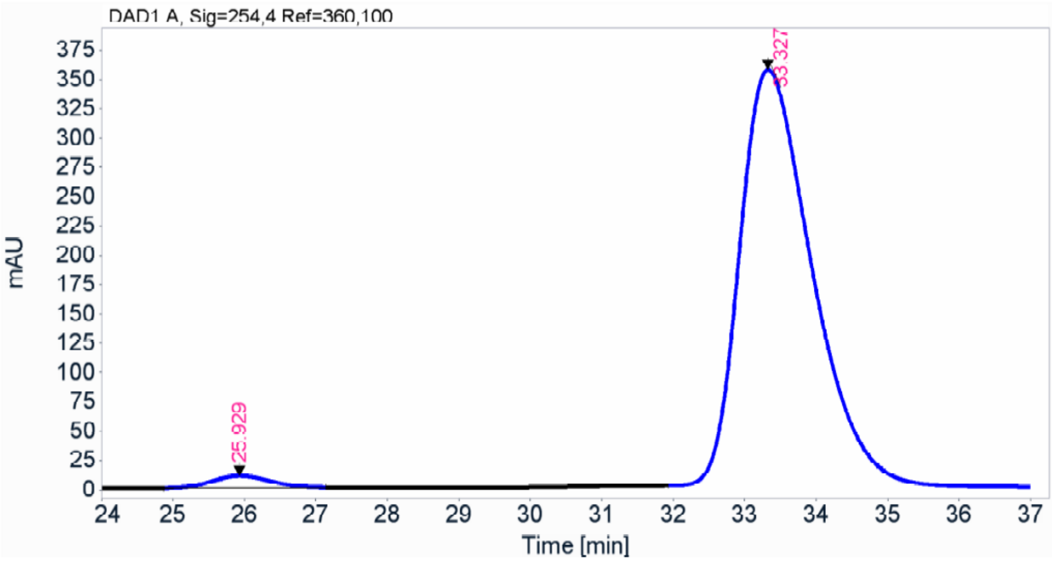
HPLC Traces



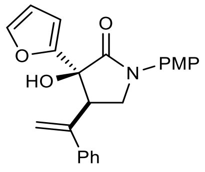
2a



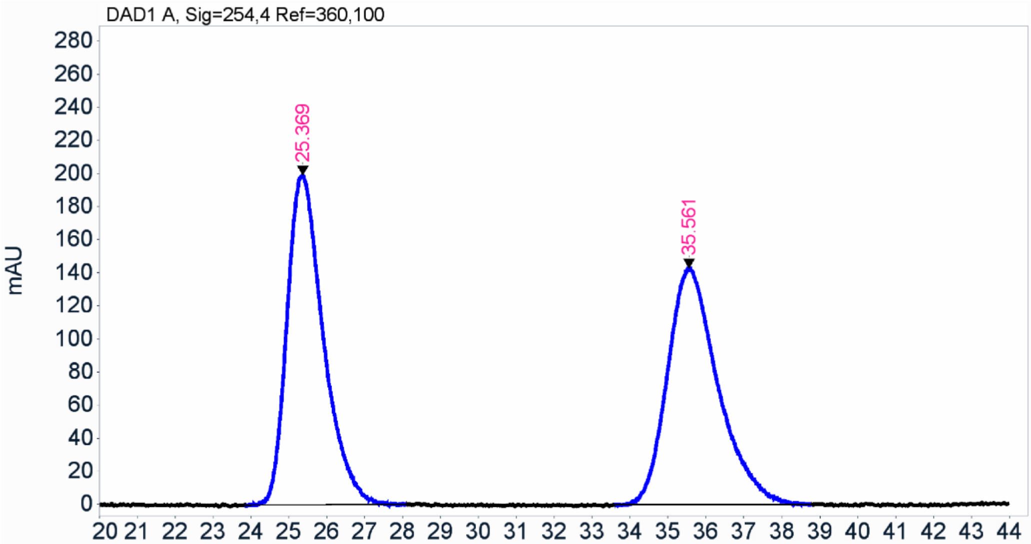
Signal:	DAD1 B, Sig=210,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
25.699	BB	0.8036	18213.279	349.7194	50.03
33.469	BB	1.0646	18192.375	261.8304	49.97



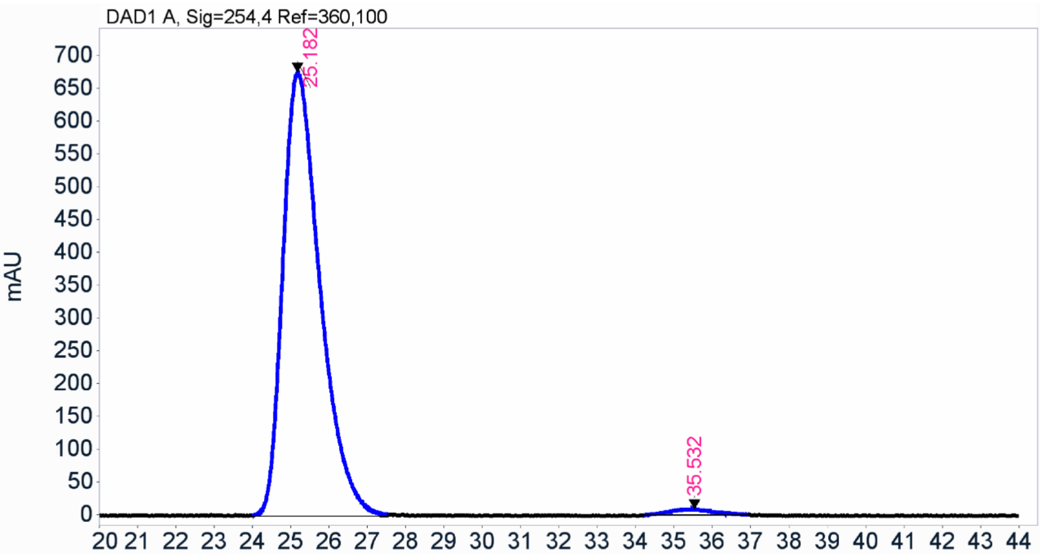
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
25.929	MM	0.9225	557.040	10.0644	2.19
33.327	BB	1.0700	24847.635	355.2706	97.81



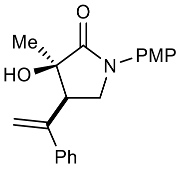
2b



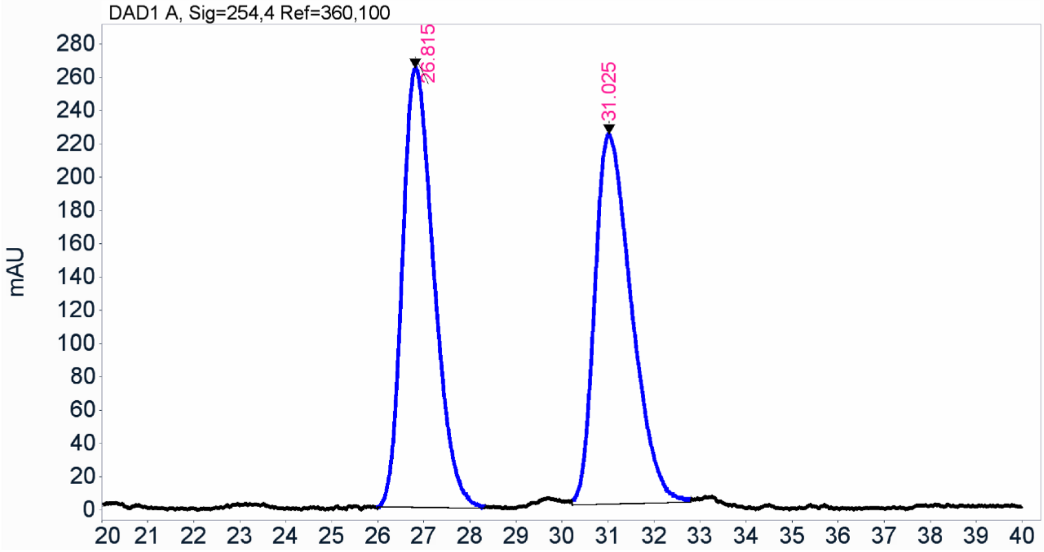
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
25.369	MM	1.1079	13234.310	199.0919	50.04
35.561	MM	1.5401	13212.133	142.9782	49.96



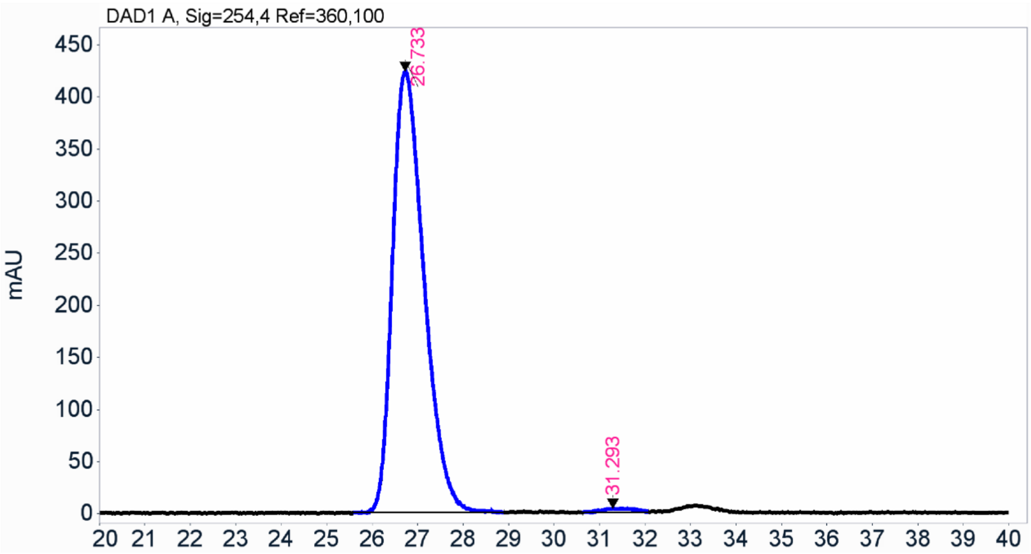
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
25.182	MM	1.1224	45534.895	676.1537	98.46
35.532	MM	1.3408	712.000	8.8502	1.54



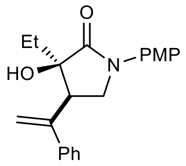
2c



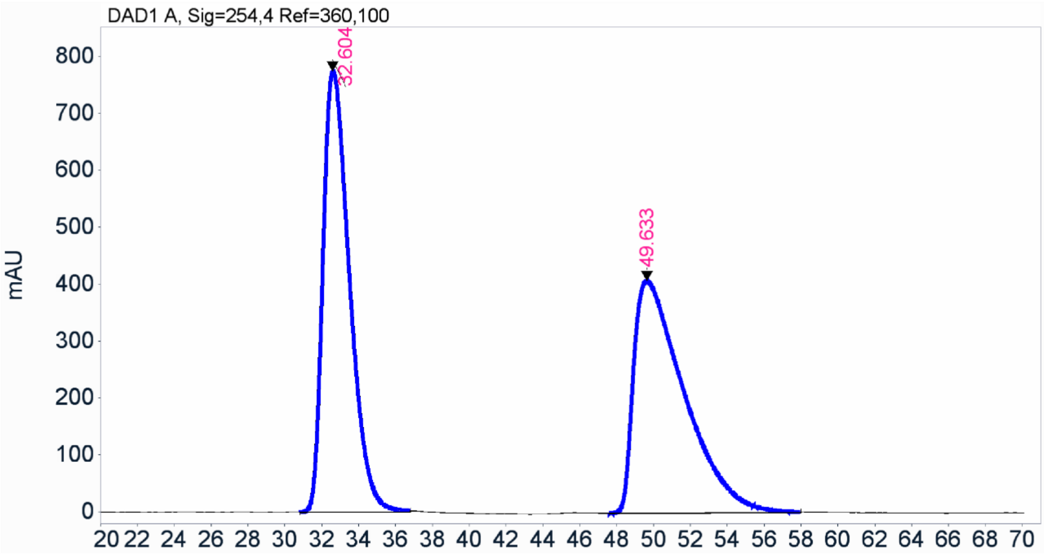
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
26.815	MM	0.7933	12564.892	263.9943	50.44
31.025	MM	0.9252	12344.252	222.3730	49.56



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
26.733	MM	0.8037	20415.271	423.3376	99.03
31.293	MM	0.8312	199.672	4.0035	0.97

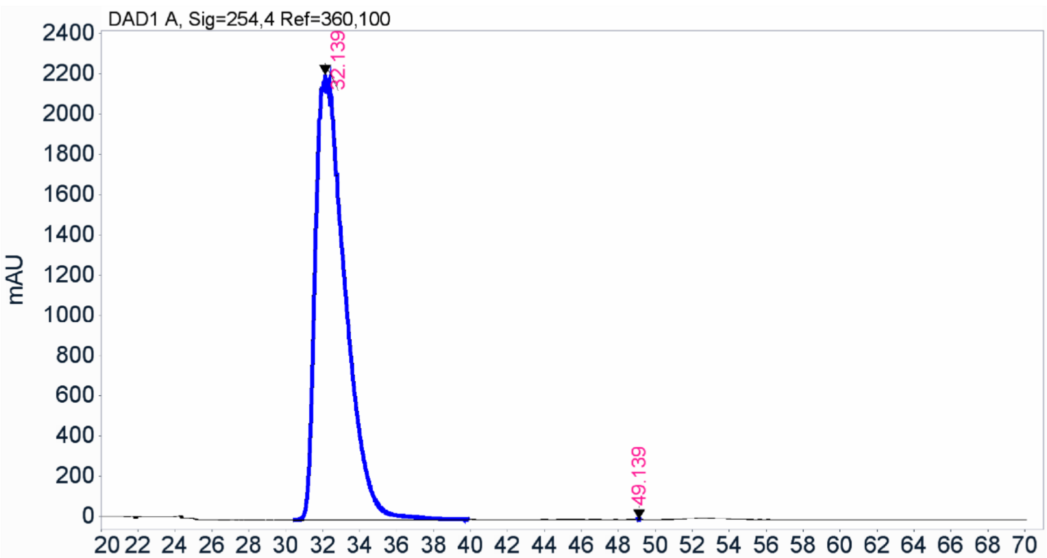


2d



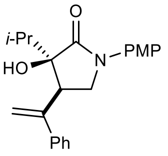
Signal: DAD1 A, Sig=254,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
32.604	MM	1.6617	77293.281	775.2402	49.81
49.633	MM	3.1803	77878.516	408.1319	50.19

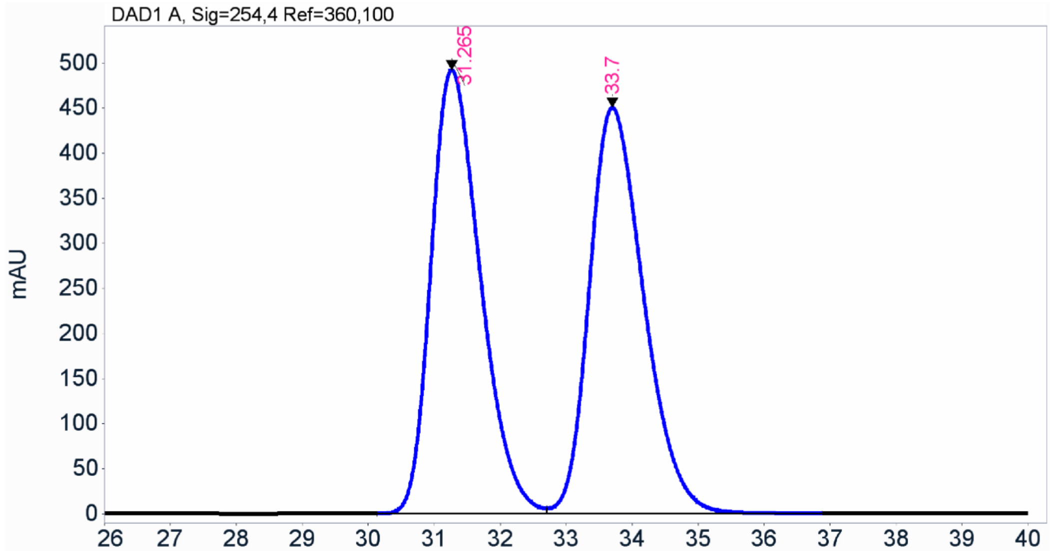


Signal: DAD1 A, Sig=254,4 Ref=360,100

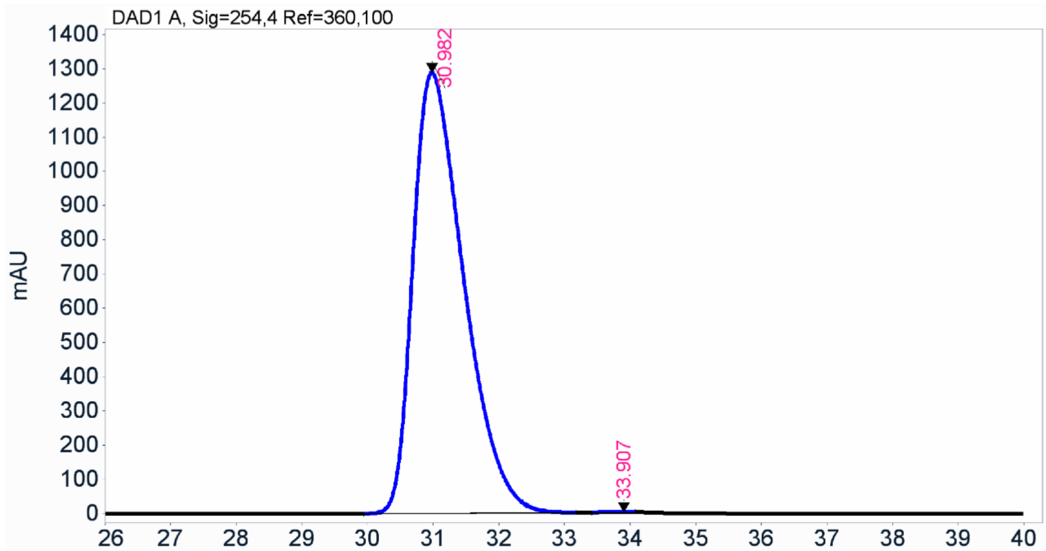
RT [min]	Type	Width [min]	Area	Height	Area%
32.139	MM	1.8484	245207.156	2210.9839	100.00
49.139	MM	0.1087	10.474	1.6057	0.00



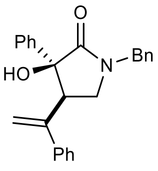
2e



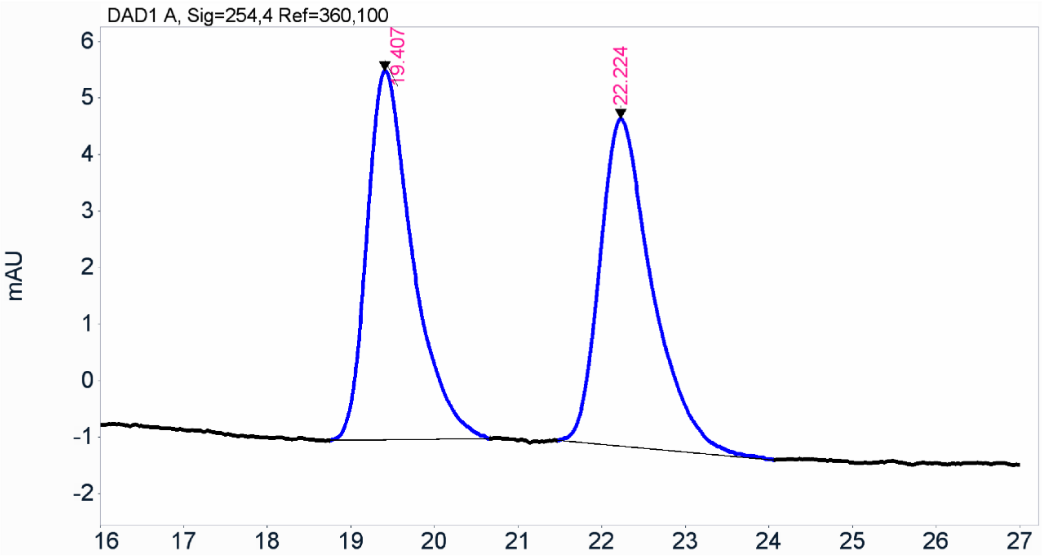
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
31.265	BV	0.8073	25531.139	492.1060	49.81
33.700	VB	0.8844	25727.092	450.4184	50.19



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
30.982	BB	0.8392	69180.984	1286.7573	99.86
33.907	MM	0.5544	95.963	2.8850	0.14

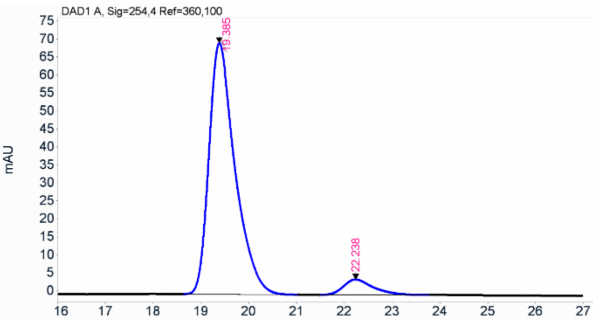


2f



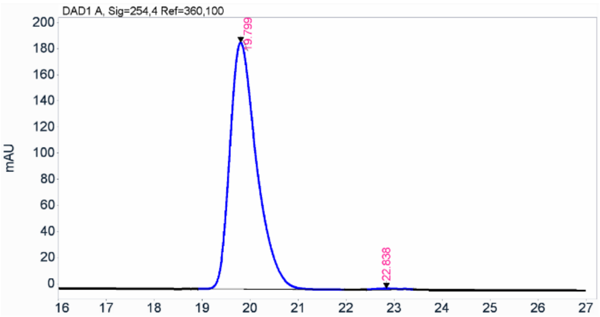
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.407	BB	0.5537	247.088	6.5257	49.47
22.224	BB	0.6222	252.377	5.7940	50.53

Reaction carried out in TFE:

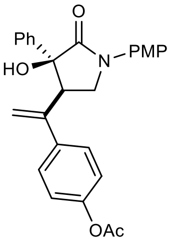


Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.385	BB	0.5612	2642.818	69.8879	93.47
22.238	BB	0.5829	184.562	4.2647	6.53

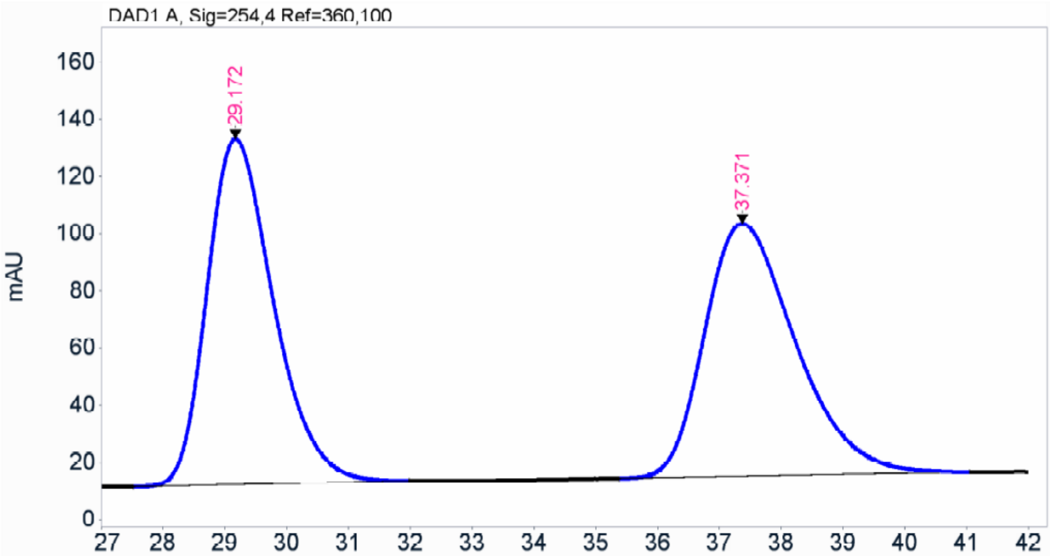
Reaction as carried out in MeCN:



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.799	BB	0.5828	7301.608	188.9537	99.51
22.838	MM	0.4612	36.165	0.9340	0.49

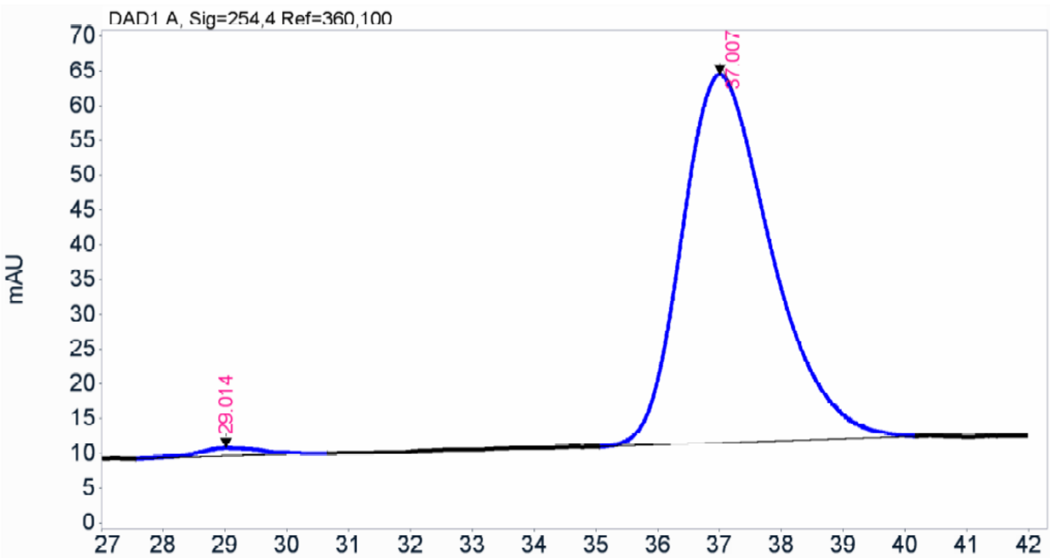


2g



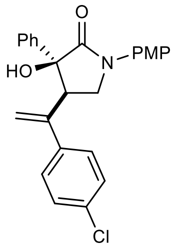
Signal: DAD1 A, Sig=254,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
29.172	BB	1.1454	9026.544	120.8490	49.96
37.371	BB	1.5009	9041.647	88.2804	50.04

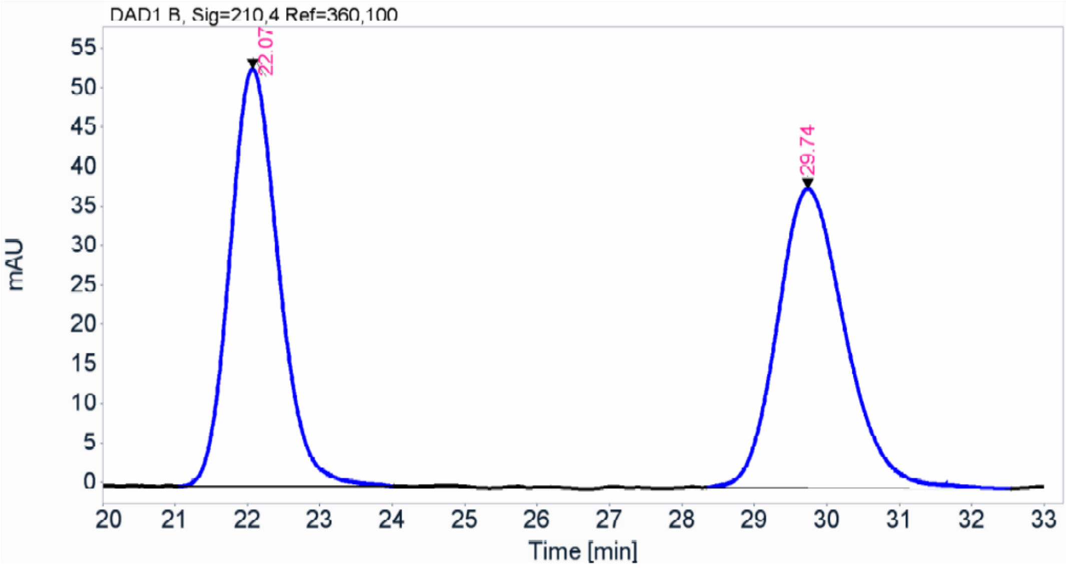


Signal: DAD1 A, Sig=254,4 Ref=360,100

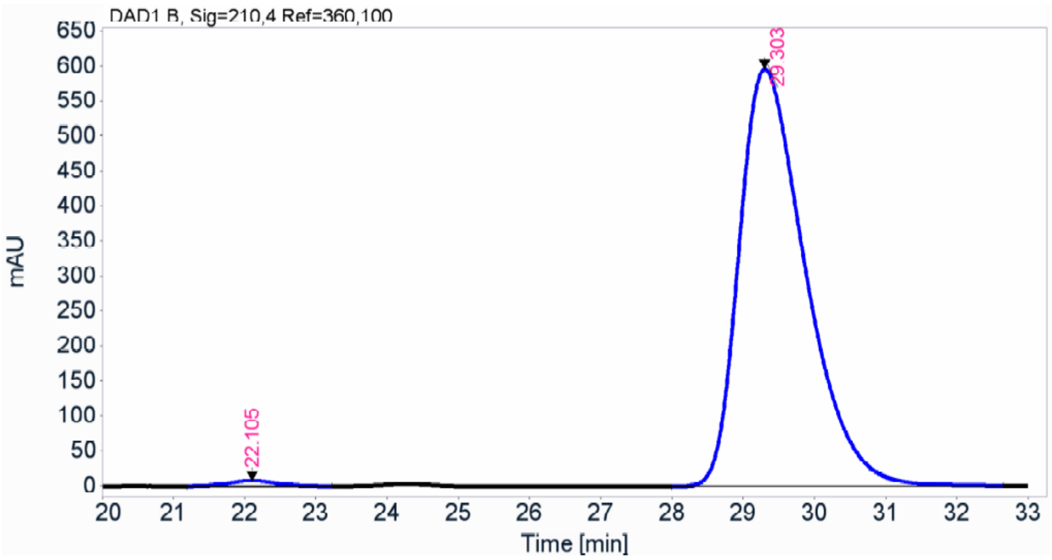
RT [min]	Type	Width [min]	Area	Height	Area%
29.014	MM	1.2323	87.398	1.1820	1.63
37.007	BB	1.4234	5289.287	52.9490	98.37



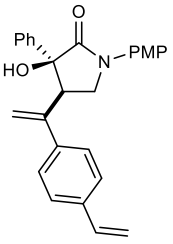
2h



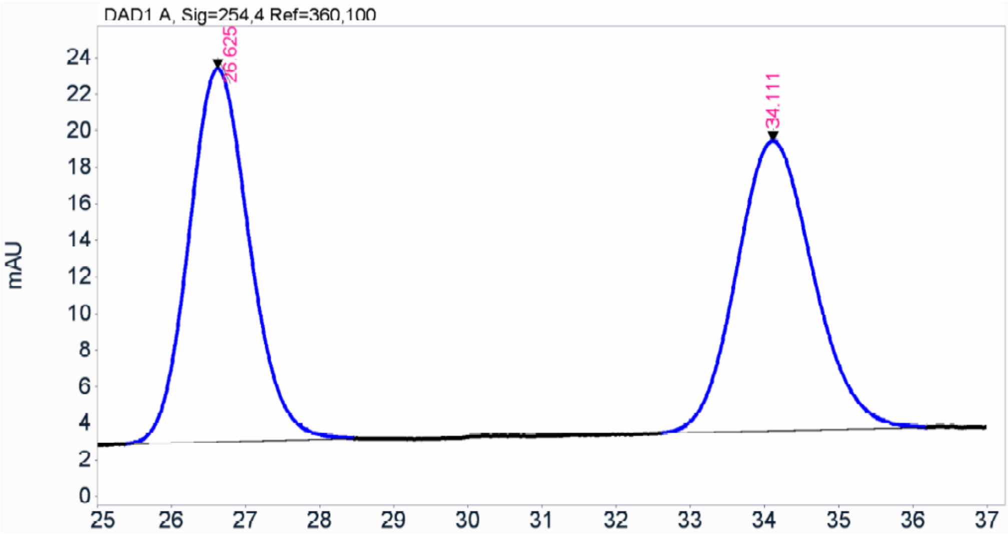
Signal:	DAD1 B, Sig=210,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
22.070	BB	0.7230	2471.330	52.9043	50.09
29.740	BB	0.9536	2462.733	37.9243	49.91



Signal:	DAD1 B, Sig=210,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
22.105	BB	0.5936	370.359	8.0981	0.95
29.303	BB	0.9912	38502.746	596.3964	99.05

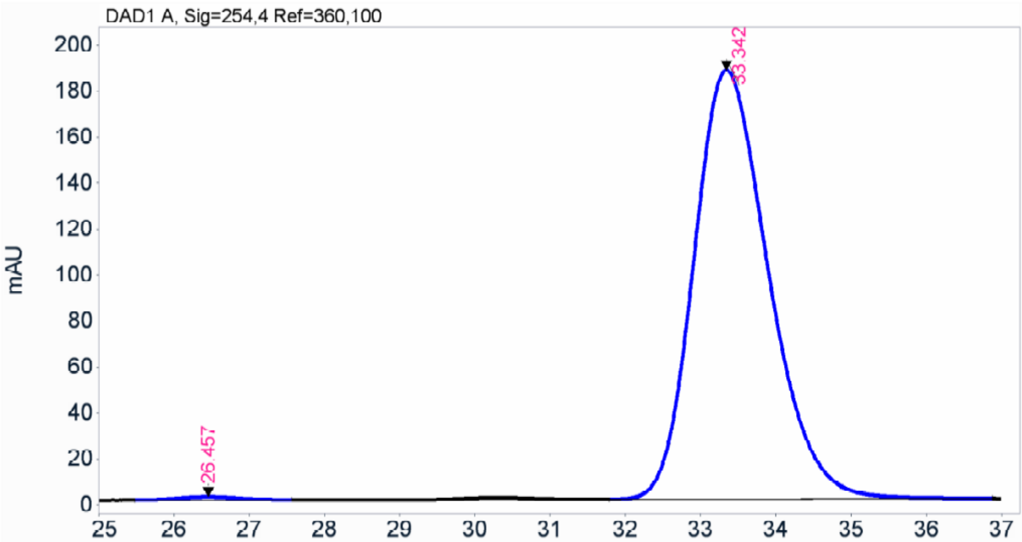


2i



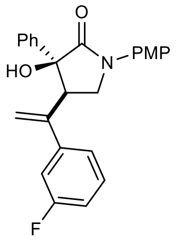
Signal: DAD1 A, Sig=254,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
26.625	BB	0.8565	1151.465	20.4002	50.29
34.111	BB	0.9306	1138.096	15.8342	49.71

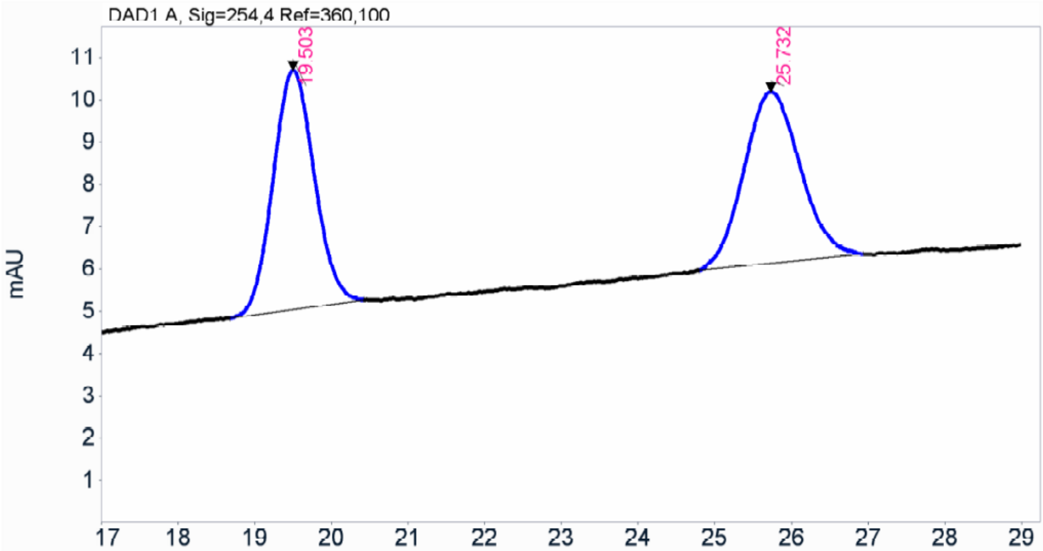


Signal: DAD1 A, Sig=254,4 Ref=360,100

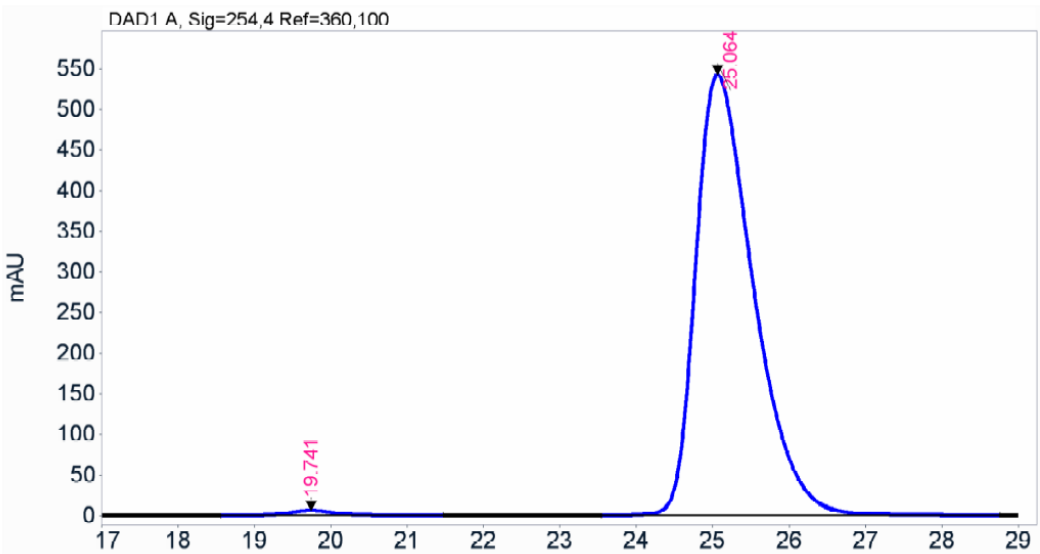
RT [min]	Type	Width [min]	Area	Height	Area%
26.457	MM	0.9859	92.070	1.5564	0.71
33.342	BB	1.0721	12830.535	186.6275	99.29



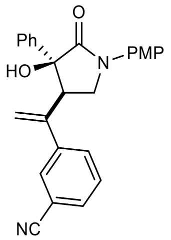
2j



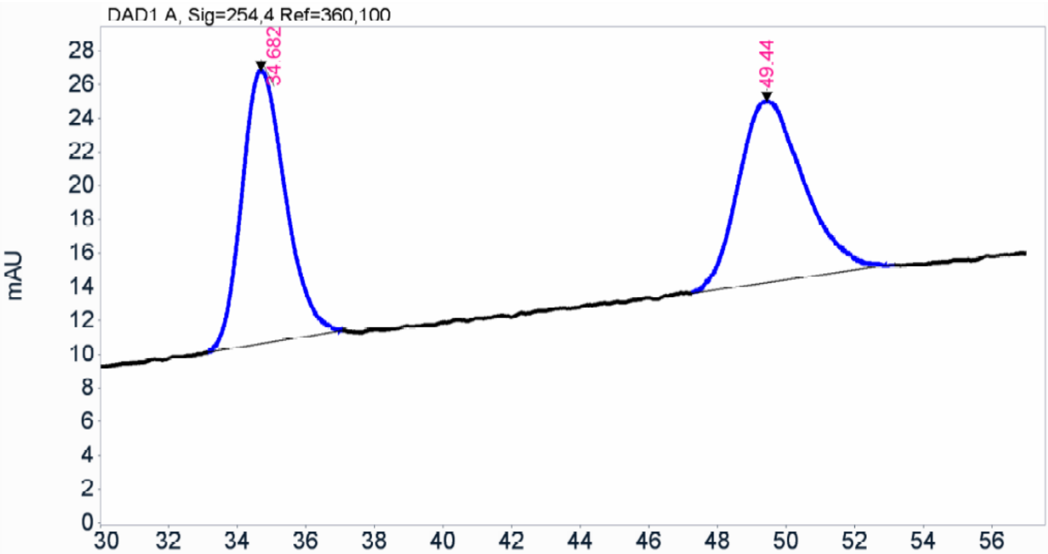
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.503	BB	0.5129	211.861	5.6577	50.58
25.732	BB	0.6118	207.035	4.0542	49.42



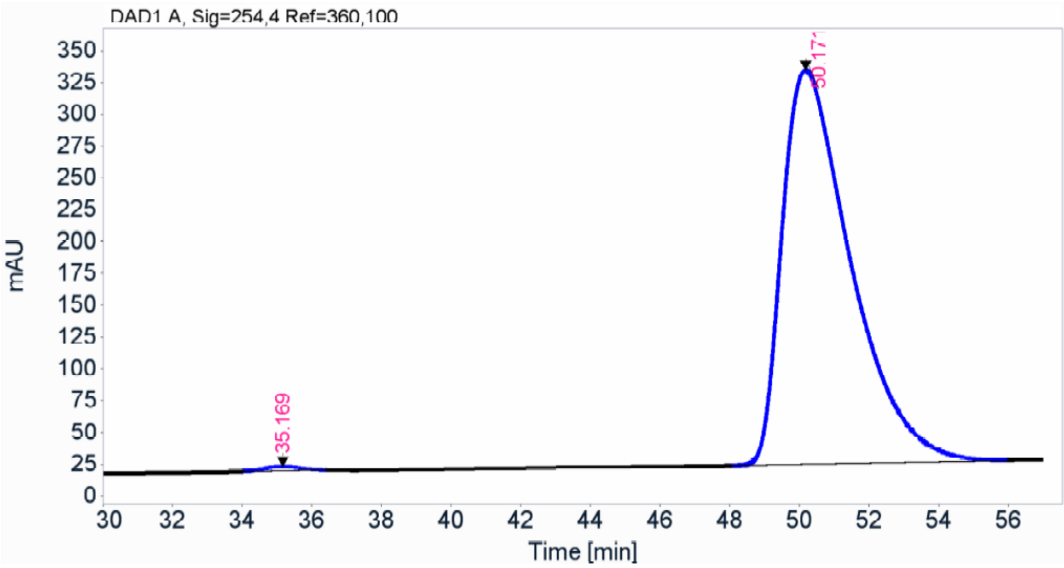
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.741	BB	0.6121	269.926	6.2725	0.94
25.064	BB	0.7989	28405.742	542.4609	99.06



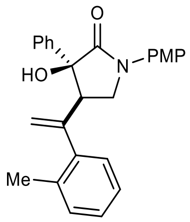
2k



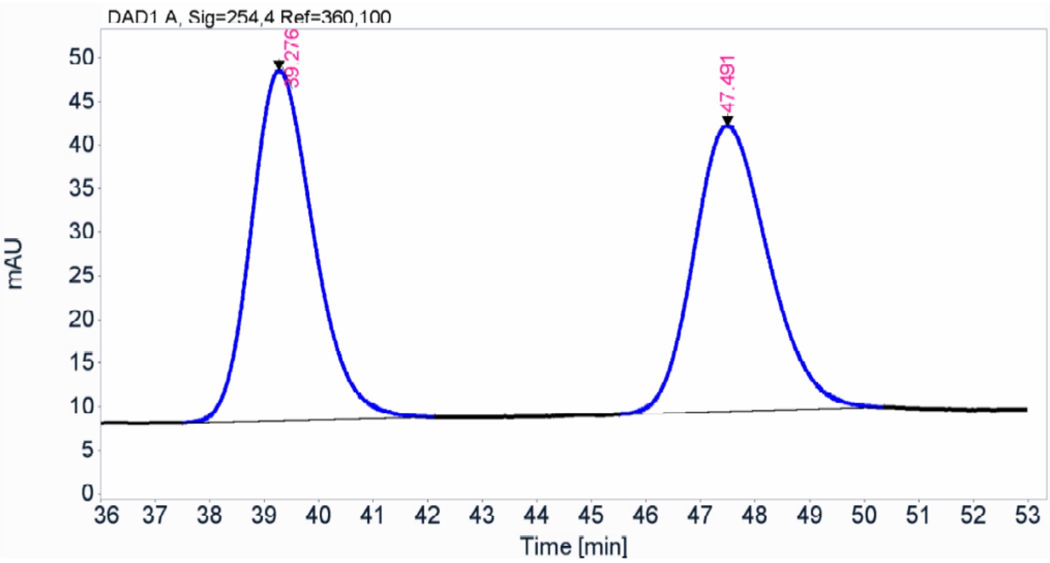
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
34.682	BB	1.0932	1425.551	16.1906	50.07
49.440	MM	1.5591	1421.671	10.7336	49.93



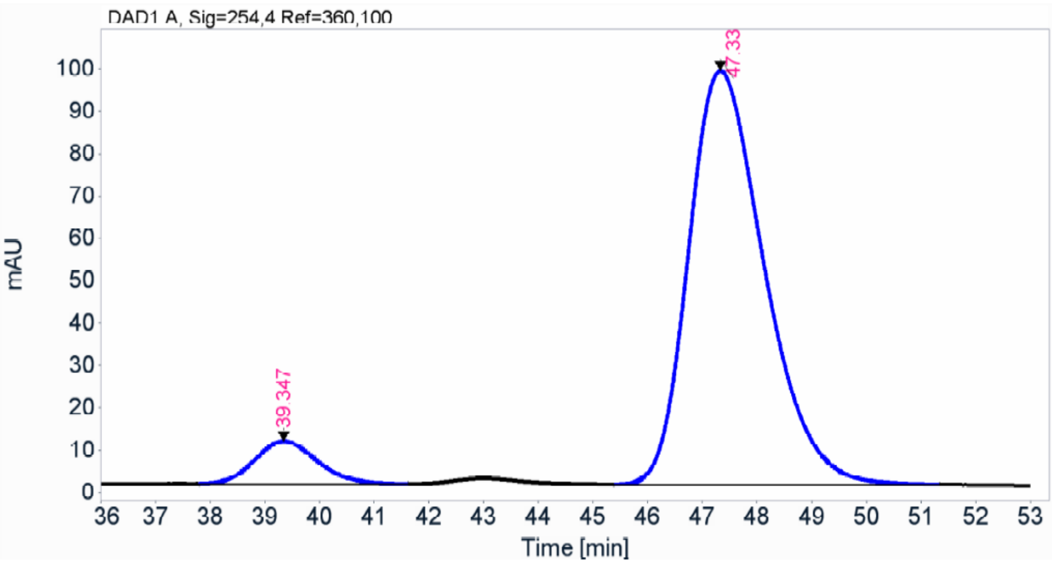
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
35.169	MM	0.8906	246.686	3.3919	0.58
50.171	BV	2.0299	42359.777	309.2750	99.42



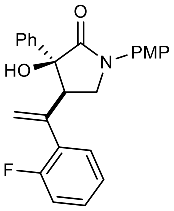
2l



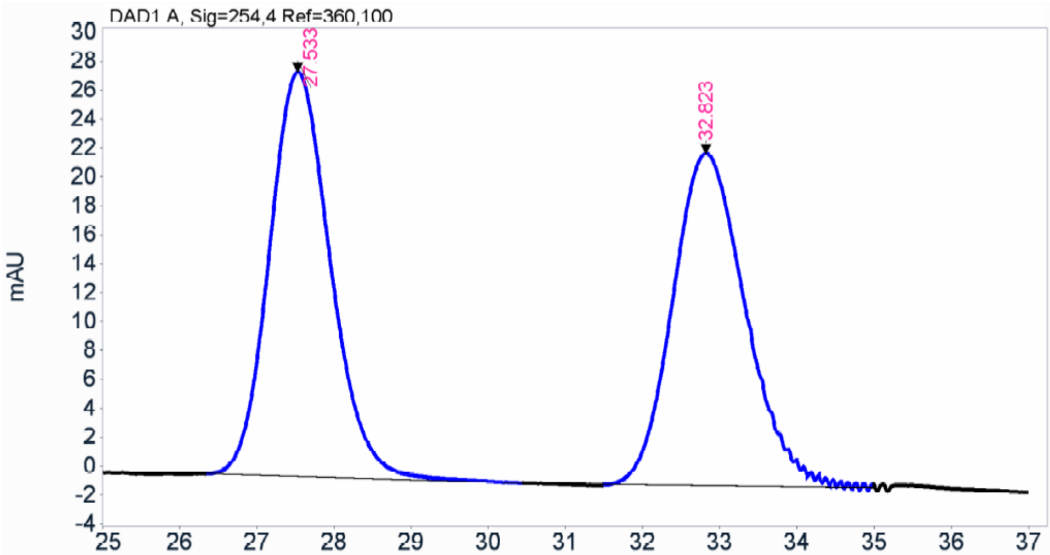
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
39.276	BB	1.1717	3183.034	40.1155	50.62
47.491	BB	1.3588	3104.945	32.7299	49.38



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
39.347	BB	0.9473	800.232	10.0459	7.86
47.330	BB	1.4280	9376.770	97.6720	92.14

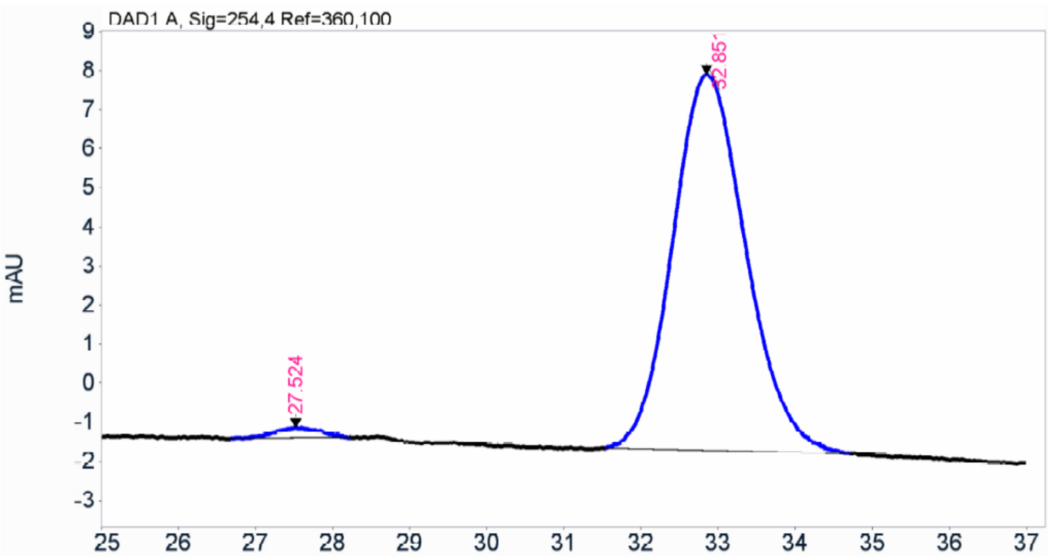


2m



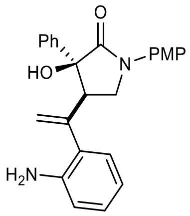
Signal: DAD1 A, Sig=254,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
27.533	BB	0.8345	1540.565	27.9721	50.60
32.823	MM	1.0928	1504.198	22.9419	49.40

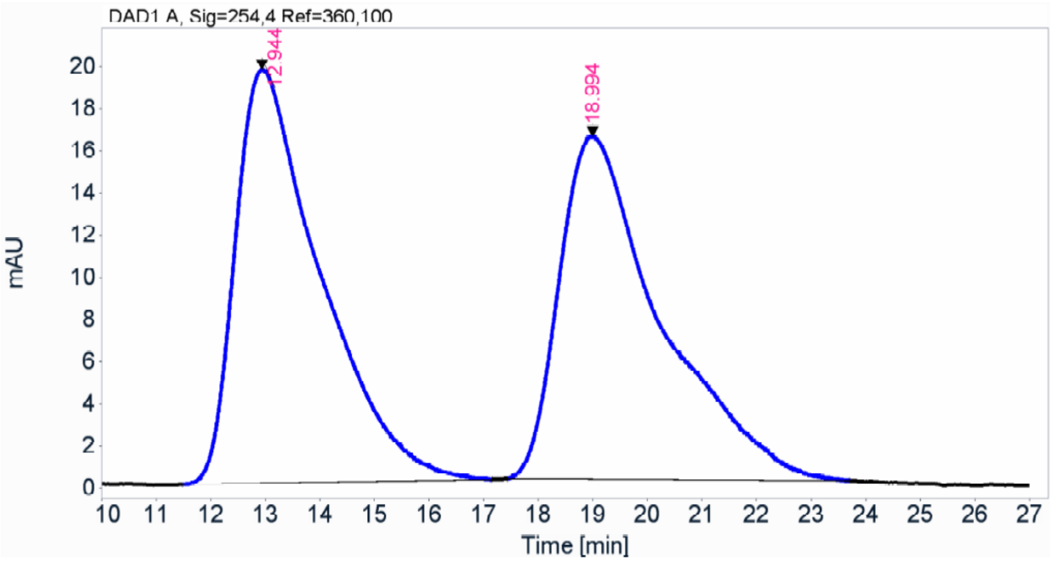


Signal: DAD1 A, Sig=254,4 Ref=360,100

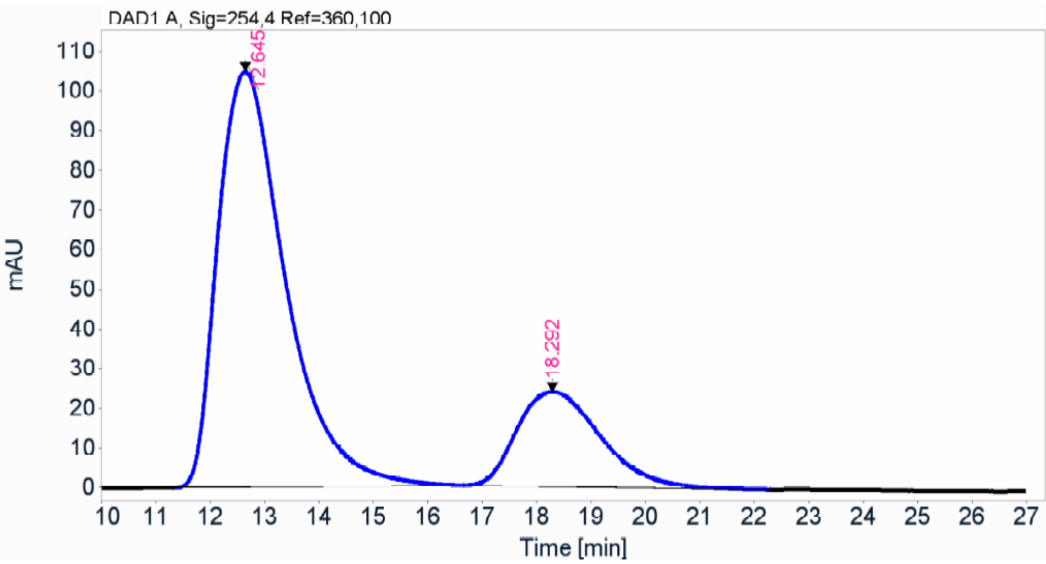
RT [min]	Type	Width [min]	Area	Height	Area%
27.524	MM	0.6787	10.932	0.2685	1.69
32.851	BB	0.8387	635.358	9.6184	98.31



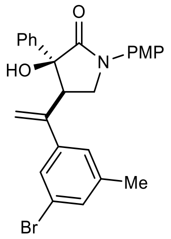
2n



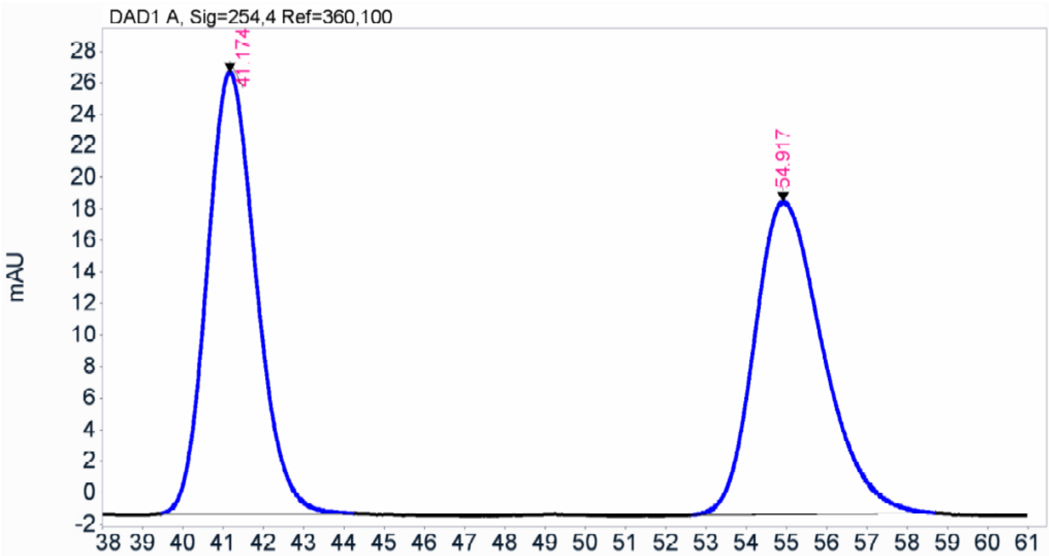
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	**Type**	**Width [min]**	**Area**	**Height**	**Area%**
12.944	BB	1.4430	2120.079	19.6151	50.37
18.994	BB	1.5348	2089.147	16.2405	49.63



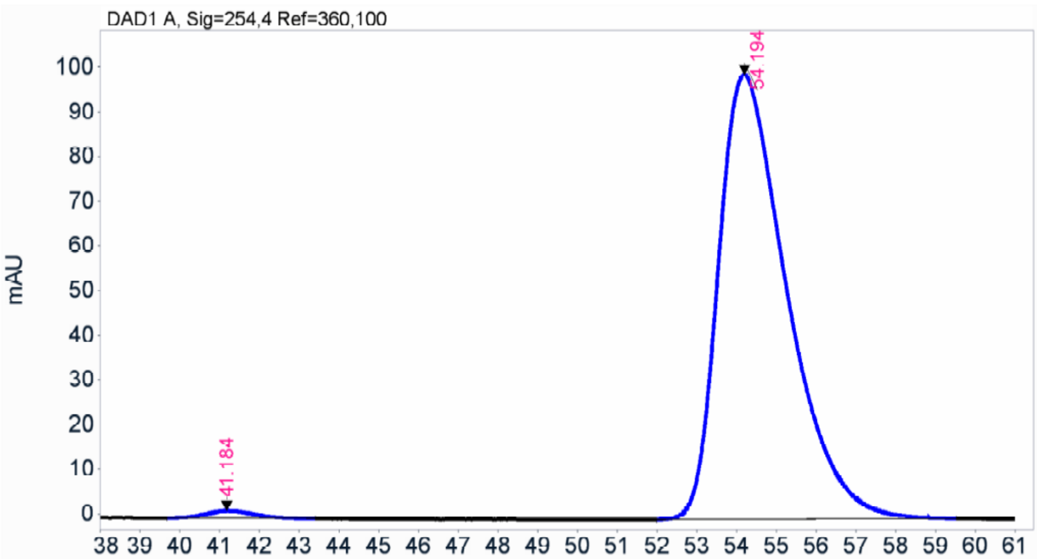
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	**Type**	**Width [min]**	**Area**	**Height**	**Area%**
12.645	BB	1.3214	9063.034	104.7481	78.01
18.292	BB	1.4680	2555.103	23.9236	21.99



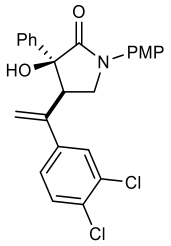
2o



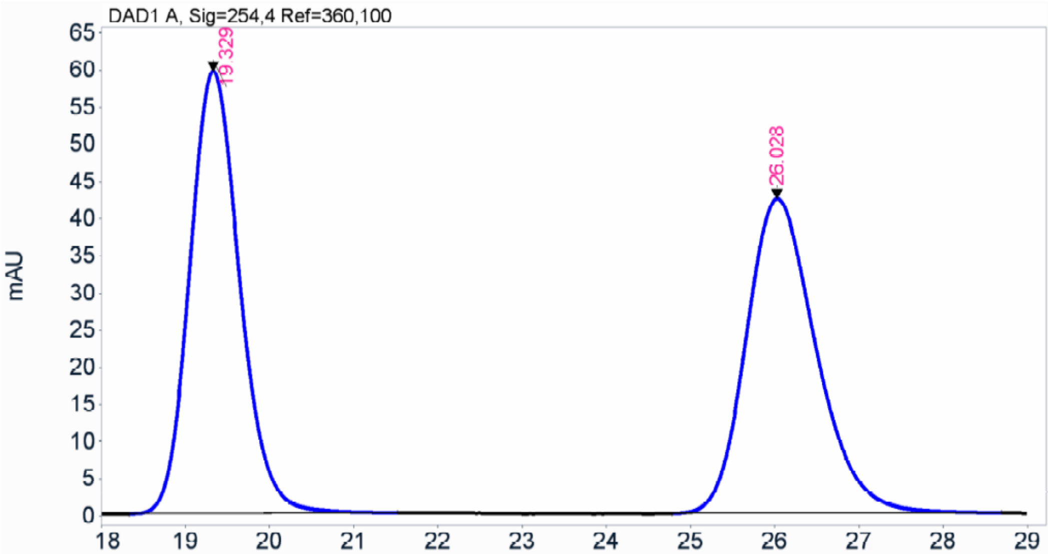
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
41.174	BB	1.1917	2359.033	27.9776	50.17
54.917	BB	1.4701	2343.136	19.8078	49.83



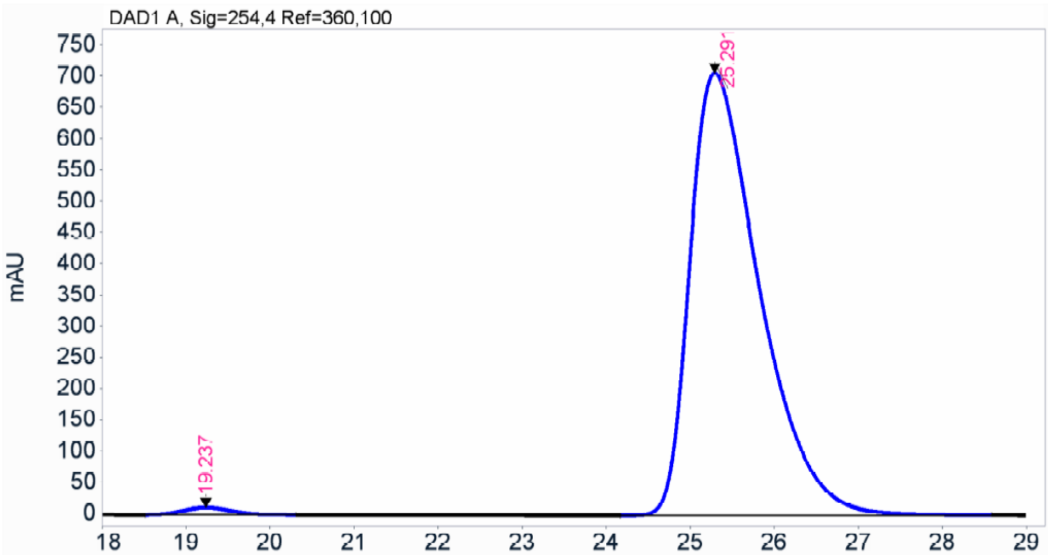
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
41.184	MM	1.3828	134.670	1.6232	1.13
54.194	BB	1.6949	11835.738	99.5656	98.87



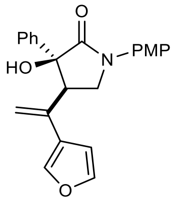
2p



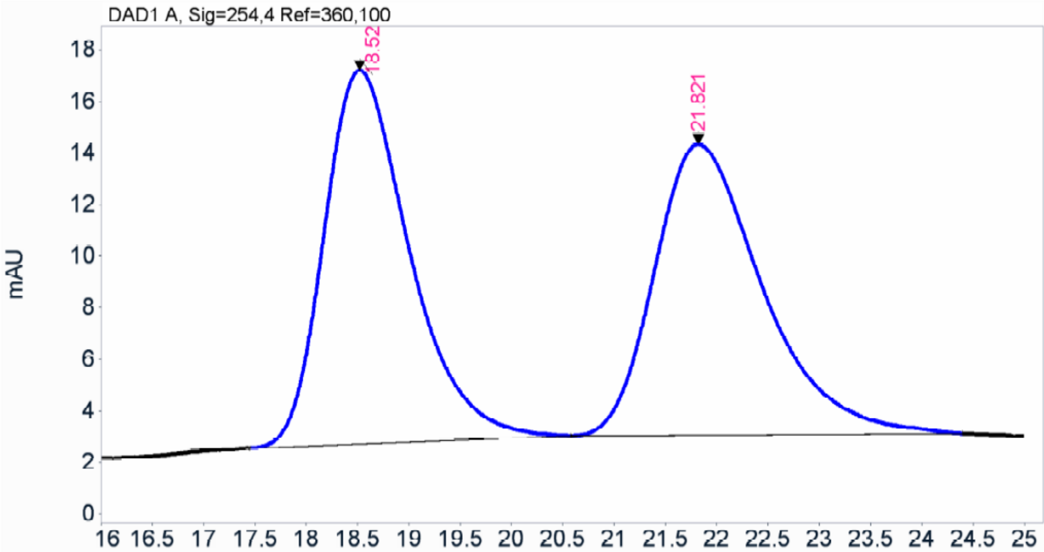
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.329	BB	0.6405	2451.615	59.5295	50.08
26.028	BB	0.8895	2444.082	42.3390	49.92



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
19.237	MM	0.6670	468.863	11.7162	1.14
25.291	MM	0.9564	40631.875	708.0849	98.86

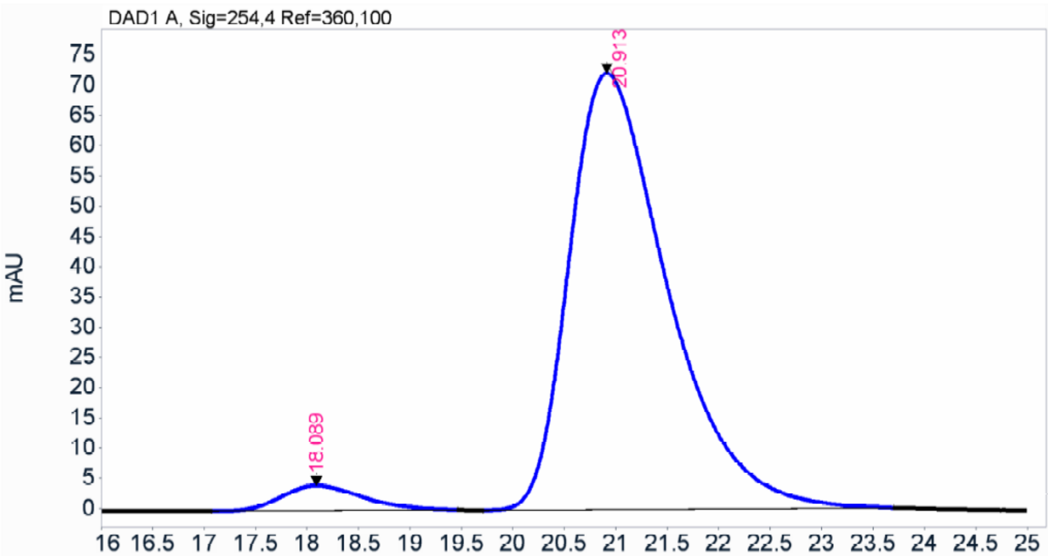


2q



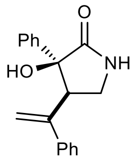
Signal: DAD1 A, Sig=254,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
18.520	BB	0.8359	837.584	14.4996	50.36
21.821	BB	0.9937	825.528	11.2812	49.64

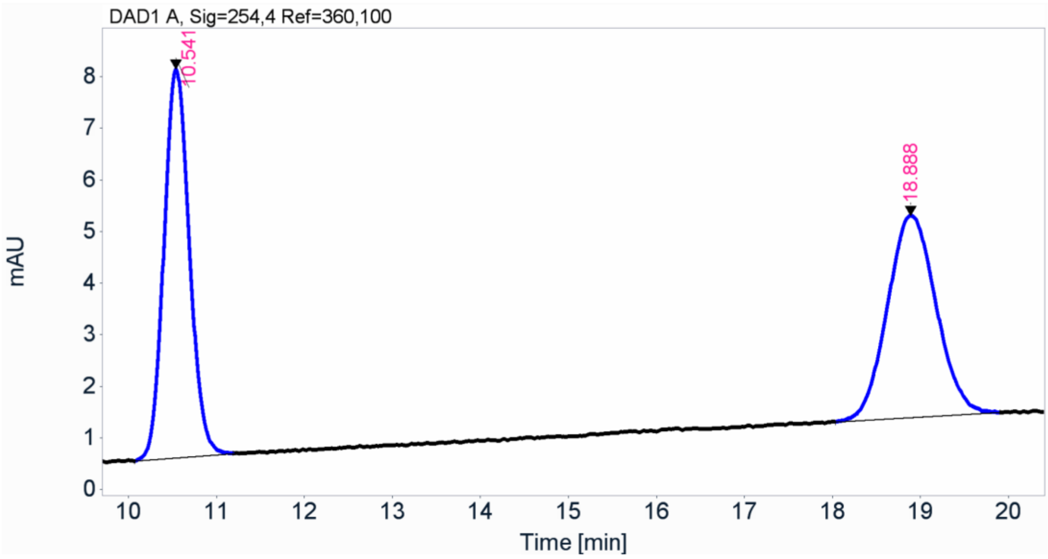


Signal: DAD1 A, Sig=254,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
18.089	MM	0.9076	222.466	4.0851	4.44
20.913	BB	1.0110	4790.959	72.1197	95.56

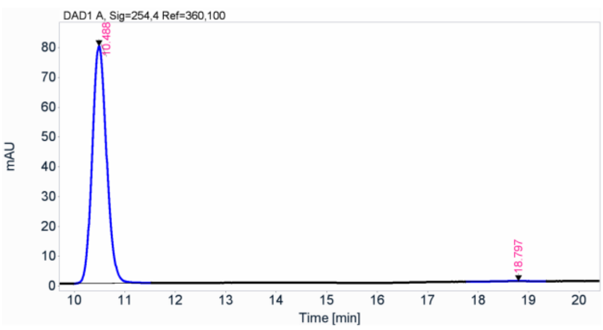


2r



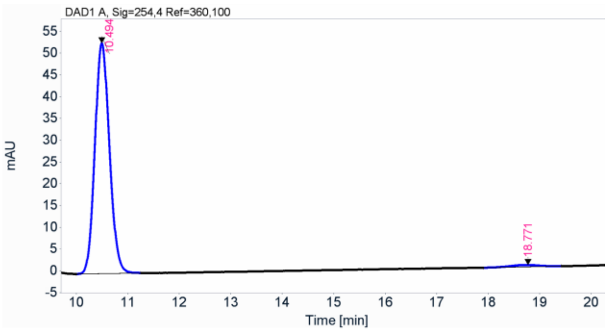
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
10.541	BB	0.3147	151.400	7.5259	50.11
18.888	BB	0.5333	150.721	3.9134	49.89

Arylative cyclization to produce **2r**:

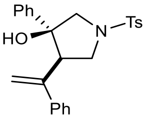


Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
10.488	BB	0.3062	1570.278	79.5666	99.63
18.797	MM	0.7085	5.818	0.1369	0.37

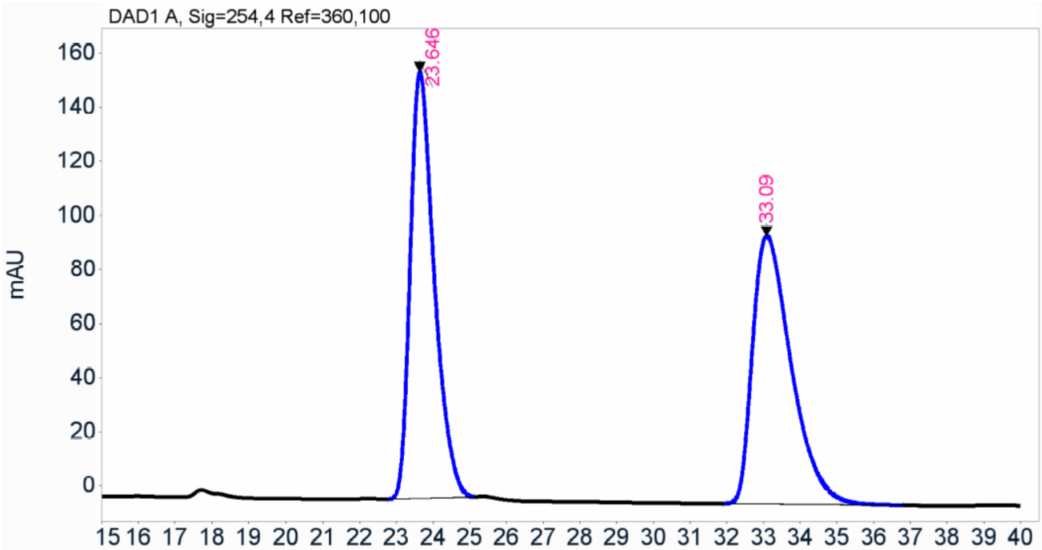
Deprotection of **2a** (96% ee) to produce **2r**:



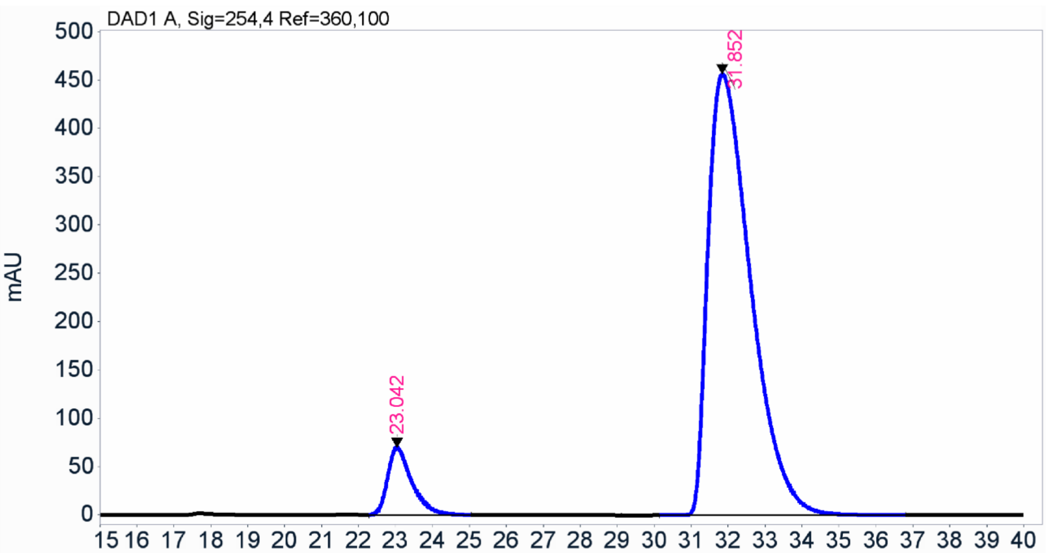
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
10.494	BB	0.3074	1040.981	52.9311	98.24
18.771	MM	0.6890	18.649	0.4511	1.76



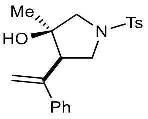
5a



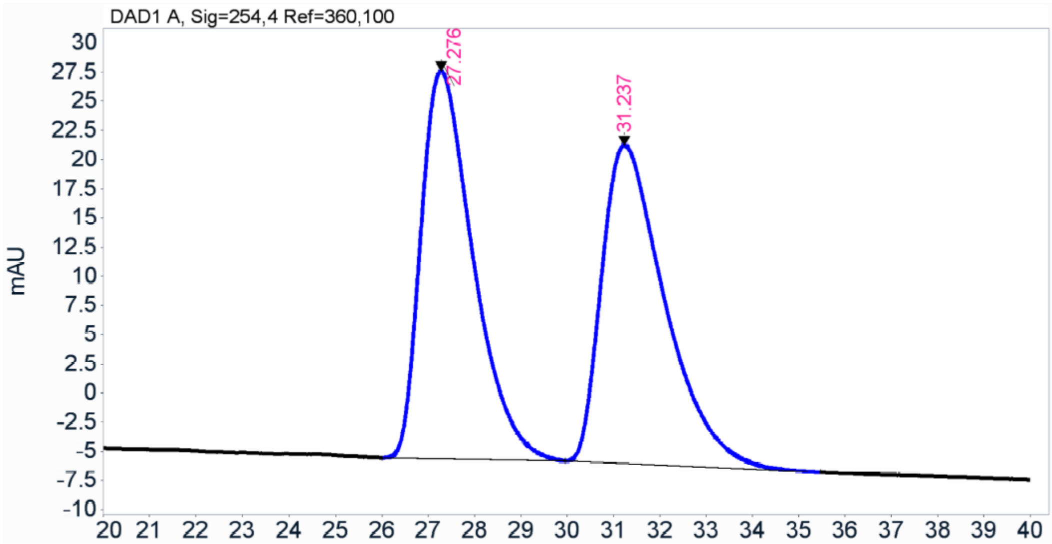
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
23.646	BB	0.6878	7175.295	157.9983	49.66
33.090	BB	1.1129	7272.276	99.2466	50.34



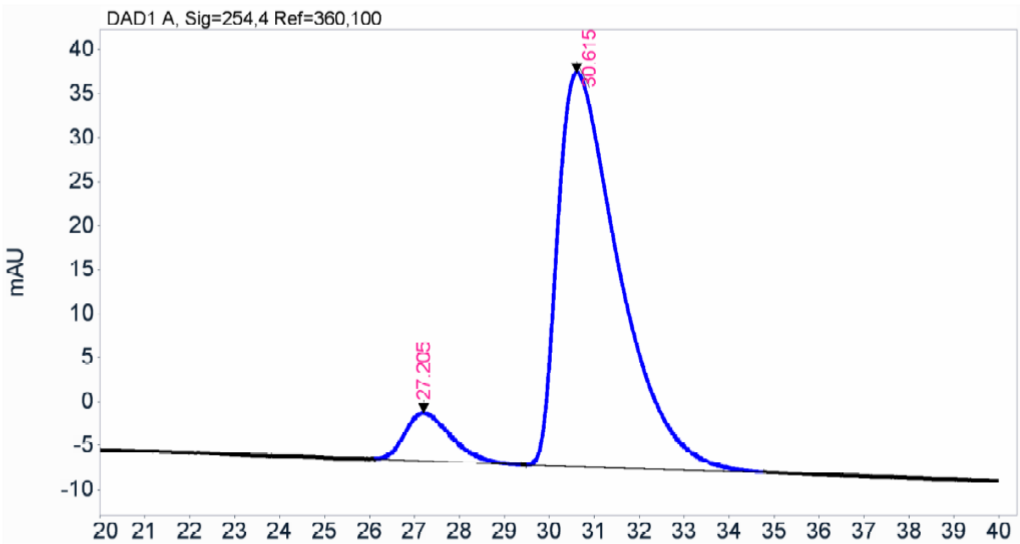
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
23.042	MM	0.7648	3200.952	69.7592	8.04
31.852	MM	1.3367	36632.145	456.7636	91.96



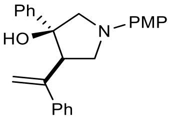
5b



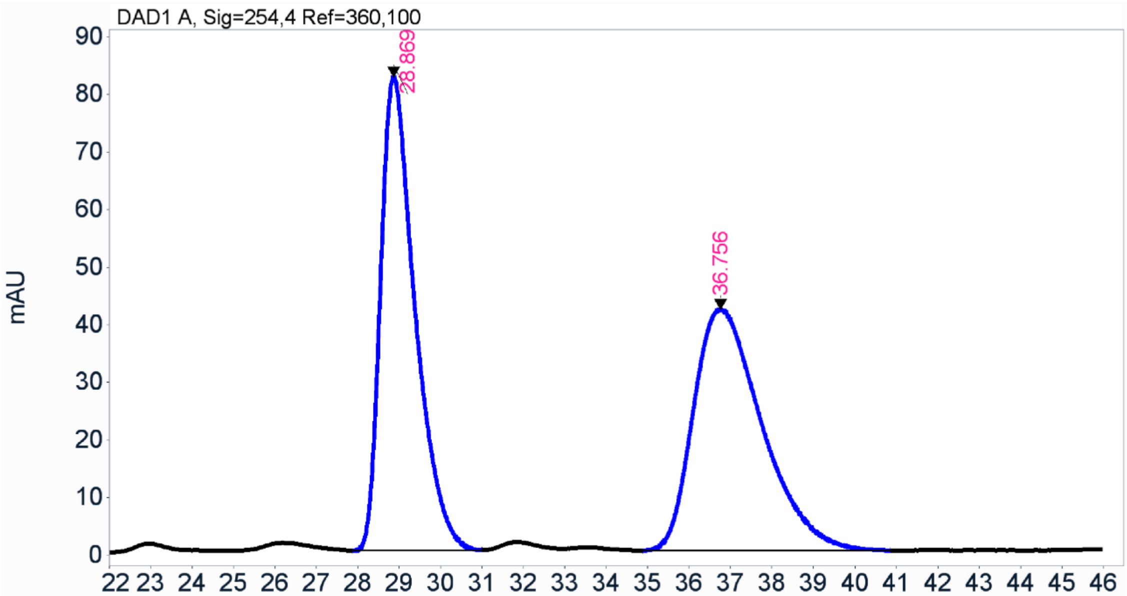
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
27.276	BB	1.1473	2596.034	33.2342	50.03
31.237	BB	1.3070	2593.351	27.2815	49.97



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
27.205	BB	0.8496	384.856	5.4519	8.34
30.615	BB	1.3208	4231.603	44.7677	91.66

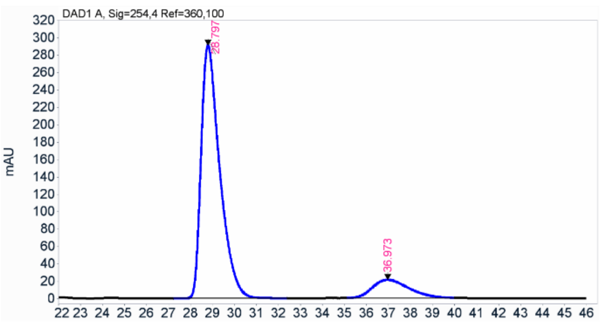


5c



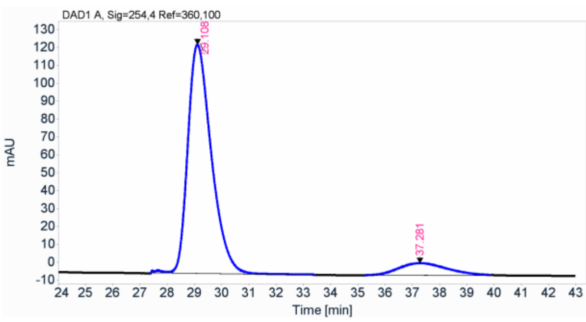
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
28.869	BB	0.8571	4739.494	82.1530	49.67
36.756	BB	1.6185	4802.273	41.7956	50.33

Reaction carried out in TFE:

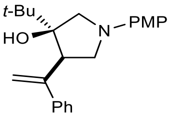


Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
28.797	MM	0.9767	17031.924	290.6238	87.56
36.973	MM	1.9256	2419.486	20.9414	12.44

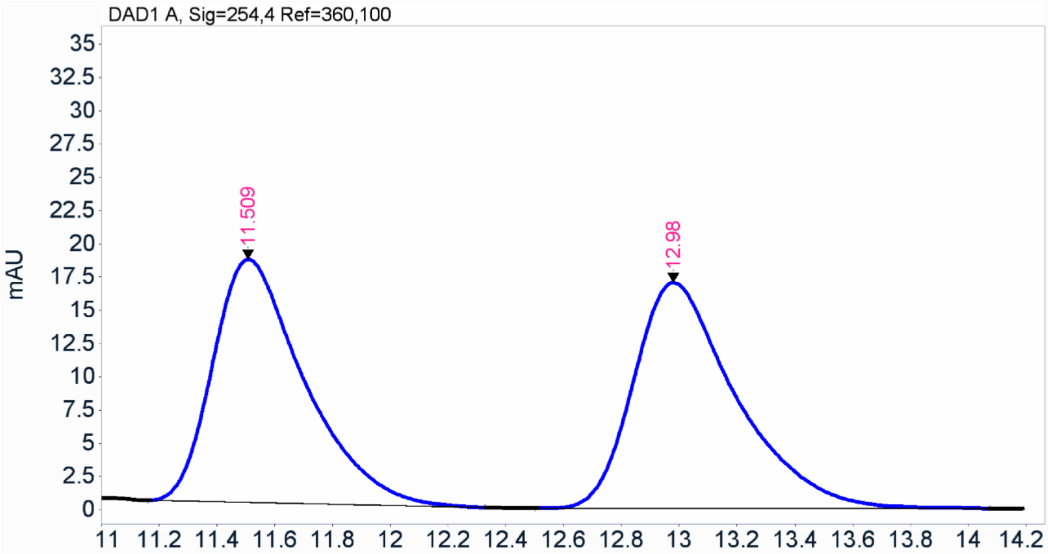
Reaction as carried out in MeCN:



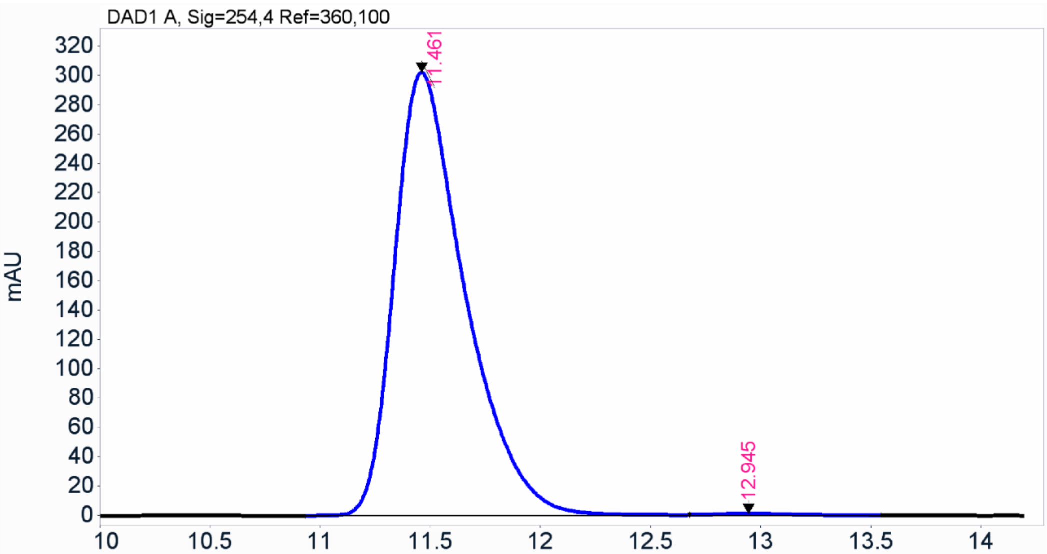
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
29.108	MM	1.0085	7737.827	127.8751	90.09
37.281	MM	2.0996	851.216	6.7571	9.91



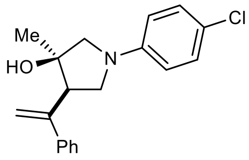
5d



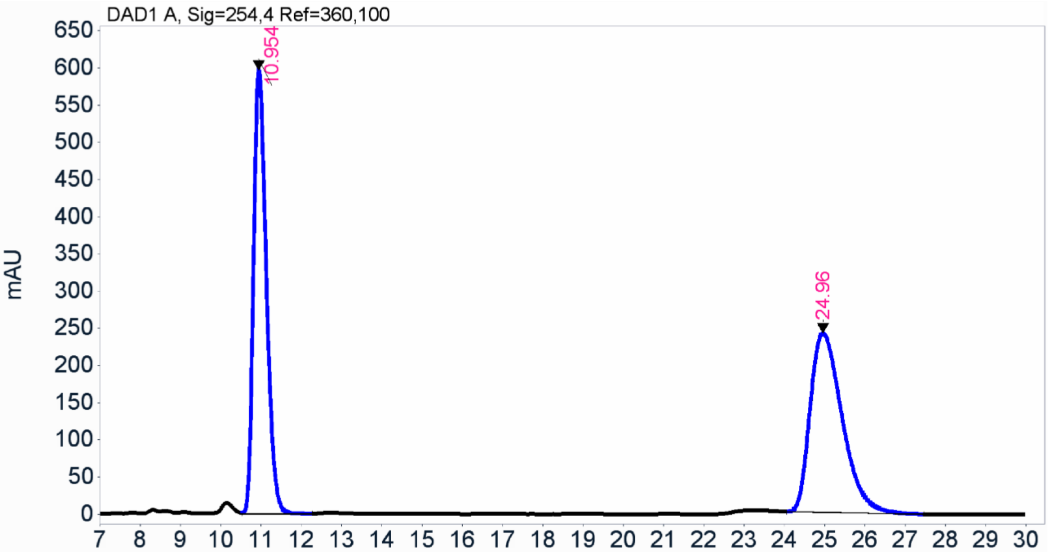
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
11.509	BB	0.3267	402.336	18.2870	49.06
12.980	BB	0.3631	417.676	16.9732	50.94



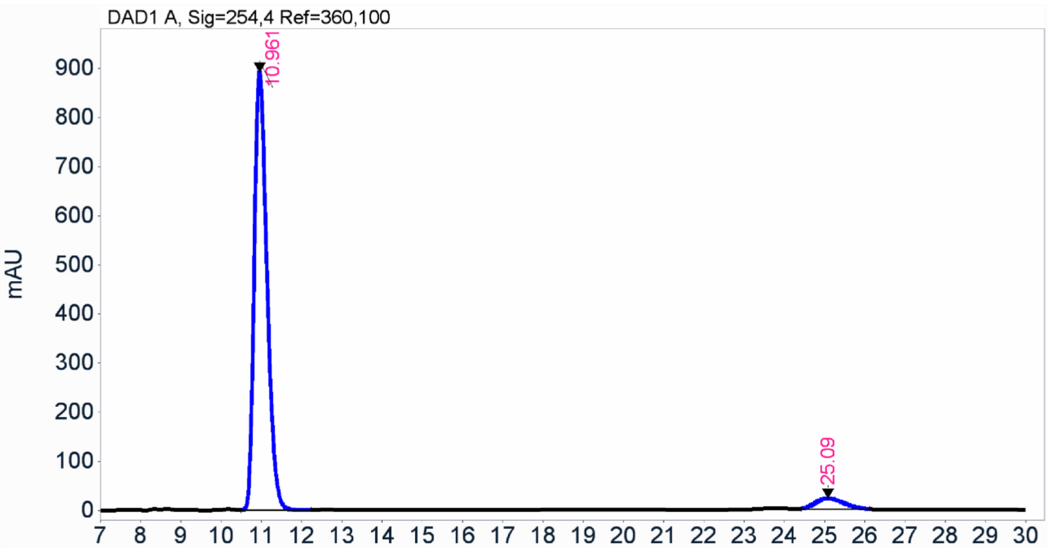
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
11.461	MM	0.3708	6724.485	302.2877	99.55
12.945	MM	0.4007	30.625	1.2740	0.45



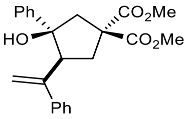
5e



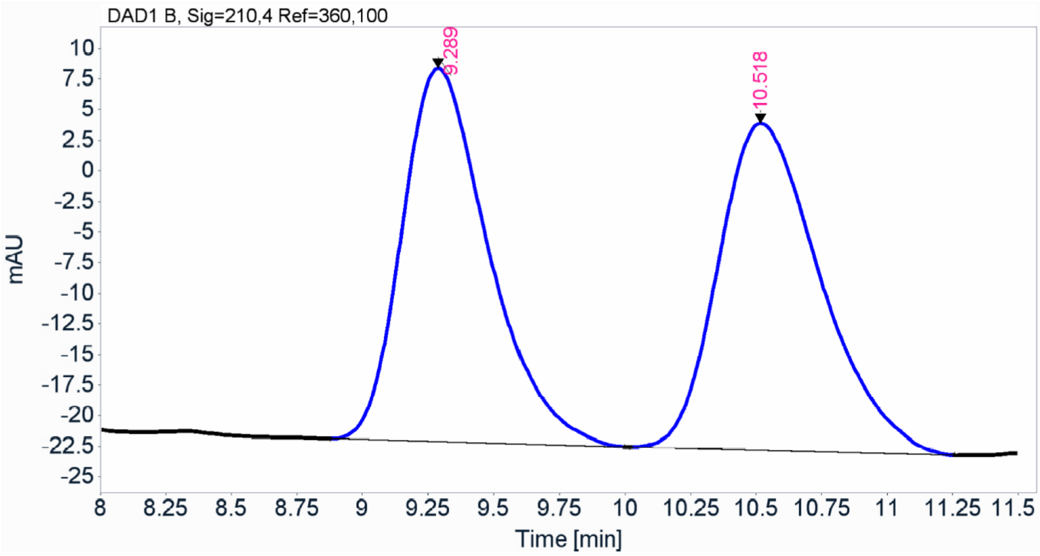
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	**Type**	**Width [min]**	**Area**	**Height**	**Area%**
10.954	VB	0.3411	13139.221	596.1681	49.59
24.960	BB	0.8638	13356.048	241.2753	50.41



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	**Type**	**Width [min]**	**Area**	**Height**	**Area%**
10.961	VB	0.3409	19644.066	892.2686	94.84
25.090	MM	0.8171	1069.034	21.8043	5.16

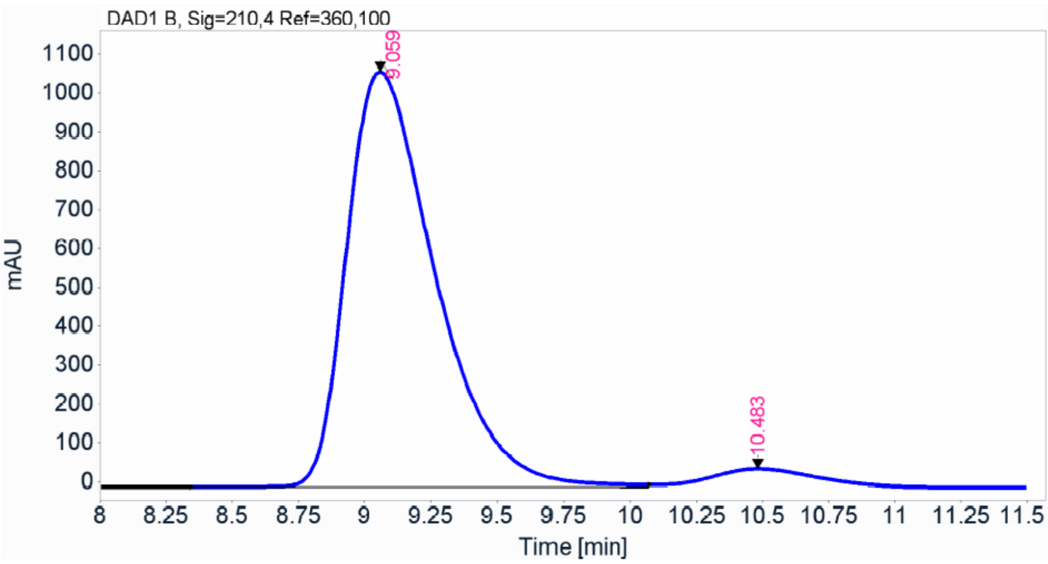


5f



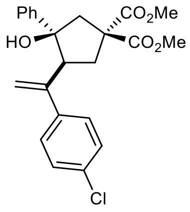
Signal: DAD1 B, Sig=210,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
9.289	BB	0.3497	699.403	30.4857	49.20
10.518	BB	0.4158	722.033	26.6784	50.80

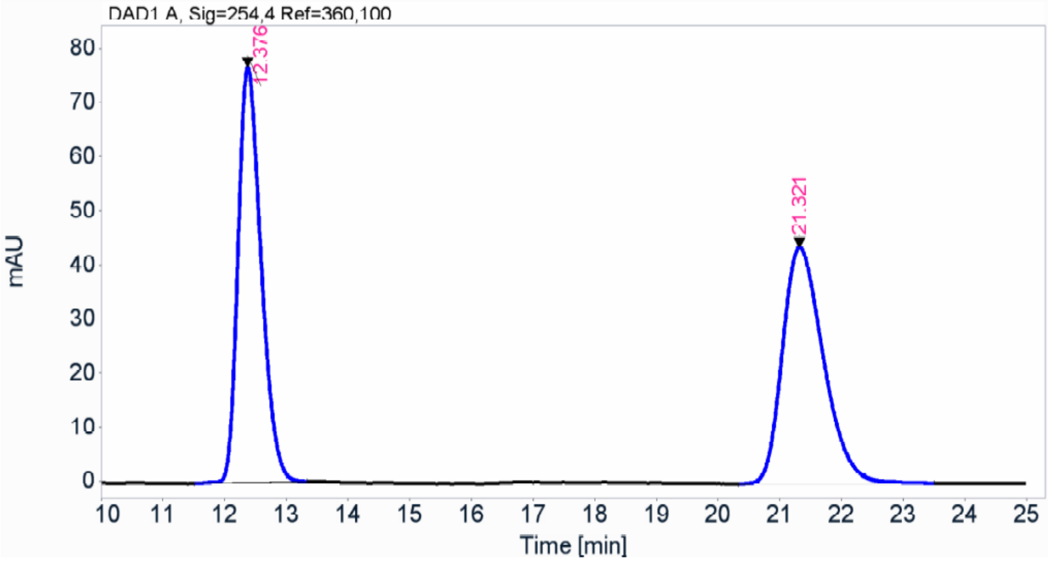


Signal: DAD1 B, Sig=210,4 Ref=360,100

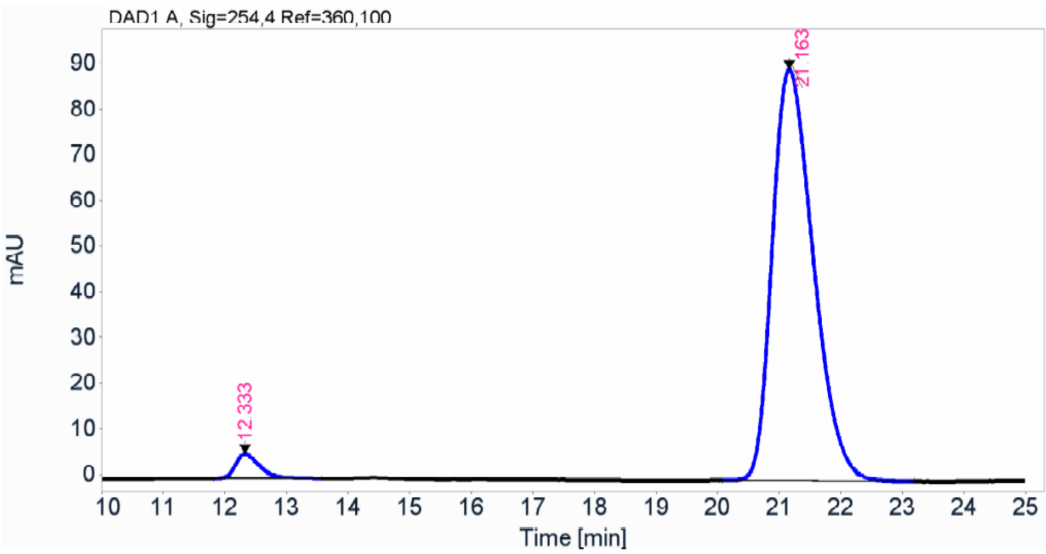
RT [min]	Type	Width [min]	Area	Height	Area%
9.059	BV	0.3547	24784.941	1068.1560	94.89
10.483	VB	0.4321	1334.299	47.1622	5.11



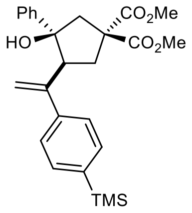
5g



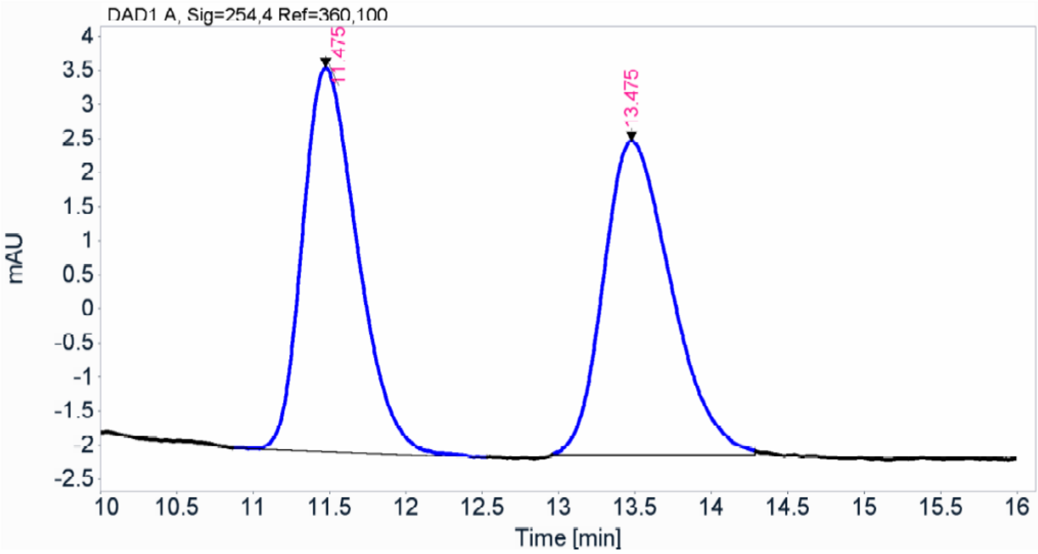
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
12.376	BB	0.3989	1991.814	76.7141	49.72
21.321	BB	0.7168	2013.975	43.6066	50.28



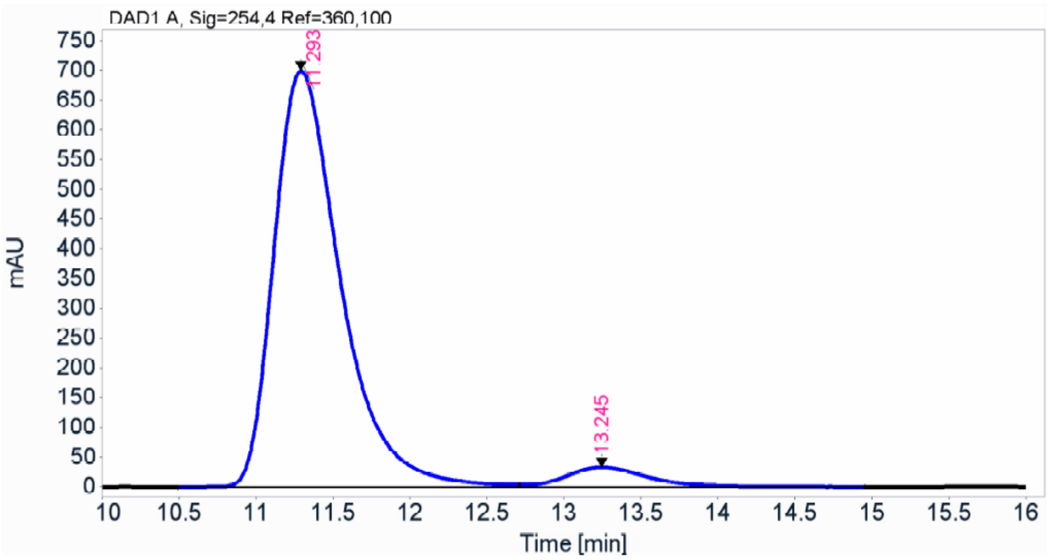
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
12.333	BB	0.4138	147.003	5.3973	3.41
21.163	BB	0.7238	4163.964	90.0011	96.59



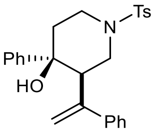
5h



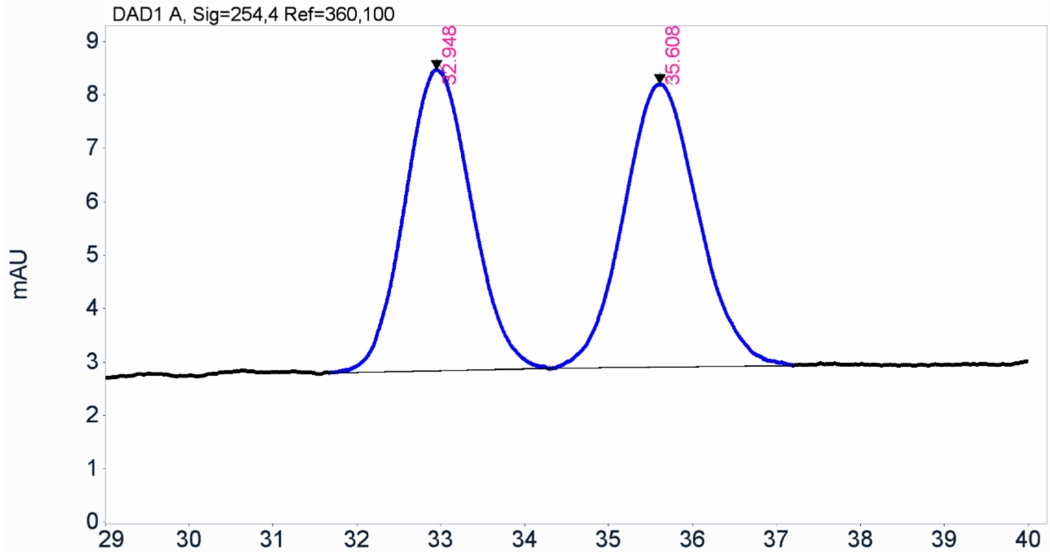
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
11.475	MM	0.4166	140.926	5.6384	49.91
13.475	MM	0.5123	141.455	4.6017	50.09



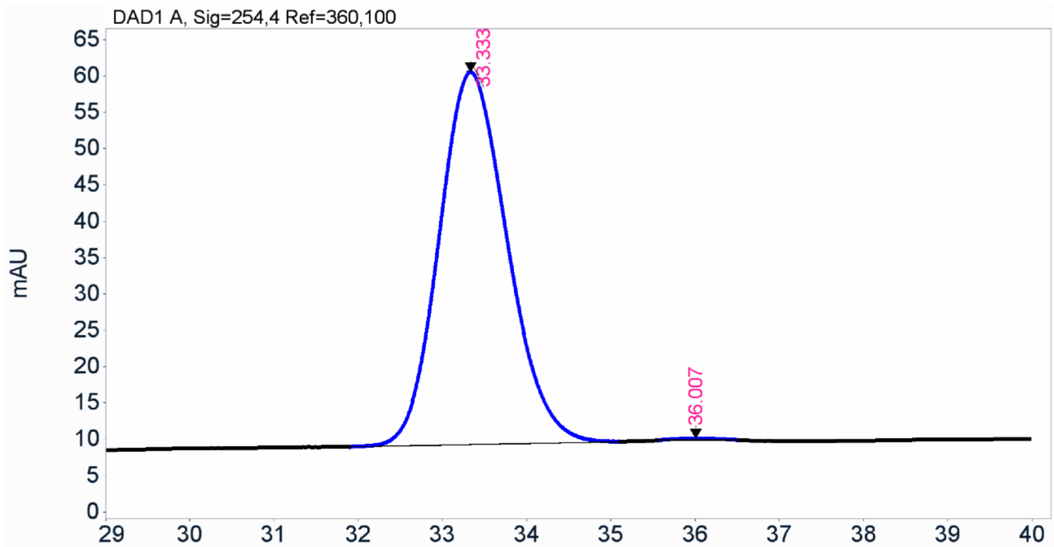
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
11.293	BV	0.4583	20997.943	699.3309	94.54
13.245	VB	0.5620	1212.658	32.9001	5.46



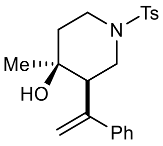
5i



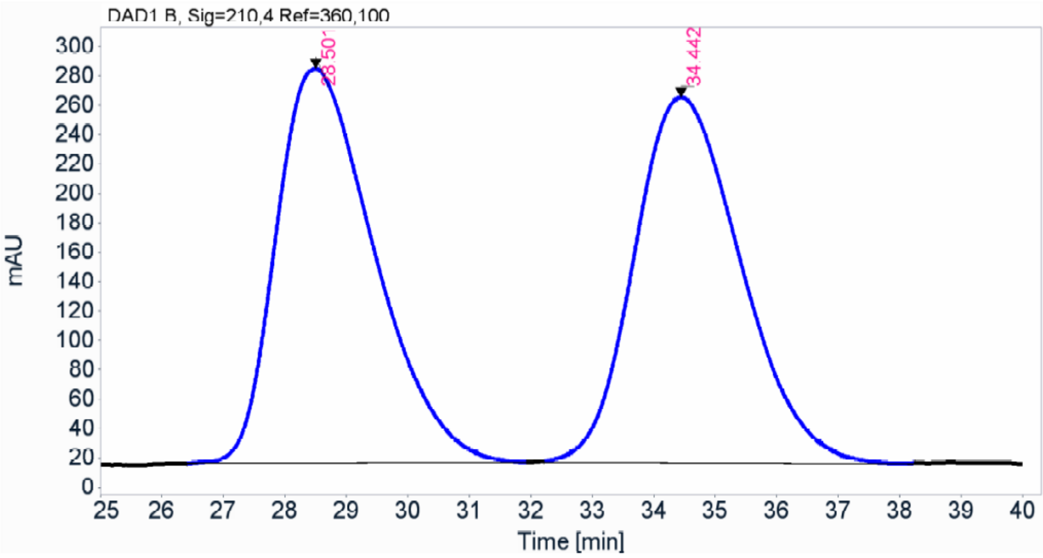
Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	**Type**	**Width [min]**	**Area**	**Height**	**Area%**
32.948	BB	0.7080	311.942	5.6333	48.83
35.608	BB	0.7360	326.890	5.2966	51.17



Signal:	DAD1 A, Sig=254,4 Ref=360,100				
RT [min]	**Type**	**Width [min]**	**Area**	**Height**	**Area%**
33.333	BB	0.8548	2876.049	51.2456	99.64
36.007	MM	0.6157	10.267	0.2779	0.36

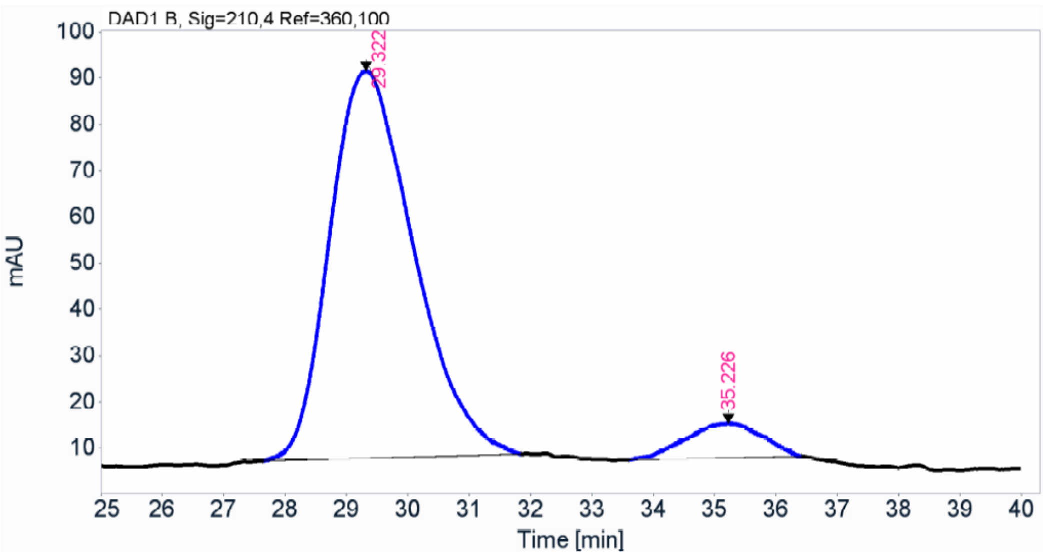


5j



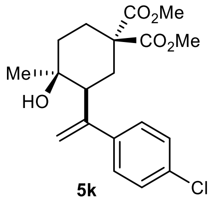
Signal: DAD1 B, Sig=210,4 Ref=360,100

RT [min]	Type	Width [min]	Area	Height	Area%
28.501	BB	1.6572	29771.641	268.5816	49.83
34.442	MM	2.0086	29977.330	248.7364	50.17

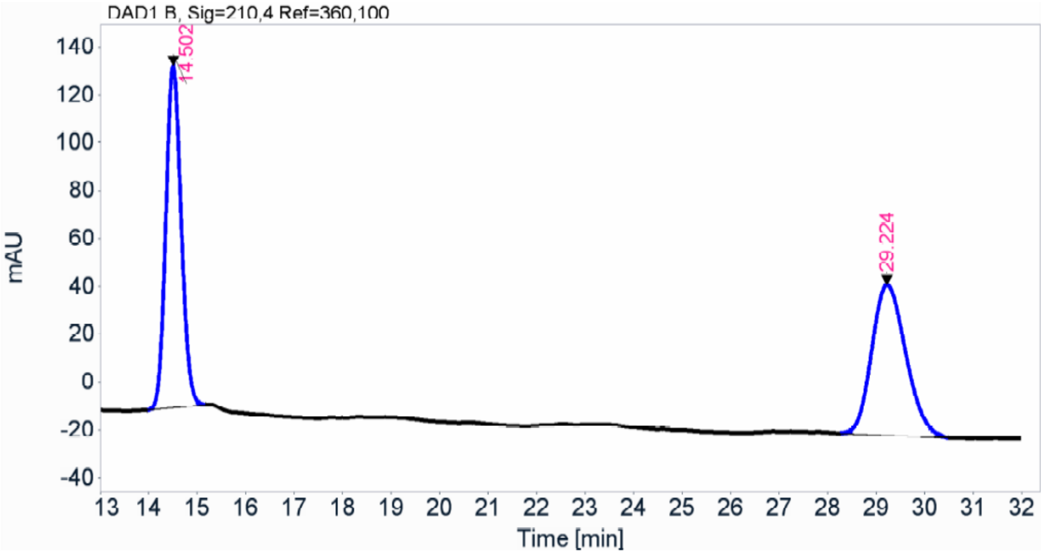


Signal: DAD1 B, Sig=210,4 Ref=360,100

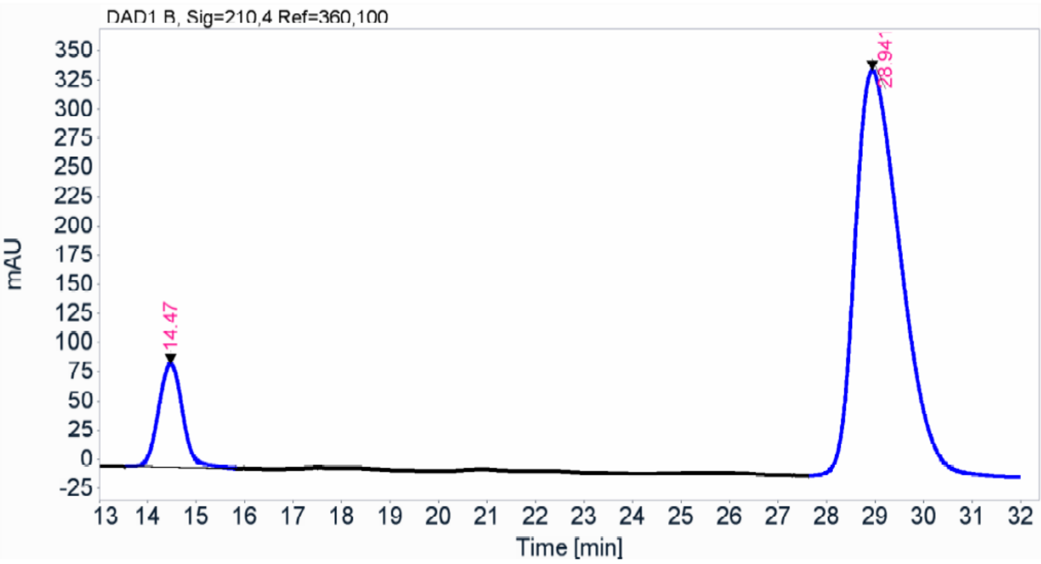
RT [min]	Type	Width [min]	Area	Height	Area%
29.322	BB	1.3479	7956.773	83.6343	92.45
35.226	BB	1.0280	649.418	7.4721	7.55



5k



Signal:	DAD1 B, Sig=210,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
14.502	BB	0.3436	3152.104	142.7668	50.65
29.224	BB	0.7574	3071.185	62.9227	49.35



Signal:	DAD1 B, Sig=210,4 Ref=360,100				
RT [min]	Type	Width [min]	Area	Height	Area%
14.470	BB	0.5478	3065.188	88.5627	11.92
28.941	BB	1.0045	22649.174	347.4564	88.08

References

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