The Enantioselective α-Amination of Aldehydes via Photoredox Organocatalysis

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Supporting Information

I. General Information. Commercial reagents were purified prior to use following the guidelines of Perrin and Armarego.[1] Dimethylsulfoxide (DMSO) and 2,6-lutidine were distilled from CaH_2 prior to use. Octanal and propanal were passed through a short plug of basic alumina and then distilled. All other solvents were purified according to the method of Grubbs.[2] Organic solutions were concentrated under reduced pressure on a Büchi rotary evaporator. Chromatographic purification of products was accomplished using force-flow chromatography according to the method of Still[3] on ICN 60 32-64 mesh silica gel 63. Silicycle silica gel or Iatrobeads 6RS-8060 silica gel were used where specified. Thin-layer chromatography (TLC) was performed on Silicycle 250 mm silica gel F-254 plates. Visualization of the developed plates was performed by fluorescence quenching or by KMnO4, anisaldehyde, ceric ammonium molybdate, or ninhydrin stain.

^{1}H and ^{13}C NMR spectra were recorded on a Bruker UltraShield 500 (500 MHz or 125 MHz) outfitted with a cryoprobe and are internally referenced to residual protio solvent signals (note: $CDCl_3$ referenced at δ 7.27 ppm for ^{1}H and δ 77.0 ppm for ^{13}C; DMSO-d6 referenced at δ 2.54 ppm for ^{1}H). Data for ^{1}H NMR are reported as follows: chemical shift (δ ppm), multiplicity (s = singlet, bs = broadsinglet, d = doublet, t = triplet, q = quartet, hept = heptet, m = multiplet, dd = doublet of doublets, dt = doublet of triplets, ap = apparent), integration, coupling constant (Hz), and assignment. Data for ^{13}C NMR are reported in terms of chemical shift. IR spectra were recorded on a Perkin Elmer Paragon 1000 spectrometer and are reported in terms of frequency of absorption (cm−1). UV/Vis measurements were taken on a Thermo Genesys 6 single-beam

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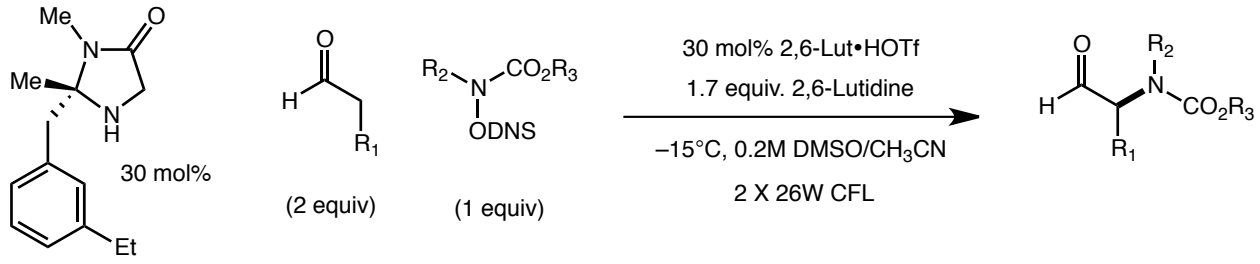
[1] Perrin, D. D.; Armarego, W. L. F. *Purification of Laboratory Chemicals*; 3rd ed., Pergamon Press, Oxford, 1988.
[2] Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics,* **1996**, *15*, 1518.
[3] Still, W. C.; Kahn, M.; Mitra, A. J. *J. Org. Chem.* **1978**, *43*, 2923.

spectrophotometer in a 10.0 mm path-length quartz cell. High Resolution Mass spectra were obtained from the Princeton Mass Spectrometry Laboratory. Supercritical fluid chromatography (SFC) was performed on a Berger Multigram II equipped with a diode array UV detector (λ = 214–280 nm) using a chiral column (2 x 15 cm) as noted for each compound. High Performance Liquid chromatography (HPLC) was performed on a Hewlett-Packard 1100 Series chromatographs using a chiral column (25 cm) and guard column (5 cm) as noted for each compound. Optical rotations were measured on a Jasco P-1010 polarimeter with $[\alpha]_D^{20}$ values reported in degrees; concentration (c) is in g/100 mL.

II. General Procedure for Enantioselective α-Amination of Aldehydes.



To an oven-dried 8 mL vial equipped with a magnetic stir bar and Teflon septum was added (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), and the amine reagent **1**-**8** (0.533 mmol, 1.0 equiv). The vial was then degassed by alternative evacuation and back filling with nitrogen (1 min x 3). DMSO (0.66 mL), CH_3CN (1.98 mL), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and aldehyde (1.07 mmol, 2.0 equiv) were then added to the vial via syringe addition. The resulting clear solution was degassed for 5 min by bubbling nitrogen through the reaction medium. The reaction vial (sealed with parafilm) was placed in a −15 °C acetone-containing cryocool and positioned approximately 3 cm from 2 X 26 W compact fluorescent light bulb (inserted into a Pyrex glass tube).[4] Upon completion, the reaction mixture was poured into a separatory funnel containing 10 mL of saturated aqueous $NaHCO_3$ and extracted with EtOAc (2 x 20 mL). The combined organic layers were washed with brine (20 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resulting crude oil was purified by flash chromatography on Iatrobeads with the

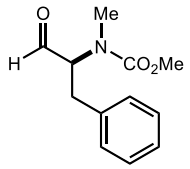
[4] Refer to Section X for a detailed description of the photo-cryocool.

solvent mixture as noted to provide the pure aldehyde products. Racemic samples were obtained by carrying out the reaction with *rac*-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one catalyst. The enantiomeric excess was determined by chiral HPLC analysis of the corresponding alcohol (Procedure A) or 2-naphthoyl ester derivative (Procedure B).

Procedure A, conversion to the corresponding alcohol: to a stirred suspension of $NaBH_4$ (1 equiv) in a 1:1 mixture of CH_2Cl_2/EtOH (0.1 M) at −30 °C was added dropwise a solution of aldehyde starting material (1.0 equiv) in CH_2Cl_2 (0.4 M). The reaction mixture was stirred for 15 min at −30 °C then allowed to warm to 0 °C for 20 min before being quenched by the careful addition of aqueous citric acid (10 wt.%, 0.6 mL). The resulting solution was warmed to room temperature then poured into water (5 mL) and extracted with EtOAc (2 x 10 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (5 mL) and brine (5 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. The obtained alcohol was submitted to chiral HPLC analysis without any further purification.

Procedure B, conversion to the corresponding 2-naphthoyl ester derivative: the alcohol obtained following Procedure A was dissolved in CH_2Cl_2 (0.2 M) and treated with with DMAP (2.0 equiv) and 2-naphthoyl chloride (2.0 equiv). After complete consumption of the alcohol (as judged by TLC analysis), the resulting crude product was purified directly by flash column chromatography on silica gel (1% EtOAc/CH_2Cl_2→5% EtOAc/CH_2Cl_2) to provide the corresponding 2-naphthoyl ester derivative, which was submitted to chiral HPLC analysis.

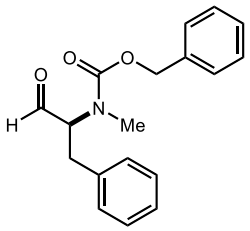
(*S*)-Methyl methyl(1-oxo-3-phenylpropan-2-yl)carbamate (Table 2, entry 1)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-phenylpropanal (140

μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 16 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (30% EtOAc/hexanes) to provide the pure title compound (93 mg, 79% yield, 92% ee) as a light yellow oil. IR (thin film): 3028, 2956, 1737, 1688, 1455, 1389, 1316, 1196, 1151, 771, 743, 700 cm^{-1}; $[\alpha]_D^{20} = -31.55$ (c = 0.8, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.66 (s, 1H, C**H**O), 7.35-7.12 (m, 5H, Ar**H**), 4.28 (dd, 1H, *J* = 10.2, 4.9 Hz, C**H**NR_2), 4.22 (dd, 1H, *J* = 10.0, 4.5 Hz, ·C**H**NR_2), 3.72 (s, 3H, OC**H**$_3$), 3.62 (s, 3H, *OC**H**$_3$), 3.33 (ap dt, 1H, *J* = 15.3, 4.6 Hz, PhC**H**H), 3.01 (dd, 1H, *J* = 14.3, 10.3 Hz, PhCH**H**), 2.90 (dd, 1H, *J* = 14.0, 10.4 Hz, *PhCH**H**), 2.77 (s, 3H, *NC**H**$_3$), 2.69 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 198.9 *(198.8), 157.1 *(156.3), 137.3 *(137.1), 129.0 (2C), 128.6 (2C) *(128.7, 2C), 126.7 *(126.8), 68.7, 53.1 *(52.9), 34.3 *(34.7), 32.7 *(33.3); HRMS (ESI-TOF) calculated for $C_{12}H_{16}NO_3$ $[M+H]^+$ m/z 222.1125, found 222.1124; HPLC analysis of the corresponding alcohol (OD, 5% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 92% ee: t_R(major) = 23.2 minutes, t_R(minor) = 26.0 minutes.

(*S*)-Benzyl methyl(1-oxo-3-phenylpropan-2-yl)carbamate (Table 2, entry 2)

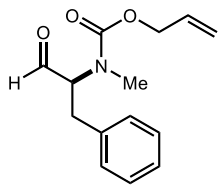


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), benzyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (219 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-phenylpropanal (140 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 16 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (15% EtOAc/hexanes) to provide the pure title compound (119 mg, 75%

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

yield, 88% ee) as a colorless oil. IR (thin film): 2941, 1738, 1693, 1455, 1399, 1314, 1248, 1201, 1052, 993, 933, 772, 744, 702 cm^{-1}; $[\alpha]_D^{20} = -21.11$ (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.69 (s, 1H, *CHO), 9.66 (s, 1H, C**H**O), 7.38-7.07 (m, 10H, Ar**H**), 5.18-5.00 (m, 2H, OC**H**$_2$Ph), 4.31-4.28 (m, 1H, C**H**NR_2), 3.36-3.28 (m, 1H, PhC**H**H), 3.05-3.00 (m, 1H, PhCH**H**), 2.78 (s, 3H, *NC**H**$_3$), 2.70 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 198.9 *(198.8), 155.7 *(156.5), 137.2 *(137.1), 136.3 *(135.8), 129.0 (2C), 128.6 (2C) *(128.7, 2C), 128.5 (2C), 128.3 (2C), 128.1, 126.7 *(126.8), 68.6 *(68.7), 67.5 *(67.8), 34.6 *(34.4), 32.6 *(32.2); HRMS (ESI-TOF) calculated for $C_{18}H_{20}NO_3$ $[M+H]^+$ m/z 298.1438, found 298.1442; HPLC analysis of the corresponding alcohol (AS, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 88% ee: t_R(major) = 25.2 minutes, t_R(minor) = 29.0 minutes.

(*S*)-Allyl methyl(1-oxo-3-phenylpropan-2-yl)carbamate (Table 2, entry 3)

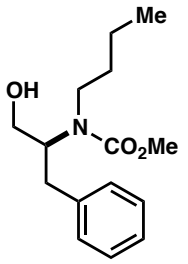


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), allyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (193 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-phenylpropanal (140 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:2, 2.64 mL, 0.2 M). After 19 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (20% EtOAc/hexanes) to provide the pure title compound (99 mg, 75% yield, 90% ee) as a colorless oil. IR (thin film): 2941, 1738, 1693, 1455, 1399, 1314, 1248, 1201, 1152, 1053, 993, 933, 772, 744, 702 cm^{-1}; $[\alpha]_D^{20} = -22.89$ (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.69 (s, 1H, *CHO), 9.67 (s, 1H, C**H**O), 7.34-7.15 (m, 5H, Ar**H**), 5.92 (m, 1H, C**H**=CH_2), 5.80 (m, 1H, $^\cdot$C**H**=CH_2), 5.27 (d, 1H, *J* = 17.2 Hz, CH=C**H**H), 5.22 (d, 1H, *J* = 11.0 Hz, CH=CH**H**), 4.65-4.46 (m, 2H, OC**H**$_2$CH=CH_2), 4.30 (dd, 1H, *J* = 10.3, 4.9 Hz, C**H**NR_2),

$^\cdot$ Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

4.30 (dd, 1H, *J* = 10.4, 4.4 Hz, *C**H**NR$_2$), 3.34 (m, 1H, PhC**H**H), 3.02 (dd, 1H, *J* = 14.3, 10.4 Hz, PhCH**H**), 2.92 (dd, 1H, *J* = 14.1, 10.5 Hz, *PhCH**H**), 2.77 (s, 3H, *NC**H**$_3$), 2.72 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 198.9 *(198.8), 155.6 *(156.4), 137.3 *(137.1), 132.5 *(132.1), 129.0 (2C), 128.7 (2C), 126.7 *(126.8), 117.5 *(118.3), 68.6 *(68.7), 66.4 *(66.6), 34.6 *(34.3), 32.7 *(33.3); HRMS (ESI-TOF) calculated for $C_{14}H_{18}NO_3$ $[M+H]^+$ m/z 248.1281, found 248.1279; HPLC analysis of the corresponding alcohol (AS, 3% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 90% ee: t_R(major) = 28.2 minutes, t_R(minor) = 33.5 minutes.

(*S*)-Methyl butyl(1-oxo-3-phenylpropan-2-yl)carbamate (Table 2, entry 4)

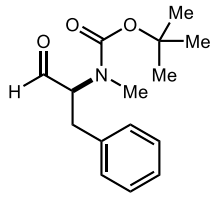


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), butyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (201 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-phenylpropanal (140 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 24 h, the reaction mixture was subjected to the workup protocol and in-situ reduction as outlined in the general procedures and purified by flash chromatography (0–15% EtOAc/hexanes) to provide the pure title compound (107 mg, 76% yield, 91% ee) as a light yellow oil. IR (thin film): xxxx, xxx cm^{-1}; $[\alpha]_D^{20}$ = −31.04 (c = 0.5, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) ^{1}H NMR (501 MHz, CDCl3) 9.62 (s, 1H), 7.10–7.31 (m, 5H), 3.71 (d, *J* = 28.4 Hz, 4H), 3.35 (tt, *J* = 13.0, 6.1 Hz, 2H), 3.23 (dt, *J* = 15.0, 7.2 Hz, 1H), 3.10 (dd, *J* = 14.1, 10.0 Hz, 1H), 2.94 (dd, *J* = 13.9, 9.9 Hz, 1H), 2.50, 2.35 (m, 0H), 1.64 (s, 1H).^{13}C NMR (125 MHz, $CDCl_3$) δ xxx.x [·](xxx.x); HRMS (ESI-TOF) calculated for $C_{15}H_{22}NO_3$ $[M+H]^+$ m/z 264.1594, found 264.1952; HPLC

[·] Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

analysis of the corresponding alcohol (AS, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 91% ee: t_R(major) = 8.2 minutes, t_R(minor) = 6.7 minutes.

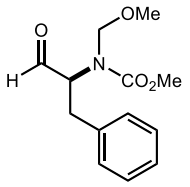
(*S*)-*tert*-Butyl methyl(1-oxo-3-phenylpropan-2-yl)carbamate (Table 2, entry 5)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), *tert*-butyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (201 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-phenylpropanal (140 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:2, 2.64 mL, 0.2 M). After 19 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (10% EtOAc/hexanes) to provide the pure title compound (96 mg, 68% yield, 89% ee) as colorless crystals. IR (thin film): 3029, 2977, 2933, 1738, 1683, 1497, 1480, 1454, 1391, 1367, 1322, 1251, 1149, 1074, 955, 868, 772, 744, 700 cm^{-1}; $[\alpha]_D^{20} = -24.47$ (c = 1.5, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.66 (s, 1H, C**H**O), 7.33-7.14 (m, 5H, Ar**H**), 4.18 (dd, 1H, *J* = 10.3, 4.7 Hz, ·C**H**NR_2), 4.00 (dd, 1H, *J* = 10.4, 4.0 Hz, C**H**NR_2), 3.31 (dd, 1H, *J* = 14.1, 3.7 Hz, PhC**H**H), 3.01 (dd, 1H, *J* = 14.1, 10.5 Hz, *PhCH**H**), 3.01 (dd, 1H, *J* = 13.9, 10.6 Hz, PhCH**H**), 2.67 (s, 3H, NC$\mathbf{H}_3$), 2.61 (s, 3H, *NC$\mathbf{H}_3$), 1.43 (s, 9H, *C(C$\mathbf{H}_3$)$_3$), 1.38 (s, 9H, C(C$\mathbf{H}_3$)$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.4 *(199.0), 155.8 *(154.7), 137.6, 129.2 (2C), 128.8 (2C) *(128.6, 2C), 126.8 *(126.6), 77.3, 69.5, 35.0 *(34.7), 33.5 *(32.7), 28.2 (3C) *(28.3, 3C); HRMS (ESI-TOF) calculated for $C_{15}H_{22}NO_3$ $[M+H]^+$ m/z 264.1594, found 264.1593; HPLC analysis of the corresponding alcohol (AS, 2% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 89% ee: t_R(major) = 12.0 minutes, t_R(minor) = 14.8 minutes.

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

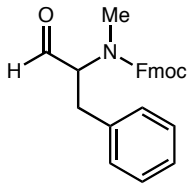
(*S*)-Methyl methoxymethyl(1-oxo-3-phenylpropan-2-yl)carbamate (Table 2, entry 6)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methoxymethyl)carbamate **x** (195 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-phenylpropanal (140 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 16 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (30% EtOAc/hexanes) to provide the pure title compound (101 mg, 75% yield, 94% ee) as a light yellow oil which solidified spontaneously upon standing. IR (thin film): 2939, 2816, 1739, 1688, 1453, 1292, 1099, 912, 747, 702 cm^{-1}; $[\alpha]_D^{20} = -33.88$ (c = 0.5, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.65 (s, 1H, C**H**O), 9.63 (s, 1H, *C**H**O), 7.34-7.13 (m, 5H, Ar**H**), 4.82 (d, 1H, *J* = 10.5 Hz, ·C**H**HOMe), 4.67 (d, 1H, *J* = 10.8 Hz, C**H**HOMe), 4.04 (ap dt, 1H, *J* = 10.9, 4.7 Hz, C**H**NR_2), 3.93 (ap t, 1H, *J* = 11.5 Hz, CH**H**OMe + *CH**H**OMe), 3.80 (s, 3H, OC$\mathbf{H}_3$), 3.75 (s, 3H, *OC$\mathbf{H}_3$), 3.40 (ap dt, 1H, *J* = 14.3, 4.6 Hz, PhC**H**H), 3.27 (s, 3H, *OC$\mathbf{H}_3$), 3.23 (s, 3H, OC$\mathbf{H}_3$), 3.10 (dd, 1H, *J* = 14.2, 10.4 Hz, PhCH**H**), 2.98 (dd, 1H, *J* = 14.1, 10.2 Hz, *PhCH**H**); ^{13}C NMR (125 MHz, $CDCl_3$) δ 198.6 *(198.4), 156.2 *(156.3), 137.6 *(137.2), 129.0 (2C), 128.6 (2C) *(128.7, 2C), 126.7 *(126.8), 79.4 *(79.8), 67.1 *(66.8), 55.6 *(55.9), 53.4 *(53.2), 33.0 *(33.8); HRMS (ESI-TOF) calculated for $C_{13}H_{17}NNaO_4$ $[M+Na]^+$ m/z 274.1050, found 274.1050; HPLC analysis of the corresponding alcohol (AS, 3% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 94% ee: t_R(major) = 23.5 minutes, t_R(minor) = 32.3 minutes.

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

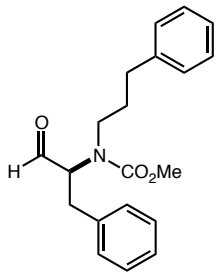
(*S*)-Methyl methyl(3-methyl-1-oxobutan-2-yl)carbamate (Table 2, entry 7)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.04 mmol, 0.30 equiv), 2,6-lutidinium triflate (10.6 mg, 0.04 mmol, 0.30 equiv), 9-fluorenyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (66 mg, 0.133 mmol, 1.0 equiv), 2,6-lutidine (26 μL, 0.23 mmol, 1.7 equiv) and hydrocinnamaldehyde (35 μL, 0.267 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 0.66 mL, 0.2 M). After 35 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (10-30% EtOAc/hexanes) to provide the pure title compound (34mg, 72% yield, 89% ee) as a colorless oil. IR (thin film): cm^{-1}; $[\alpha]_D^{20} = -51.7$ (c = 0.1 EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.62 (s, 1H, C**H**O), 9.16 (s, 1H, *C**H**O), 7.77 (d, 5H, *J* = 6.70 Hz, Ar**H**), 7.64-7.14 (m, 20H, Ar**H**) 6.82 (d, 1H, J=6.70, Ar**H**) 4.73 (dd, 1H, *J* = 4.75, 15.42 Hz, *Hfmoc·), 4.48 (m, 1H, fmoc), 4.40 (m, 2H, $CO_2C\mathbf{H_2}$), 4.23 (m, 1H, C**H**NR_2) 4.12 (m, 2H, *Fmoc) 3.87 (dd, 1H, J=4.86, 14.95 Hz, *C**H**NR_2) 3.34 (dd, 1H, J= 4.62, 18.84, PhC**H**H) 3.00 (dd, 1H, J=10.57, 24.44, PhCH**H**) 2.90 (dd, 1H, J=13.98, 18.60 Hz, *PhC**H**H) 2.65 (s, 3H, N**Me**) 2.61 (s, 3H, *N**Me**) 2.32 (dd, 1H, J=10.82, 24.55 Hz, *PhCH**H**); ^{13}C NMR (125 MHz, $CDCl_3$) δ 198.86 (*198.39), 143.76, 141,30, 137.34, 129.07, 128.76, 127.78, 127,24, 127.07, 126.80, 127.71, 125.04, 124.42, (*120.14) 120.03, 68.93 (*68.40), 67.66, 66.85 (*66.68), 47.25, 34.56, 32.93 (*32.73), 29.72, 27.44, 14.38; HRMS (ESI-TOF) calculated for $C_{25}H_{23}NO_3$ $[M+H]^+$ m/z 385.1679, found 385.1678; HPLC analysis of the corresponding alcohol (AS, 20% ^{i}PrOH/hexanes, 0.8 mL/min, 220 nm) indicates 89% ee: t_R(major) = 7.99 minutes, t_R(minor) = 7.38 minutes.

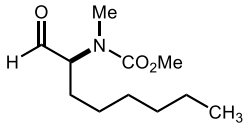
· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

(*S*)-Methyl butyl(3-phenylpropan-2-yl)carbamate (Table 2, entry 8)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (21 mg, 0.09 mmol, 0.30 equiv), 2,6-lutidinium triflate (23 mg, 0.09 mmol, 0.30 equiv), propylphenyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (132 mg, 0.3 mmol, 1.0 equiv), 2,6-lutidine (59 μL, 0.510 mmol, 1.7 equiv) and 3-phenylpropanal (79 μL, 0.60 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 1.50 mL, 0.2 M). After 36 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (0–25% EtOAc/hexanes) to provide the pure title compound (69 mg, 71% yield, 86% ee) as a light yellow oil. IR (thin film): xxxx, xxx cm^{-1}; $[\alpha]_D^{20}$ = −xx.x (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ x.xx (s, 1H, C**H**O); ^{13}C NMR (125 MHz, $CDCl_3$) δ xxx.x ·(xxx.x); HRMS (ESI-TOF) calculated for $C_{20}H_{23}NO_3$ $[M+H]^+$ m/z 264.1594, found 264.xxxx; HPLC analysis of the corresponding alcohol (AS, 3% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 86% ee: t_R(major) = 11.2 minutes, t_R(minor) = 8.9 minutes.

(*S*)-Methyl(1-oxooctan-2-yl)carbamate (Table 3, entry 1)

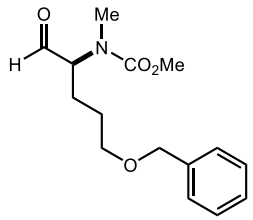


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg,

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and octanal (166 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 18 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (20% EtOAc/hexanes) to provide the pure title compound (81 mg, 71% yield, 90% ee) as a colorless oil. IR (thin film): 2928, 2858, 1737, 1695, 1458, 1391, 1306, 1194, 1158, 772 cm^{-1}; $[\alpha]_D^{20} = -34.20$ (c = 0.1, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.60 (s, 1H, C**H**O), 4.45 (dd, 1H, *J* = 10.5, 4.7 Hz, C**H**NR_2), 4.23 (dd, 1H, *J* = 10.4, 4.5 Hz, ·C**H**NR_2), 3.76 (s, 3H, OC**H**$_3$), 3.71 (s, 3H, *OC**H**$_3$), 2.92 (s, 3H, *NC**H**$_3$), 2.86 (s, 3H, NC**H**$_3$), 1.93 (m, 1H, CHOCHC**H**H), 1.60 (m, 1H, CHOCHCH**H**), 1.40-1.24 (m, 8H, $CH_2(CH_2)_4CH_3$), 0.88 (t, 3H, *J* = 6.4 Hz, CH_2CH_3); ^{13}C NMR (125 MHz, $CDCl_3$) δ 200.2 *(200.1), 157.6 *(156.9), 65.8 *(65.9), 53.0 *(52.9), 31.6 *(32.4), 31.5, 28.9 *(28.8), 25.8 (2C), 22.5, 14.0; HRMS (ESI-TOF) calculated for $C_{11}H_{22}NO_3$ $[M+H]^+$ m/z 216.1594, found 216.1593; HPLC analysis of the corresponding 2-naphthoyl ester derivative (OJ, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 90% ee: t_R(major) = 17.2 minutes, t_R(minor) = 13.1 minutes.

(*S*)-Methyl 5-(benzyloxy)-1-oxopentan-2-yl(methyl)carbamate (Table 3, entry 2)

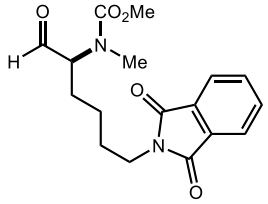


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 5-(benzyloxy)pentanal (205 mg, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:2, 2.64 mL, 0.2 M). After 19 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (25% EtOAc/hexanes) to provide the pure title compound (109 mg, 73%

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

yield, 89% ee) as a colorless oil. IR (thin film): 2953, 2858, 1734, 1698, 1543, 1455, 1393, 1317, 1199, 1158, 1103, 772, 739, 699 cm^{-1}; $[\alpha]_D^{20}$ = 40.02 (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.59 (s, 1H, C**H**O), 7.39-7.26 (m, 5H, Ar**H**), 4.51 (s, 2H, OC**H**$_2$Ph), 4.45 (dd, 1H, *J* = 9.7, 4.3 Hz, C**H**NR_2), 4.26 (m, 1H, ·C**H**NR_2), 3.75 (s, 3H, OC**H**$_3$), 3.69 (s, 3H, *OC**H**$_3$), 3.55-3.48 (m, 2H, C**H**$_2$OBn), 2.92 (s, 3H, *NC**H**$_3$), 2.86 (s, 3H, NC**H**$_3$), 2.10 (m, 1H, CHOCHC**H**H), 1.80-1.61 (m, 3H, CHOCHCH**H** + C**H**$_2CH_2$OBn); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.9 *(199.7), 157.6 *(156.8), 138.3 *(138.2), 128.6 (2C), 128.4 (2C), 127.7, 73.0 *(72.9), 69.3 *(69.4), 65.7 *(65.6), 53.0 *(53.1), 32.5 *(31.8), 26.1, 22.8 *(23.4); HRMS (ESI-TOF) calculated for $C_{15}H_{22}NO_4$ $[M+H]^+$ m/z 280.1543, found 280.1542; HPLC analysis of the corresponding alcohol (OJ, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 89% ee: t_R(major) = 27.4 minutes, t_R(minor) = 28.8 minutes.

(*S*)-Methyl 6-(1,3-dioxoisoindolin-2-yl)-1-oxohexan-2-yl(methyl)carbamate (Table 3, entry 3)

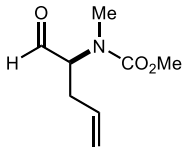


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 6-(1,3-dioxoisoindolin-2-yl)hexanal (262 mg, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:2, 2.64 mL, 0.2 M). After 19 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (25% EtOAc/hexanes) to provide the pure title compound (124 mg, 77% yield, 89% ee) as a colorless oil. IR (thin film): 3346, 2934, 2864, 1672, 1469, 1421, 1348, 1206, 1157, 1105, 1059, 957, 917, 798, 772, 747, 733, 698 cm^{-1}; $[\alpha]_D^{20}$ = −9.26 (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.58 (s, 1H, C**H**O), 7.84 (m, 2H,

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

Ar**H**), 7.73 (m, 2H, Ar**H**), 4.39 (dd, 1H, *J* = 9.9, 4.0 Hz, C**H**NR_2), 4.20 (m, 1H, *C**H**NR_2), 3.72 (s, 3H, OC$\mathbf{H}_3$), 3.70 (s, 3H, *OC$\mathbf{H}_3$), 3.71-3.67 (m, 2H, C$\mathbf{H}_2$NPhth), 2.91 (s, 3H, *NC$\mathbf{H}_3$), 2.86 (s, 3H, NC$\mathbf{H}_3$), 2.03 (m, 1H, CHOCHC**H**H), 1.82-1.64 (m, 3H, CHOCHCH**H** + C$\mathbf{H}_2$$CH_2$NPhth), 1.48-1.35 (m, 2H, C$\mathbf{H}_2$$CH_2$$CH_2$NPhth); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.7 *(199.6), 168.4 (2C), 157.5 *(156.7), 134.0 (2C), 132.0 (2C), 123.2 (2C), 65.7 *(65.8), 53.1, 37.5, 32.0 *(32.7), 28.1, 25.5 *(26.6), 23.2; HRMS (ESI-TOF) calculated for $C_{17}H_{21}N_2O_5$ $[M+H]^+$ m/z 333.1445, found 333.1450; HPLC analysis of the corresponding alcohol (Procedure A, reduction with $NaCNBH_3$, 3.0 equiv) (AS, 15% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 90% ee: t_R(major) = 16.2 minutes, t_R(minor) = 18.9 minutes.

(*S*)-Methyl(1-oxopent-4-en-2-yl)carbamate (Table 3, entry 4)



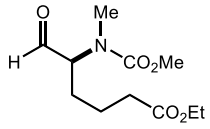
General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 4-pentenal (105 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 16 h, the reaction mixture was purified directly by flash chromatography[5] (55% Et_2O/pentane) to provide the pure title compound (69 mg, 76% yield, 90% ee) as a light yellow oil. IR (thin film): 2957, 2850, 1735, 1689, 1457, 1390, 1313, 1194, 1161, 918, 772 cm^{-1}; $[\alpha]_D^{20} = -21.23$ (c = 0.5, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.61 (s, 1H, C**H**O), 5.78 (m, 1H, C**H**=CH_2), 5.16 (d, 1H, *J* = 17.0 Hz, CH=C**H**H), 5.12 (d, 1H, *J* = 10.2 Hz, CH=CH**H**), 4.41 (dd, 1H, *J* = 10.1, 4.9 Hz, C**H**NR_2), 4.22 (dd, 1H, *J* = 9.8, 4.8 Hz, ·C**H**NR_2), 3.75 (s, 3H, OC$\mathbf{H}_3$), 3.71 (s, 3H, *OC$\mathbf{H}_3$), 2.94 (s, 3H, *NC$\mathbf{H}_3$), 2.89 (s, 3H, NC$\mathbf{H}_3$), 2.74 (m, 1H, CHOCHC**H**H), 2.42 (m, 1H, CHOCHCH**H**); ^{13}C

[5] The workup protocol outlined in the general procedure was avoided due to loss of desired aldehyde in the aqueous medium (during workup) with consequently lower isolated yields.

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

NMR (125 MHz, $CDCl_3$) δ 199.3 *(199.1), 157.5 *(156.6), 133.5 *(133.2), 118.3 *(118.5), 65.7 *(65.9), 53.1 *(53.0), 32.6 *(33.4), 30.8 *(31.4); HRMS (ESI-TOF) calculated for $C_8H_{14}NO_3$ $[M+H]^+$ m/z 172.0968, found 172.0973; HPLC analysis of the corresponding 2-naphthoyl ester derivative (OJ, 5% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 90% ee: t_R(major) = 28.9 minutes, t_R(minor) = 22.8 minutes.

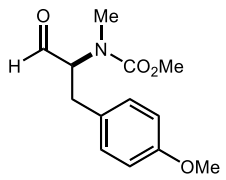
(*S*)-Ethyl 5-(methoxycarbonyl(methyl)amino)-6-oxohexanoate (Table 3, entry 5)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and ethyl 6-oxohexanoate (169 mg, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 18 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (50% EtOAc/hexanes) to provide the pure title compound (103 mg, 79% yield, 90% ee) as a colorless oil. IR (thin film): 2957, 1729, 1693, 1459, 1377, 1304, 1173, 1027, 772 cm^{-1}; $[\alpha]_D^{20} = -31.09$ (c = 0.3, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.58 (s, 1H, C**H**O), 4.43 (dd, 1H, *J* = 9.6, 4.3 Hz, C**H**NR_2), 4.24 (dd, 1H, *J* = 9.0, 4.5 Hz, ·C**H**NR_2), 4.12 (q, 1H, *J* = 7.1 Hz, OC**H**$_2CH_3$), 3.75 (s, 3H, OC**H**$_3$), 3.71 (s, 3H, *OC**H**$_3$), 2.93 (s, 3H, *NC**H**$_3$), 2.87 (s, 3H, NC**H**$_3$), 2.44-2.27 (m, 2H, C**H**$_2CO_2Et$), 1.97 (m, 1H, CHOCHC**H**H), 1.61-1.76 (m, 3H, C**H**$_2CH_2CO_2Et$ and CHOCHCH**H**), 1.25 (t, 3H, *J* = 7.1 Hz, OCH_2C**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.6 *(199.4), 173.1 *(172.9), 157.6 *(156.7), 65.5 *(65.7), 60.4, 53.1 *(53.0), 33.6, 31.8 *(32.5), 25.3 *(25.9), 21.2 *(21.3), 14.2; HRMS (ESI-TOF) calculated for $C_{11}H_{20}NO_5$ $[M+H]^+$ m/z 246.1336, found 246.1341; HPLC analysis of the corresponding 2-naphthoyl ester derivative (AD, 10% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 90% ee: t_R(major) = 24.0 minutes, t_R(minor) = 30.0 minutes.

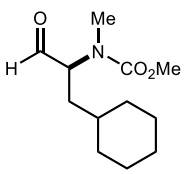
· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

(*S*)-Methyl 1-(4-methoxyphenyl)-3-oxopropan-2-yl(methyl)carbamate (Table 3, entry 6)



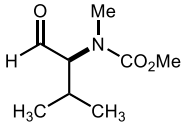
General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **x** (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and 3-(4-methoxyphenyl)propanal (176 mg, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 16 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (25% EtOAc/hexanes) to provide the pure title compound (106 mg, 79% yield, 91% ee) as a light yellow oil. IR (thin film): 2957, 2837, 1737, 1695, 1613, 1584, 1514, 1463, 1392, 1302, 1248, 1179, 1156, 1111, 1034, 835, 794, 773 cm^{-1}; $[\alpha]_D^{20} = 40.61$ (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.66 (s, 1H, C**H**O), 7.12 (d, 2H, *J* = 8.4 Hz, Ar**H**), 7.08 (d, 2H, *J* = 8.4 Hz, *Ar**H**), 6.85 (d, 2H, *J* = 8.4 Hz, Ar**H**), 4.26 (dd, 1H, *J* = 10.2, 5.1 Hz, C**H**NR_2), 4.17 (dd, 1H, *J* = 10.2, 4.7 Hz, *C**H**NR_2), 3.80 (s, 3H, ArOC**H**$_3$), 3.72 (s, 3H, OC**H**$_3$), 3.64 (s, 3H, *OC**H**$_3$), 3.27 (ap dt, 1H, *J* = 14.7, 4.9 Hz, PhC**H**H), 2.95 (dd, 1H, *J* = 14.5, 10.3 Hz, PhCH**H**), 2.85 (dd, 1H, *J* = 14.5, 10.3 Hz, *PhCH**H**), 2.77 (s, 3H, *NC**H**$_3$), 2.70 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.2 *(199.1), 158.4, 157.2 *(156.3), 129.9 (2C), 129.1 *(128.9), 114.0 (2C), 68.7 *(68.8), 55.2, 53.1 *(52.9), 34.2 *(34.8), 31.8 *(32.4); HRMS (ESI-TOF) calculated for $C_{13}H_{18}NO_4$ $[M+H]^+$ m/z 252.1230, found 252.1218; HPLC analysis of the corresponding alcohol (OJ, 5% EtOH/hexanes, 1.0 mL/min, 220 nm) indicates 91% ee: t_R(major) = 25.7 minutes, t_R(minor) = 27.2 minutes.

(*S*)-Methyl 1-cyclohexyl-3-oxopropan-2-yl(methyl)carbamate (Table 3, entry 7)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (27.9 mg, 0.12 mmol, 0.30 equiv), 2,6-lutidinium triflate (30.9 mg, 0.12 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (134 mg, 0.40 mmol, 1.0 equiv), 2,6-lutidine (78 μL, 0.68 mmol, 1.7 equiv) and 3-cyclohexylpropanal (166 μL, 0.80 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 1.98 mL, 0.2 M). After 18 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography (20% EtOAc/hexanes) to provide the pure title compound (65 mg, 72% yield, 91% ee) as a colorless oil. IR (thin film): 2922, 2851, 1735, 1695, 1449, 1390, 1307, 1204, 1191, 1157, 771 cm^{-1}; $[\alpha]_D^{20} = -18.92$ (c = 0.5, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 9.59 (s, 1H, C**H**O), 4.62 (dd, 1H, *J* = 10.6, 4.3 Hz, C**H**NR_2), 4.40 (dd, 1H, *J* = 10.4, 4.0 Hz, ·C**H**NR_2), 3.76 (s, 3H, OC**H**$_3$), 3.72 (s, 3H, *OC**H**$_3$), 2.90 (s, 3H, *NC**H**$_3$), 2.84 (s, 3H, NC**H**$_3$), 1.89-1.62 (m, 7H, CHOCHC**H**H and **Cy**), 1.55 (m, 1H, CHOCHCH**H**), 1.32-1.11 (m, 3H, **Cy**), 1.01 (m, 1H, **Cy**), 0.89 (m, 1H, **Cy**); ^{13}C NMR (125 MHz, $CDCl_3$) δ 200.6 *(200.4), 157.5 *(156.9), 63.3 *(63.4), 53.0, 34.0, 33.9, 33.3, 32.2 (2C), 31.4, 26.4 (2C) *(26.2, 26.0); HRMS (ESI-TOF) calculated for $C_{12}H_{22}NO_3$ $[M+H]^+$ m/z 228.1594, found 228.1600; HPLC analysis of the corresponding 2-naphthoyl ester derivative (OJ, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 91% ee: t_R(major) = 17.7 minutes, t_R(minor) = 13.0 minutes.

(*S*)-Methyl methyl(3-methyl-1-oxobutan-2-yl)carbamate (Table 3, entry 8)

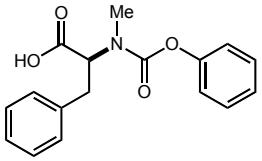


General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (37.2 mg, 0.16 mmol, 0.30 equiv), 2,6-lutidinium triflate (41.2 mg, 0.16 mmol, 0.30 equiv), methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (179 mg, 0.533 mmol, 1.0 equiv), 2,6-lutidine (105 μL, 0.907 mmol, 1.7 equiv) and isovaleraldehyde (114 μL, 1.07 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 2.64 mL, 0.2 M). After 35 h, the reaction mixture

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

was purified directly by flash chromatography[6] (50% Et_2O/pentane) to provide the pure title compound (62 mg, 67% yield, 94% ee) as a light yellow oil. IR (thin film): 2963, 2876, 1732, 1694, 1457, 1384, 1300, 1193, 1164, 772 cm^{-1}; $[\alpha]_D^{20} = -15.18$ (c = 0.2, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 9.69 (s, 1H, C**H**O), 9.66 (s, 1H, *C**H**O), 4.16 (d, 1H, *J* = 9.9 Hz, C**H**NR_2), 3.93 (d, 1H, *J* = 9.8 Hz, $^\cdot$C**H**NR_2), 3.74 (s, 3H, OC**H**$_3$), 3.71 (s, 3H, *OC**H**$_3$), 2.90 (s, 3H, *NC**H**$_3$), 2.84 (s, 3H, NC**H**$_3$), 2.25 (m, 1H, CHOCHC**H**), 1.13 (d, 3H, *J* = 6.5 Hz, C**H**$_3$CHCH_3), 1.10 (d, 3H, *J* = 6.5 Hz, *C**H**$_3$CHCH_3), 0.93 (d, 3H, *J* = 6.3 Hz, CH_3CHC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 199.1 *(198.7), 157.7 *(156.9), 70.9 *(70.7), 53.1 *(52.9), 32.4 *(33.0), 26.4 *(26.7), 20.1 *(20.2), 19.4; HRMS (ESI-TOF) calculated for $C_8H_{16}NO_3$ $[M+H]^+$ m/z 174.1125, found 174.1124; HPLC analysis of the corresponding 2-naphthoyl ester derivative (AD, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 94% ee: t_R(major) = 24.5 minutes, t_R(minor) = 28.7 minutes.

Cbz-N-Me-phenylalanine (Scheme 2)



General α-amination procedure was followed using (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (9.8 mg, 0.04 mmol, 0.30 equiv), 2,6-lutidinium triflate (10.6 mg, 0.04 mmol, 0.3 equiv), benzyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (55 mg, 0.133 mmol, 1.0 equiv), 2,6-lutidine (26 μL, 0.23 mmol, 1.7 equiv) and 3-phenylpropanal (35 μL, 0.267 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 0.66 mL, 0.2 M). After 16 h, the reaction mixture was subjected to the workup protocol outlined in the general procedure and immediately dissolved in 1mL of tBuOH with 100μL of water. To this stirring solution was added NaH_2PO_4 (158 mg, 1.33 mmol, 10 equiv) and $KMnO_4$ (105 mg, 0.665 mmol, 5 equiv). The reaction was allowed to stir for 3 hours and was then quenched with 500μL of NaH_2SO_3. The product was extracted into ethyl acetate (2 x 1mL), washed with brine (1 x 1mL), dried over Mg_2SO_4 and

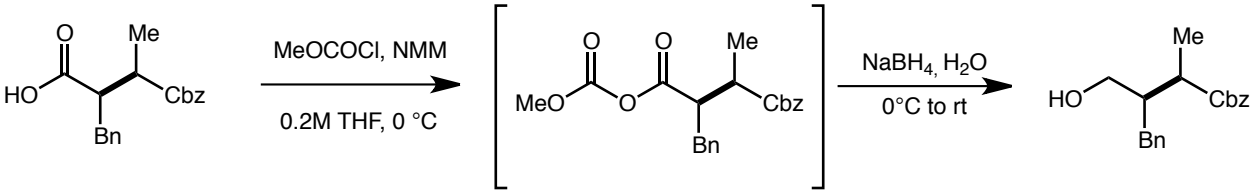
[6] The workup protocol outlined in the general procedure was avoided due to loss of desired aldehyde in the aqueous medium with consequently lower isolated yields.

$^\cdot$ Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

concentrated *in vacuo* to yield a clear oil. The product was purified by flash chromatography on silica gel (40% EtOAc/hexanes + 1% AcOH) to yield the title compound as a white solid (22 mg, 57% yield, 89% ee). IR thin film cm^{-1}; $[\alpha]_D^{20} = -21.2$ (c = 0.1, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 7.33 (m, 5H, J= 9.44, 17.14 Hz, Ar**H**) 7.26 (m, 1H, J=6.60, 21.4 Hz, Ar**H**) 7.19 (t, 3H, J=7.71, 15.41 Hz, Ar**H**) 7.13 (d, 1H, J=7.08 Hz, Ar**H**) 5.12 (s, 2H, C**H$_2$**Ph (Cbz)) 5.03 (s, 2H, *C**H$_2$**Ph), 4.89 (dd, 1H, J=4.78, 16.05 Hz, C**H**NR$_2$) 3.38 (ddd, 2H, C**H**HPh and *C**H**HPh), 3.13 (dd, 1H, J= 13.15, 25.87 Hz, CH**H**Ph), 3.02 (dd, 1H, J=13.15, 25.86 Hz, *CH**H**Ph), 2.86 (s, 3H, N**Me**) 2.78 (s, 3H, *N**Me**) ^{13}C NMR (125 MHz, $CDCl_3$) δ175.56, 157.01, 138.20, 136.72, 128.91 (128.82), 128.48 (128.41), 127.90 (127.75), 127.38, 126.42, 67.13, 60.82, 63.26, 35.19, 34.97, 33.96, 31.65, 29.77; HRMS (ESI-TOF) calculated for $C_{18}H_{19}NO_4$ $[M+H]^+$ m/z 174.1125, found 174.1124; SFC analysis of the N-Cbz amino acid (OZ, 4% MeCN, 1.0 mL/min, 220 nm) indicates 89% ee: t_R(major) = 24.5 minutes, t_R(minor) = 28.7 minutes.

III. Absolute stereochemical proof.

Preparation of an authentic sample of (2*S*)-Benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate

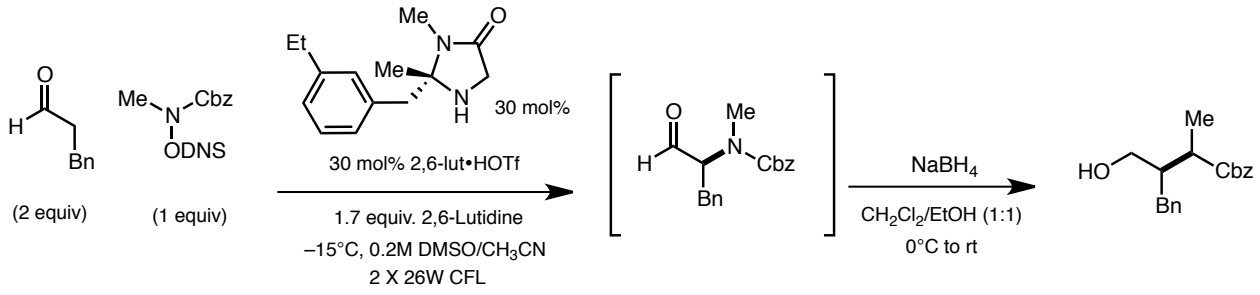


To a stirred solution of (2*S*)-2-[[(benzyloxy)carbonyl](methyl)amino]-3-phenylpropanoic acid[7] (100 mg, 0.319 mmol, 1.0 equiv) in anhydrous THF (1.6 mL) at 0 °C was added *N*-methyl morpholine (35 μL, 0.319 mmol, 1.0 equiv) followed by methyl chloroformate (25 μL, 0.319 mmol, 1.0 equiv). After 30 min, the resulting white suspension was filtered through a sintered funnel and the collected solid (*N*-methyl morpholinium chloride) washed with further anhydrous THF (1.0 mL). The filtrate was then re-cooled to 0 °C and treated with a solution of $NaBH_4$ (18 mg, 0.478 mmol, 1.5 equiv) in H_2O (0.6 mL). After 15 min, the reaction was allowed to warm up to room temperature and stirred for further 30 min before being quenched by the addition of aqueous citric acid (10 wt.%, 1.0 mL). The reaction mixture was poured into water (5 mL) and

[7] Purchased from Aldrich and used without further purification, %ee > 98%, CAS #: 2899-07-2.

extracted with EtOAc (2 x 15 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (5 mL) and brine (5 mL), dried (Mg_2SO_4) and concentrated *in vacuo* to afford the desired (2*S*)-benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate (77 mg, 81% yield, >98% ee) as a colorless oil which was characterized without any further purification. IR (thin film): 3424, 2937, 1680, 1455, 1405, 1341, 1216, 1142, 1031, 746, 699 cm^{-1}; $[\alpha]_D^{20} = -42.5$ (c = 0.5, EtOAc); ^1H NMR (500 MHz, $CDCl_3$) δ 7.39-7.08 (m, 10H, Ar**H**), 5.12 (s, 2H, OC**H**$_2$Ph), 5.01 (bs, 2H, *OC**H**$_2$Ph), 4.45 (m, 1H, ·C**H**NR_2), 4.26 (m, 1H, C**H**NR_2), 3.81-3.63 (m, 2H, HOC**H**$_2$), 2.90 (m, 1H, PhC**H**H), 2.87 (s, 3H, *NC**H**$_3$), 2.78 (s, 3H, NC**H**$_3$), 2.76 (m, 1H, PhCH**H**), 2.56 (bs, 1H, O**H**); ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.3 *(156.8), 138.0 *(137.7), 136.7 *(136.5), 128.9 (2C) *(128.8, 2C), 128.5 (2C), 128.4 (2C), 127.9, 127.6, 126.4 (2C) *(126.5, 2C), 67.0 *(67.2), 63.2 *(62.6), 60.9 *(59.1), 34.6 *(35.1), 31.5 *(29.1); HRMS (ESI-TOF) calculated for $C_{18}H_{22}NO_3$ $[M+H]^+$ m/z 300.1594, found 300.1596; HPLC analysis (AS, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates >98% ee: t_R(major) = 25.2 minutes, t_R(minor) = 29.0 minutes.

General Procedure for Enantioselective α-Amination of Aldehydes followed by an in situ reduction: synthesis of (2*S*)-Benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate (Scheme 2)

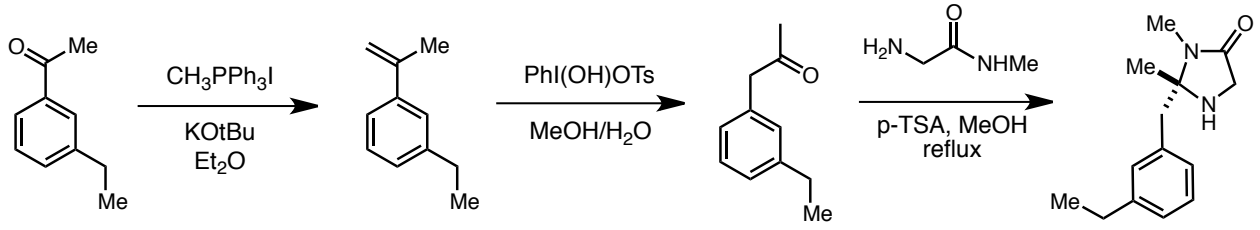


To an oven-dried 8 mL vial equipped with a magnetic stir bar and Teflon septum was added (+)-(2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (18.6 mg, 0.080 mmol, 0.30 equiv), 2,6-lutidinium triflate (20.6 mg, 0.080 mmol, 0.30 equiv), and benzyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (109.7 mg, 0.2667 mmol, 1.0 equiv). The vial was then degassed by alternative evacuation and back filling with nitrogen (1 min x 3). DMSO (0.33

· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

mL), CH_3CN (0.99 mL), 2,6-lutidine (52 μL, 0.453 mmol, 1.7 equiv) and 3-phenylpropanal (70 μL, 0.533 mmol, 2.0 equiv) were then added to the vial via syringe addition. The resulting clear solution was degassed for 5 min by bubbling nitrogen through the reaction medium. The reaction vial (sealed with parafilm) was placed in a −15 °C acetone-containing cryocool and positioned approximately 3 cm from a 26 W compact fluorescent light bulb (inserted into a Pyrex glass tube).[8] After 16 h, the reaction mixture was directly added via syringe to a stirred suspension of $NaBH_4$ (~30 mg, 3 equiv) in a 1:1 mixture of CH_2Cl_2/EtOH (1.6 mL) at −30 °C. The reaction mixture was stirred for 15 min at −30 °C then allowed to warm to 0 °C for 20 min before being quenched by the careful addition of aqueous citric acid (10 wt.%, 0.6 mL). The reaction mixture was poured into water (10 mL) and extracted with EtOAc (2 x 20 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (5 mL) and brine (5 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. Purification by flash chromatography on silica gel (10% EtOAc/CH_2Cl_2 + 1% MeOH) provided the pure title compound (60 mg, 75% yield, 88% ee) as a colorless oil. Spectroscopic data matched that previously obtained for (2*S*)-Benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate. HPLC analysis (AS, 4% ^{i}PrOH/hexanes, 1.0 mL/min, 220 nm) indicates 88% ee: t_R(major) = 25.2 minutes, t_R(minor) = 29.0 minutes. $[\alpha]_D^{20} = -37.6$ (c = 0.5, EtOAc). The experimental optical rotation indicates that the compound is indeed (2*S*)-Benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate when compared to the optical rotation obtained for the authentic sample (>98% ee, $[\alpha]_D^{20} = -42.5$ (c = 0.5, EtOAc)). The stereochemistry of all the other compounds in this publication was assigned by analogy.

IV. Synthesis of *rac*-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one



[8] Refer to Section X for detailed description of the photo-cryocool.

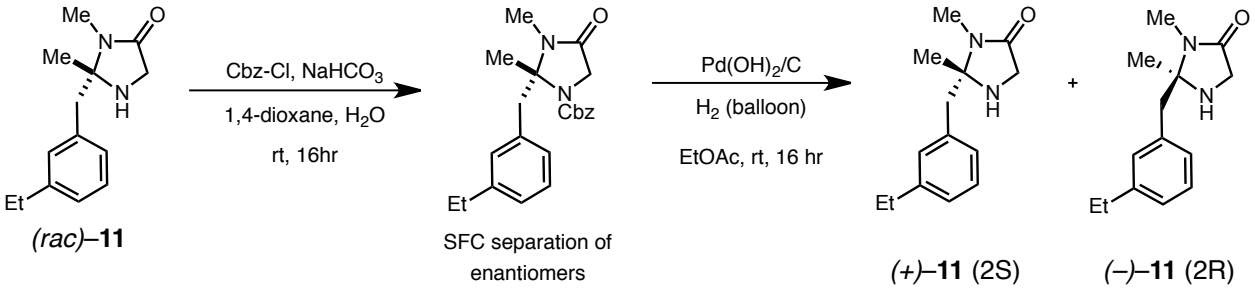
To a stirred suspension of methyl triphenylphosphonium iodide (6.87 g, 17.00 mmol, 1.2 equiv) in anhydrous Et_2O (20 mL) at room temperature was added KO^{t}Bu (1.91 g, 17.00 mmol, 1.2 equiv) and the resulting bright-yellow mixture was stirred for 30 min. After cooling to 0 °C, a solution of 1-(3-ethylphenyl)ethan-1-one[9] (2.10 g, 14.17 mmol, 1.0 equiv) in Et_2O (20 mL) was added via cannula and the reaction was allowed to warm to room temperature for 1 h. The resulting white slurry was filtered through a pad of celite and the filter cake was rinsed with Et_2O (2 × 10 mL). The filtrate was concentrated *in vacuo* and purified by flash chromatography on silica gel (100% hexanes) providing 1-ethyl-3-(prop-1-en-2-yl)benzene (1.84 g, 89% yield) as a colorless oil.; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.34-7.25 (m, 3H, Ar**H**), 7.14 (d, 1H, *J* = 7.2 Hz, Ar**H**), 5.38 (s, 1H, C**H**H=C), 5.09 (s, 1H, CH**H**=C), 2.68 (q, 2H, *J* = 7.6 Hz, Ar-C**H**$_2$CH$_3$), 2.17 (s, 3H, C**H**$_3$C=), 1.27 (t, 3H, *J* = 7.6 Hz, Ar-CH$_2$C**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 144.1, 143.4, 141.2, 128.2, 127.0, 125.1, 122.9, 112.2, 28.9, 21.9, 15.7; HRMS (ESI-TOF) calculated for $C_{11}H_{15}$ $[M+H]^+$ m/z 147.1168, found 147.1166.

To a solution of 1-ethyl-3-(prop-1-en-2-yl)benzene (1.84 g, 12.58 mmol, 1.0 equiv) in a 95:5 mixture of MeOH/H_2O (55.0 mL) at room temperature was added in one portion hydroxy(tosyloxy)iodobenzene (Koser's reagent) (4.93 g, 12.58 mmol, 1.0 equiv). After 1 h, the solvent was removed under reduced pressure and the resulting residue was partitioned between CH_2Cl_2 (2 x 40 mL) and brine (40 mL). The layers were separated and the combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo*. Purification by flash chromatography on silica gel (10% EtOAc/hexanes) provided 1-(3-ethylphenyl)propan-2-one (1.77 g, 87% yield) as a colorless oil. IR (thin film): 2966, 2933, 1710, 1607, 1356, 1222, 1157, 778, 700 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.27 (t, 1H, *J* = 7.4 Hz, Ar**H**), 7.13 (d, 1H, *J* = 7.5 Hz, Ar**H**), 7.04 (m, 2H, Ar**H**), 3.68 (s, 2H, ArC**H**$_2$CO), 2.65 (q, 2H, *J* = 7.6 Hz, ArC**H**$_2$CH$_3$), 2.17 (s, 3H, C**H**$_3$CO), 1.24 (t, 3H, *J* = 7.6 Hz, ArCH$_2$C**H**$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 206.8, 144.8, 134.1, 128.9, 128.7, 126.7, 126.6, 51.1, 29.2, 28.7, 15.5; HRMS (ESI-TOF) calculated for $C_{11}H_{15}O$ $[M+H]^+$ m/z 163.1117, found 163.1119.

[9] Purchased from Maybridge and used without further purification, CAS# 22699-70-3.

A 100 mL round-bottomed flask was charged with 1-(3-ethylphenyl)propan-2-one (1.77 g, 10.91 mmol, 1.0 equiv), glycine-*N*-methylamide[10] (2.88g, 32.73 mmol, 3.0 equiv), *p*-toluenesulfonic acid monohydrate (0.208 g, 1.09 mmol, 0.10 equiv) and MeOH (30 mL). The flask was then equipped with a reflux condenser and heated at 90 °C for three days. The solution was concentrated *in vacuo* and the residue was partitioned between CH_2Cl_2 (50 mL) and saturated aqueous $NaHCO_3$ (50 mL). The layers were separated and the organic phase was dried ($MgSO_4$) and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (50% EtOAc/hexanes + 2% MeOH→50% EtOAc/hexanes + 6% MeOH) to provide *rac*-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (1.90 g, 75% yield) as a light yellow solid. IR (thin film): 3317, 2967, 2929, 2868, 1677, 1422, 1398, 1233, 1169, 1117, 1014, 951, 808, 798, 778, 710 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.22 (t, 1H, *J* = 7.5 Hz, Ar**H**), 7.11 (d, 1H, *J* = 7.5 Hz, Ar**H**), 7.02-6.96 (m, 2H, Ar**H**), 3.28 (d, 1H, *J* = 16.1 Hz, COC**H**$_2$NH), 2.95 (d, 1H, *J* = 13.9 Hz, ArC**H**$_2$), 2.92 (s, 3H, NC**H**$_3$), 2.84 (d, 1H, *J* = 16.1 Hz, COC**H**$_2$NH), 2.75 (d, 1H, *J* = 13.8 Hz, ArC**H**$_2$), 2.63 (q, 2H, *J* = 7.6 Hz, ArC**H**$_2$CH$_3$), 1.90 (bs, 1H, N**H**), 1.43 (s, 3H, CC**H**$_3$), 1.22 (t, 3H, *J* = 7.6 Hz, ArCH$_2$C**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.5, 144.4, 135.3, 129.8, 128.4, 127.4, 126.7, 79.8, 48.6, 43.4, 28.7, 25.6 (2C), 15.7; HRMS (ESI-TOF) calculated for $C_{14}H_{21}N_2O$ $[M+H]^+$ m/z 233.1648, found 233.1648.

V. Synthesis of (2*S*) and (2*R*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one



(rac)–**11**

SFC separation of enantiomers

(+)–**11** (2S)

(–)–**11** (2R)

To a stirred solution of *rac*-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (700 mg, 3.01 mmol, 1.0 equiv) in a 2:1 mixture of 1,4-dioxane/H_2O (12.0 mL) at room temperature was added $NaHCO_3$ (506 mg, 6.026 mmol, 2 equiv) followed by benzyl chloroformate (0.473 mL, 3.314 mmol, 1.1 equiv). After 16 h, the reaction mixture was poured into water (20 mL) and extracted

[10] Naef, R.; Seebach, D. *Helv. Chim. Acta* **1985**, *68*, 135-143.

with EtOAc (2 x 25 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (20 mL) and brine (20 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. Purification by flash chromatography on silica gel (50% EtOAc/hexanes) provided the corresponding *N*-Cbz protected imidazolidinone catalyst (994 mg, 90% yield) as a colorless oil. IR (thin film): 2965, 2933, 2871, 1702, 1454, 1412, 1388, 1351, 1299, 1128, 1058, 766, 736, 697 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ7.51 (d, 2H, *J* = 7.2 Hz, ·Ar**H**), 7.45-7.33 (m, 5H, Ar**H**), 7.13 (t, 1H, *J* = 7.8 Hz, *Ar**H**), 7.08-7.02 (m, 2H, Ar**H**), 6.80 (s, 1H, Ar**H**), 6.72 (d, 1H, *J* = 6.8 Hz, Ar**H**), 6.63 (d, 2H, *J* = 6.2 Hz, *Ar**H**), 5.40 (d, 1H, *J* = 12.0 Hz, *OC**H**HPh), 5.27 (d, 1H, *J* = 11.9 Hz, *OCH**H**Ph), 5.26 (d, 1H, *J* = 12.4 Hz, OC**H**HPh), 5.12 (d, 1H, *J* = 12.4 Hz, OCH**H**Ph), 3.73 (d, 1H, *J* = 15.9 Hz, *COC**H**$_2$NH), 3.69 (d, 1H, *J* = 15.6 Hz, COC**H**$_2$NH), 3.60 (d, 1H, *J* = 14.3 Hz, ArC**H**H), 3.31 (d, 1H, *J* = 14.4 Hz, *ArC**H**H), 2.99 (s, 3H, NC**H**$_3$), 2.96 (s, 3H, *NC**H**$_3$), 2.89 (d, 1H, *J* = 15.9 Hz, *COC**H**$_2$NH), 2.87 (d, 1H, *J* = 14.3 Hz, ArCH**H**), 2.83 (d, 1H, *J* = 15.6 Hz, COC**H**$_2$NH), 2.49 (q, 2H, *J* = 7.5 Hz, ArC**H**$_2$CH$_3$), 1.85 (s, 3H, CC**H**$_3$), 1.75 (s, 3H, *CC**H**$_3$), 1.13 (t, 3H, *J* = 7.6 Hz, ArCH$_2$C**H**$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.0 *(166.9), 152.5 *(152.8), 144.5 *(144.7), 136.2 *(135.7), 134.8 *(134.4), 129.0 *(128.9), 128.5 (2C) *(128.9, 2C), 128.5 *(128.6), 128.2 *(128.6), 128.0 (2C) *(128.8, 2C), 126.8 *(127.0), 126.7 *(126.5), 81.7 *(81.2), 66.9 *(67.9), 48.7 *(49.2), 39.1 *(40.5), 28.7, 25.0 *(25.2), 23.5 *(24.6), 15.8; HRMS (ESI-TOF) calculated for $C_{22}H_{27}N_2O_3$ $[M+H]^+$ m/z 367.2016, found 367.2019. Separation of the enantiomers was performed by preparative SFC (LUX-2 cellulose, 40% MeOH + 0.1% $HNEt_2/CO_2$ (100 bar), 65.0 mL/min, 220 nm, sample concentration = 20 mg/mL, 0.5 mL/injection) to provide enantiomerically pure (+)-(2*S*)[11]-benzyl 2-(3-ethylbenzyl)-2,3-dimethyl-4-oxoimidazolidine-1-carboxylate (432 mg, t_R = 1.5 minutes, $[\alpha]_D^{20}$ = +80.1 (c = 0.5, EtOAc), 43% yield) and (−)-(2*R*)-benzyl 2-(3-ethylbenzyl)-2,3-dimethyl-4-oxoimidazolidine-1-carboxylate (440 mg, t_R = 3.1 minutes, $[\alpha]_D^{20}$ = −79.4 (c = 0.5, EtOAc) 44% yield) as colorless oils. To the optically pure (+) and (−)-*N*-Cbz protected catalysts (432 mg, 1.18 mmol) dissolved in EtOAc (15 mL) was added $Pd(OH)_2/C$ (~45 mg, 20 wt.%) and the resulting suspension was purged by evacuation and then back filled with a stream of hydrogen (balloon) for three times. The mixture was stirred for 16 h at room temperature under hydrogen atmosphere and then filtered directly through a pad of celite. The filter cake was rinsed with EtOAc (2 x 10 mL) and the filtrate concentrate *in vacuo* yielded, respectively, pure (−) and

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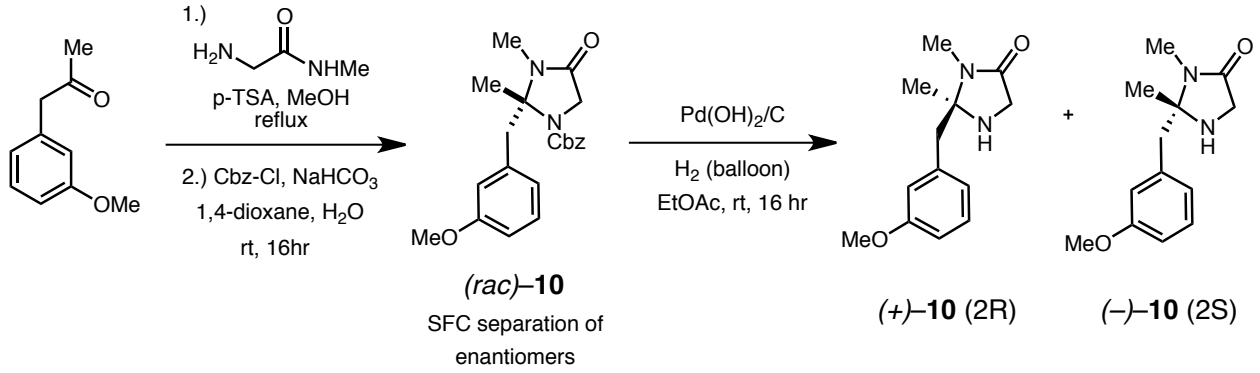
· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

[11] For the stereochemical assignment of the (+) and (−)-catalysts **x** see Section VIII.

(+)-imidazolidinone catalyst **11** (260 mg, 95% yield, >98% ee) as colorless oils that were used without further purification. Spectroscopic data matched that previously obtained for *rac*-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one. Optical rotation for (2*R*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one: $[\alpha]_D^{20} = -67.3$ (c = 0.5, EtOAc); optical rotation for (2*S*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one: $[\alpha]_D^{20} = +70.6$ (c = 0.5, EtOAc).

VI. Synthesis of (2*S*) and (2*R*)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one



A 100 mL round-bottomed flask was charged with 1-(3-methoxyphenyl)propan-2-one[12] (2.00 g, 12.18 mmol, 1.0 equiv), glycine-*N*-methylamide[10] (3.22g, 36.54 mmol, 3.0 equiv), *p*-toluenesulfonic acid monohydrate (0.232 g, 1.218 mmol, 0.10 equiv) and MeOH (35 mL). The flask was then equipped with a reflux condenser and heated to 90 °C for three days. The solution was concentrated *in vacuo* and the residue was partitioned between CH_2Cl_2 (60 mL) and saturated aqueous $NaHCO_3$ (50 mL). The layers were separated and the organic phase was dried ($MgSO_4$) and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (50% EtOAc/hexanes + 2% MeOH→50% EtOAc/hexanes + 15% MeOH) to provide *rac*-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (2.02 g, 71% yield) as a light yellow oil. IR (thin film): 3311, 2922, 2837, 1680, 1600, 1489, 1427, 1397, 1260, 1153, 1042, 785, 746, 693 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.22 (t, 1H, *J* = 7.8 Hz, Ar**H**), 6.81 (d, 1H, *J* = 7.8 Hz, Ar**H**), 6.78-6.73 (m, 2H, Ar**H**), 3.79 (s, 3H, OC**H**$_3$), 3.30 (d, 1H, *J* = 16.1 Hz, COC**H**$_2$NH), 2.96-2.92 (m, 2H, ArC**H**$_2$ + COC**H**$_2$NH), 2.91 (s, 3H, NC**H**$_3$), 2.74 (d, 1H, *J* = 13.8 Hz, ArC**H**$_2$), 1.89 (bs, 1H, N**H**), 1.42 (s, 3H, CC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 173.4, 159.4, 136.9, 129.4,

[12] Purchased from Aldrich and used without further purification, CAS# 3027-13-2.

122.5, 116.1, 112.2, 79.8, 55.1, 48.5, 43.3, 25.6 (2C); HRMS (ESI-TOF) calculated for $C_{13}H_{19}N_2O_2$ $[M+H]^+$ m/z 235.1441, found 235.1445.

To a stirred solution of *rac*-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (967 mg, 4.13 mmol, 1.0 equiv) in a 2:1 mixture of 1,4-dioxane/H_2O (18.0 mL) at room temperature was added $NaHCO_3$ (693 mg, 8.25 mmol, 2 equiv) followed by benzyl chloroformate (0.65 mL, 4.54 mmol, 1.1 equiv). After 16 h, the reaction mixture was poured into water (25 mL) and extracted with EtOAc (2 x 30 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (25 mL) and brine (25 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. Purification by flash chromatography on silica gel (50% EtOAc/hexanes) provided the corresponding *N*-Cbz protected imidazolidinone catalyst (1.38 g, 91% yield) as a white solid. IR (thin film): 3032, 2967, 2940, 2841, 1692, 1586, 1456, 1408, 1386, 1356, 1266, 1157, 1047, 798, 770, 751, 697, 589 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ7.49 (d, 2H, *J* = 6.6 Hz, ·Ar**H**), 7.45-7.32 (m, 5H, Ar**H**), 7.13 (t, 1H, *J* = 7.7 Hz, *Ar**H**), 7.06 (t, 1H, *J* = 7.9 Hz, Ar**H**), 6.76 (m, 1H, Ar**H**), 6.53 (s, 1H, Ar**H**), 6.49 (d, 1H, *J* = 7.3 Hz, Ar**H**), 6.41 (d, 2H, *J* = 8.0 Hz, *Ar**H**), 5.37 (d, 1H, *J* = 12.0 Hz, *OC**H**HPh), 5.27 (d, 1H, *J* = 12.4 Hz, OC**H**HPh), 5.10 (d, 1H, *J* = 12.4 Hz, OCH**H**Ph), 3.77 (d, 1H, *J* = 16.1 Hz, *COC**H**$_2$NH), 3.72 (d, 1H, *J* = 15.6 Hz, COC**H**$_2$NH), 3.68 (s, 3H, OC**H**$_3$), 3.61 (d, 1H, *J* = 14.3 Hz, ArC**H**H), 3.33 (d, 1H, *J* = 14.4 Hz, *ArC**H**H), 2.99 (s, 3H, NC**H**$_3$), 2.96 (s, 1H, *NC**H**$_3$), 2.95 (d, 1H, *J* = 15.8 Hz, COC**H**$_2$NH), 2.87 (d, 1H, *J* = 14.3 Hz, ArCH**H**), 1.84 (s, 3H, CC**H**$_3$), 1.75 (s, 3H, *CC**H**$_3$). ^{13}C NMR (125 MHz, $CDCl_3$) δ 167.0 *(166.9), 159.5 *(159.6), 152.5 *(152.8), 136.3 *(135.8), 136.1 *(135.6), 129.5 *(129.7), 128.5 (2C) *(128.8, 2C), 128.2 *(128.6), 127.9 (2C) *(128.7, 2C), 121.8 *(121.5), 115.0 *(114.9), 112.7 *(112.9), 81.6 *(81.1), 66.8 *(68.0), 55.1, 48.7 *(49.2), 39.2 *(40.5), 25.0 *(25.2), 23.5 *(24.6); HRMS (ESI-TOF) calculated for $C_{21}H_{25}N_2O_4$ $[M+H]^+$ m/z 369.1809, found 369.1809. Separation of the enantiomers was performed by preparative SFC (Chiralpak AS-H, 15% MeOH + 0.1% $HNEt_2$/CO_2 (100 bar), 60.0 mL/min, 220 nm, sample concentration = 13 mg/mL, 0.5 mL/injection) to provide enantiomerically pure (−)-(2*R*)-benzyl 2-(3-methoxybenzyl)-2,3-dimethyl-4-oxoimidazolidine-1-carboxylate (588 mg, t_R = 1.6 minutes, $[\alpha]_D^{20}$ = −81.8 (c = 0.5, EtOAc), 43% yield) and (+)-(2*S*)-

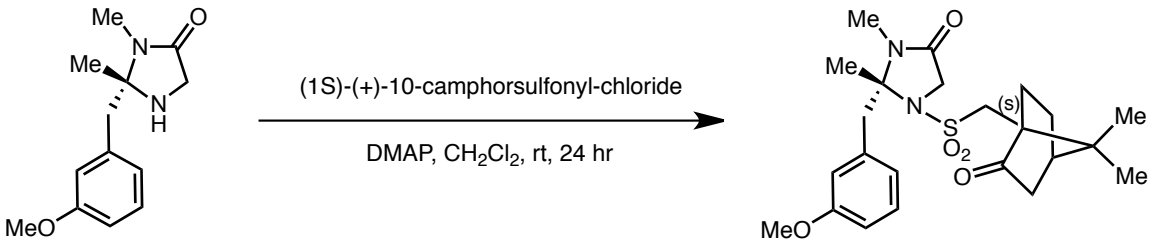
· Distinguishable resonances of the minor rotamer are denoted with an asterisk (*)

benzyl 2-(3-methoxybenzyl)-2,3-dimethyl-4-oxoimidazolidine-1-carboxylate (580 mg, t_R = 2.3 minutes, $[\alpha]_D^{20}$ = +83.9 (c = 0.5, EtOAc) 42% yield) as white crystalline solids.

To the optically pure (−) and (+)-*N*-Cbz protected catalysts (580 mg, 1.57 mmol) dissolved in EtOAc (20 mL) was added $Pd(OH)_2/C$ (~58 mg, 20 wt.%) and the resulting suspension was purged by evacuation and then back filled with a stream of hydrogen (balloon) for three times. The mixture was stirred for 16 h at room temperature under hydrogen atmosphere and then filtered directly through a pad of celite. The filter cake was rinsed with EtOAc (2 x 10 mL) and the filtrate concentrate *in vacuo* yielded, respectively, pure (+) and (−)-imidazolidinone catalyst **11** (360 mg, 98% yield, >98% ee) as light yellow oils that were used without further purification. Spectroscopic data matched that previously obtained for *rac*-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one. Optical rotation for $(2R)$[13]-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one: $[\alpha]_D^{20}$ = −63.6 (c = 0.5, EtOAc); optical rotation for (2*S*)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one: $[\alpha]_D^{20}$ = +64.9 (c = 0.5, EtOAc).

VII. Structural Studies on 2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one

Racemic resolution of (*rac*)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one with (1*S*)-(+)-10-camphor-sulfonyl chloride



(rac)–**10** **10-CS**

To a stirred solution of *rac*-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (250 mg, 1.067 mmol, 1.0 equiv) in anhydrous CH_2Cl_2 (4.0 mL) at room temperature was added DMAP (261 mg, 2.134 mmol, 2.0 equiv) followed by (1*S*)-(+)-10-camphor-sulfonyl chloride (268 mg, 1.067

[13] For the stereochemical assignment of the (+) and (−)-catalysts **10** see Section VII.

mmol, 1.0 equiv). The reaction mixture was stirred for 24 h at room temperature before being quenched by the addition of aqueous citric acid (10 wt.%, 5.0 mL). The reaction mixture was poured into water (10 mL) and extracted with EtOAc (2 x 20 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (20 mL) and brine (20 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. Purification by flash chromatography on silica gel (50% EtOAc/hexanes + 5% MeOH) provided a diasteromeric mixture of camphor sulfonamide **10-CS** (264 mg, 55% yield, 3 : 2 dr determined by ^{1}H NMR) as an amorphous white solid. The residue was dissolved in hot Et_2O/EtOH (3 : 1) and let to crystallize at room temperature for 2 h then at −15 °C for further 6 h. The resulting white crystals were filtered through a sintered funnel, washed with cold ether (2 × 5 mL), collected and dried at high vacuum for 4 h to afford camphor sulfonamide **10-CS** (145 mg, 30% yield) as a single diastereomer (> 95 : 5 dr determined by ^{1}H NMR). IR (thin film): 2959, 2836, 1742, 1705, 1345, 1262, 1148, 1037, 732 cm^{-1}; $[\alpha]_D^{20}$ = +21.0 (c = 0.5, EtOAc); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20 (t, 1H, *J* = 7.8 Hz, Ar**H**), 6.87 (s, 1H, Ar**H**), 6.81 (dd, 1H, *J* = 8.1, 1.6 Hz, Ar**H**), 6.77 (d, 1H, *J* = 7.2 Hz, Ar**H**), 3.79 (s, 3H, OC**H**$_3$), 3.62 (d, 1H, *J* = 14.4 Hz, COC**H**$_2$NH), 3.48 (d, 1H, *J* = 14.6 Hz, SO_2C**H**$_2$), 3.40 (d, 1H, *J* = 14.3 Hz, ArC**H**$_2$), 2.98 (s, 3H, NC**H**$_3$), 2.97-2.89 (m, 3H, ArC**H**$_2$ + COC**H**$_2$NH + SO_2C**H**$_2$), 2.47 (m, 1H, CH_2C**H**$_2$CH), 2.38 (d, 1H, *J* = 18.5 Hz, COC**H**H), 2.12 (s, 1H, $COCH_2$C**H**), 2.06 (m, 1H, CC**H**$_2$$CH_2$CH), 1.97-1.91 (m, 4H, CC**H**$_3$ + COC**H**$_2$), 1.64 (m, 1H, CH_2C**H**$_2$CH), 1.43 (m, 1H, CC**H**$_2$$CH_2$CH), 1.16 (s, 3H, C**H**$_3$$CCH_3$), 0.91 (s, 3H, CH_3CC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 215.3, 166.3, 159.5, 135.6, 129.4, 122.3, 115.4, 113.7, 83.6, 58.7, 55.2, 51.4, 49.6, 48.0, 43.6, 42.8, 42.5, 26.8, 25.5, 25.4, 23.7, 20.0, 19.8; HRMS (ESI-TOF) calculated for $C_{23}H_{33}N_2O_5$ $[M+H]^+$ m/z 449.2105, found 449.2113.

Crystallographic data for (*S*)-1-(((1*S*,4*R*)-7,7-dimethyl-2-oxobicyclo[2.2.1]heptan-1-yl)methylsulfonyl)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one 10-CS

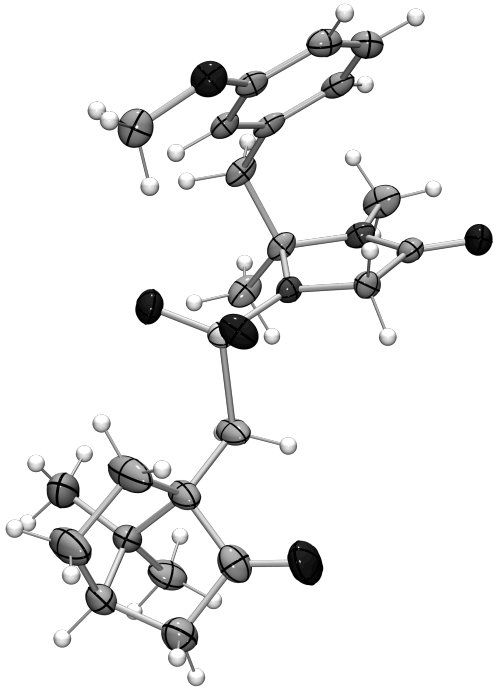


Figure 1: Molecular structure of camphor sulfonamide **10-CS** at 50% probability ellipsoids.

Single crystals of camphor sulfonamide **10-CS** were obtained from a concentrated *n*-heptane/CH_2Cl_2 solution mixture at room temperature. Single crystal X-ray diffraction was performed on a Bruker APEX II CCD system equipped with a Cu ImuS micro-focus source (λ = 1.54178 Å).[14] Importantly, the solved X-ray structure of camphor sulfonamide **10-CS** enabled the assignment of the absolute configuration of the stereogenic centre of the imidazolidinone ring as reported in the title compound.

A total of 5022 frames were collected. The total exposure time was 13.95 hours. The frames were integrated with the Bruker SAINT software package using a narrow-frame algorithm. The integration of the data using amonoclinic unit cell yielded a total of 8329 reflections to a maximum θ angle of 66.36° (0.84 Å resolution), of which 3586 were independent (average redundancy 2.323, completeness = 97.9%, Rint = 3.17%, Rsig = 4.63%) and 3486

[14] Measurements and data elaboration performed by Dr. Charles F. Campana, Bruker AXS Inc., Madison WI and Dr. Bastian M. Theis, Princeton University.

(97.21%) were greater than 2σ(F2). The final cell constants of a = 7.5804(3) Å, b = 13.0877(5) Å, c = 11.8951(4) Å, β = 94.355(2)°, volume = 1176.71(8) Å3, are based upon the refinement of the XYZ-centroids of 7051 reflections above 20 σ(I) with 10.06° < 2θ < 131.6°. Data were corrected for absorption effects using the multi-scan method (SADABS). The ratio of minimum to maximum apparent transmission was 0.481. The calculated minimum and maximum transmission coefficients (based on crystal size) are 0.2942 and 0.9156.

The structure was solved and refined using the Bruker SHELXTL Software Package, using the space group P 1 21 1, with Z = 2 for the formula unit, $C_{23}H_{32}N_2O_5S_2$. The final anisotropic full-matrix least-squares refinement on F2 with 286 variables converged at R1 = 3.45%, for the observed data and wR2 = 7.73% for all data. The goodness-of-fit was 1.712. The largest peak in the final difference electron density synthesis was 0.270e-/Å3 and the largest hole was -0.282 e-/Å3 with an RMS deviation of 0.045 e-/Å3. On the basis of the final model, the calculated density was 1.356 g/cm3 and F(000), 512 e-.

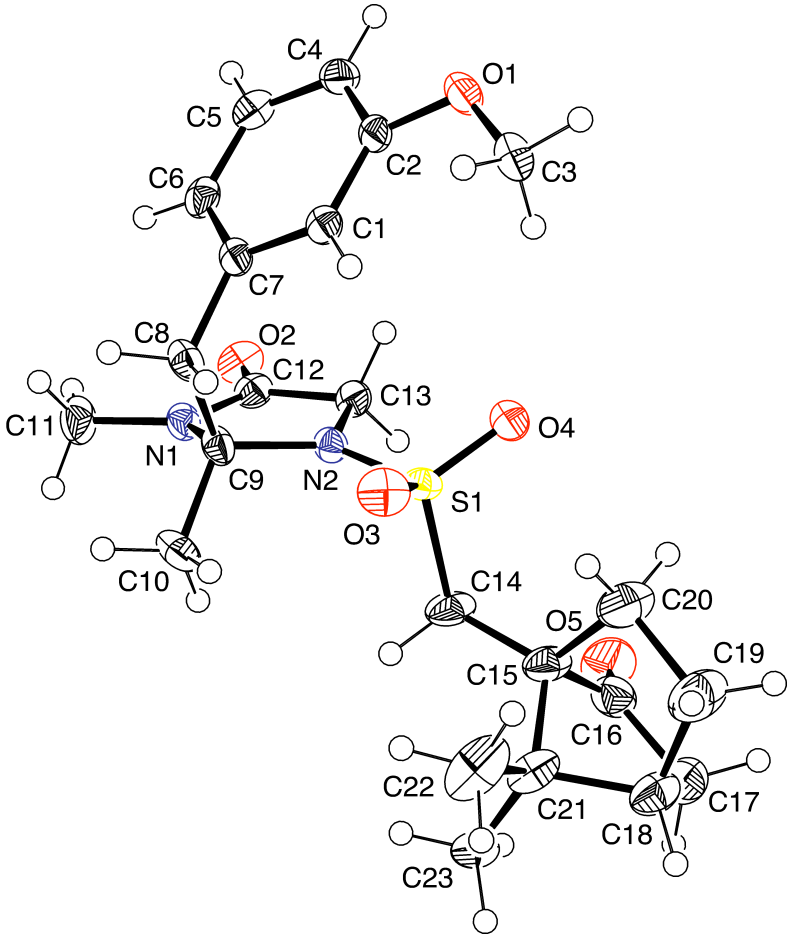


Figure 2: Molecular structure of camphor sulfonamide **10-CS** in the crystal (probability level of displacement ellipsoids 50 %).

Table 1: Crystal data and structure refinement for camphor sulfonamide **10-CS**.

Identification code	camphor sulfonamide **10-CS**
Empirical formula	C23 H32 N2 O5 S2
Formula weight	480.63
Temperature	100(2) K
Wavelength	1.54178 A

Crystal system, space group	Monoclinic, P2(1)
Unit cell dimensions	a = 7.5804(3) A alpha = 90° b = 13.0877(5) A beta = 94.355(2)° c = 11.8951(4) A gamma = 90°
Volume	1176.71(8) A^3
Z, Calculated density	2, 1.356 Mg/m^3
Absorption coefficient	2.362 mm^-1
F(000)	512
Crystal size	0.69 x 0.14 x 0.04 mm
Theta range for data collection	5.03 to 66.36 deg.
Limiting indices	-8<=h<=8, -15<=k<=13, -13<=l<=14
Reflections collected / unique	8329 / 3586 [R(int) = 0.0317]
Completeness to theta = 66.36	97.9 %
Max. and min. transmission	0.9156 and 0.2942
Refinement method	Full-matrix least-squares on F^2
Data / restraints / parameters	3586 / 1 / 286
Goodness-of-fit on F^2	1.712
Final R indices [I>2sigma(I)]	R1 = 0.0345, wR2 = 0.0769
R indices (all data)	R1 = 0.0355, wR2 = 0.0773
Absolute structure parameter	0.033(15)
Extinction coefficient	0.0000(4)

Largest diff. peak and hole 0.270 and -0.282 e.A^-3

Table 2: Atomic coordinates ($\times 10^4$) and equivalent isotropic displacement parameters ($A^2 \times 10^3$) for camphor sulfonamide **10-CS** U(eq) is defined as one third of the trace of the orthogonalized Uij tensor.

	x	y	z	U(eq)
C(1)	2746(2)	4223(2)	617(2)	23(1)
C(2)	1129(2)	3984(2)	61(2)	24(1)
O(1)	-300(2)	3643(1)	597(1)	30(1)
C(3)	-164(3)	3640(2)	1801(2)	32(1)
C(4)	870(3)	4063(2)	-1097(2)	29(1)
C(5)	2263(3)	4386(2)	-1708(2)	31(1)
C(6)	3891(3)	4618(2)	-1161(2)	28(1)
C(7)	4144(2)	4552(2)	-5(2)	24(1)
C(8)	5851(2)	4867(2)	642(2)	27(1)
C(9)	6062(2)	6028(2)	757(2)	25(1)
N(1)	6172(2)	6512(2)	-340(1)	26(1)
C(10)	7666(2)	6301(2)	1547(2)	33(1)
C(11)	7671(3)	6348(2)	-1016(2)	38(1)
C(12)	4714(3)	7017(2)	-749(2)	25(1)
O(2)	4459(2)	7411(1)	-1675(1)	34(1)
C(13)	3416(3)	7015(2)	153(2)	25(1)
N(2)	4403(2)	6520(2)	1098(1)	22(1)
S(1)	3626(1)	6477(1)	2322(1)	24(1)
O(3)	4463(2)	5657(1)	2946(1)	36(1)
O(4)	1744(2)	6501(2)	2138(1)	35(1)
C(14)	4296(3)	7657(2)	2961(2)	35(1)
C(15)	3539(3)	7935(2)	4070(2)	34(1)
C(16)	2696(3)	8993(2)	4026(2)	37(1)
O(5)	2238(2)	9472(2)	3188(2)	53(1)
C(17)	2586(3)	9335(2)	5239(2)	40(1)
C(18)	3405(3)	8430(2)	5896(2)	37(1)
C(19)	2058(4)	7558(2)	5790(2)	57(1)
C(20)	2080(4)	7234(2)	4528(2)	54(1)
C(21)	4858(3)	8059(2)	5130(2)	35(1)
C(22)	5791(5)	7081(2)	5531(2)	58(1)
C(23)	6290(3)	8868(2)	4970(2)	40(1)

Table 3: Bond lengths [A] and angles [deg] for camphor sulfonamide **10-CS**.

C(1)-C(2)	1.384(3)
C(1)-C(7)	1.405(3)
C(2)-O(1)	1.373(2)
C(2)-C(4)	1.380(3)
O(1)-C(3)	1.427(3)
C(4)-C(5)	1.393(3)
C(5)-C(6)	1.384(3)
C(6)-C(7)	1.378(3)
C(7)-C(8)	1.511(3)
C(8)-C(9)	1.533(3)
C(9)-N(1)	1.458(3)
C(9)-N(2)	1.496(2)
C(9)-C(10)	1.522(3)
N(1)-C(12)	1.347(3)
N(1)-C(11)	1.457(2)
C(12)-O(2)	1.217(3)
C(12)-C(13)	1.511(3)
C(13)-N(2)	1.454(3)
N(2)-S(1)	1.6126(15)
S(1)-O(3)	1.4263(17)
S(1)-O(4)	1.4272(13)
S(1)-C(14)	1.778(2)
C(14)-C(15)	1.522(3)
C(15)-C(16)	1.524(4)
C(15)-C(21)	1.557(3)
C(15)-C(20)	1.566(3)
C(16)-O(5)	1.206(3)
C(16)-C(17)	1.520(3)
C(17)-C(18)	1.526(3)
C(18)-C(19)	1.530(4)
C(18)-C(21)	1.560(3)
C(19)-C(20)	1.561(4)
C(21)-C(22)	1.522(4)
C(21)-C(23)	1.538(4)
C(2)-C(1)-C(7)	119.58(19)
O(1)-C(2)-C(1)	123.54(18)
O(1)-C(2)-C(4)	115.54(17)

C(1)-C(2)-C(4)	120.92(18)
C(2)-O(1)-C(3)	117.88(15)
C(2)-C(4)-C(5)	119.22(18)
C(6)-C(5)-C(4)	120.3(2)
C(7)-C(6)-C(5)	120.48(19)
C(6)-C(7)-C(1)	119.44(18)
C(6)-C(7)-C(8)	122.67(18)
C(1)-C(7)-C(8)	117.83(18)
C(7)-C(8)-C(9)	113.27(16)
N(1)-C(9)-N(2)	99.33(15)
N(1)-C(9)-C(10)	110.70(16)
N(2)-C(9)-C(10)	112.31(17)
N(1)-C(9)-C(8)	111.33(18)
N(2)-C(9)-C(8)	111.51(16)
C(10)-C(9)-C(8)	111.15(17)
C(12)-N(1)-C(11)	121.74(18)
C(12)-N(1)-C(9)	115.81(15)
C(11)-N(1)-C(9)	121.98(17)
O(2)-C(12)-N(1)	127.17(19)
O(2)-C(12)-C(13)	125.18(19)
N(1)-C(12)-C(13)	107.64(17)
N(2)-C(13)-C(12)	103.01(15)
C(13)-N(2)-C(9)	112.09(14)
C(13)-N(2)-S(1)	120.73(12)
C(9)-N(2)-S(1)	127.04(13)
O(3)-S(1)-O(4)	119.70(11)
O(3)-S(1)-N(2)	108.52(10)
O(4)-S(1)-N(2)	106.89(8)
O(3)-S(1)-C(14)	109.22(11)
O(4)-S(1)-C(14)	107.28(12)
N(2)-S(1)-C(14)	104.13(10)
C(15)-C(14)-S(1)	117.63(16)
C(16)-C(15)-C(14)	111.9(2)
C(16)-C(15)-C(21)	100.03(17)
C(14)-C(15)-C(21)	117.7(2)
C(16)-C(15)-C(20)	103.8(2)
C(14)-C(15)-C(20)	119.00(19)
C(21)-C(15)-C(20)	101.9(2)
O(5)-C(16)-C(15)	126.4(2)

O(5)-C(16)-C(17)	126.8(2)
C(15)-C(16)-C(17)	106.79(19)
C(16)-C(17)-C(18)	102.00(19)
C(17)-C(18)-C(19)	107.1(2)
C(17)-C(18)-C(21)	102.70(19)
C(19)-C(18)-C(21)	102.5(2)
C(18)-C(19)-C(20)	103.1(2)
C(19)-C(20)-C(15)	103.6(2)
C(22)-C(21)-C(23)	107.6(2)
C(22)-C(21)-C(15)	114.9(2)
C(23)-C(21)-C(15)	112.84(19)
C(22)-C(21)-C(18)	114.2(2)
C(23)-C(21)-C(18)	113.2(2)
C(15)-C(21)-C(18)	93.88(19)

Table 4: Anisotropic displacement parameters ($A^2 \times 10^3$) for camphor sulfonamide **10-CS**. The anisotropic displacement factor exponent takes the form: $-2\pi^2 [h^2 a^{*2} U11 + ... + 2 h k a^* b^* U12]$

	U11	U22	U33	U23	U13	U12
C(1)	24(1)	16(1)	30(1)	1(1)	3(1)	3(1)
C(2)	19(1)	17(1)	34(1)	-2(1)	3(1)	4(1)
O(1)	20(1)	34(1)	37(1)	1(1)	4(1)	-3(1)
C(3)	23(1)	35(1)	38(1)	4(1)	6(1)	0(1)
C(4)	25(1)	25(1)	36(1)	-6(1)	-3(1)	1(1)
C(5)	39(1)	26(1)	29(1)	-5(1)	4(1)	1(1)
C(6)	32(1)	17(1)	38(1)	-3(1)	14(1)	0(1)
C(7)	20(1)	12(1)	40(1)	-1(1)	5(1)	2(1)
C(8)	18(1)	20(1)	42(1)	4(1)	3(1)	1(1)
C(9)	18(1)	21(1)	35(1)	3(1)	4(1)	2(1)
N(1)	22(1)	21(1)	34(1)	-1(1)	6(1)	-2(1)
C(10)	20(1)	27(1)	51(1)	4(1)	-4(1)	-4(1)
C(11)	31(1)	34(1)	52(1)	-1(1)	20(1)	-5(1)
C(12)	31(1)	18(1)	27(1)	0(1)	3(1)	-2(1)
O(2)	46(1)	28(1)	28(1)	3(1)	3(1)	1(1)

C(13)	24(1)	24(1)	25(1)	0(1)	-1(1)	5(1)
N(2)	20(1)	21(1)	25(1)	1(1)	0(1)	3(1)
S(1)	25(1)	23(1)	23(1)	-1(1)	0(1)	-6(1)
O(3)	45(1)	31(1)	32(1)	9(1)	2(1)	-5(1)
O(4)	25(1)	48(1)	31(1)	-8(1)	4(1)	-4(1)
C(14)	48(1)	28(1)	30(1)	-7(1)	8(1)	-20(1)
C(15)	44(1)	32(1)	26(1)	-4(1)	5(1)	-16(1)
C(16)	31(1)	49(2)	31(1)	0(1)	-2(1)	-3(1)
O(5)	57(1)	66(1)	34(1)	5(1)	-8(1)	14(1)
C(17)	41(1)	43(2)	36(1)	-3(1)	4(1)	3(1)
C(18)	51(1)	36(1)	25(1)	-3(1)	5(1)	-4(1)
C(19)	80(2)	56(2)	36(2)	-10(1)	24(1)	-26(2)
C(20)	73(2)	55(2)	39(2)	-14(1)	25(1)	-35(2)
C(21)	55(1)	26(1)	24(1)	-2(1)	1(1)	4(1)
C(22)	93(2)	43(2)	36(1)	3(1)	5(1)	22(2)
C(23)	37(1)	46(2)	35(1)	-13(1)	-5(1)	-2(1)

Table 5: Hydrogen coordinates ($\times 10^4$) and isotropic displacement parameters ($A^2 \times 10^3$) for camphor sulfonamide **10-CS**.

	x	y	z	U(eq)
H(1)	2909	4166	1414	28
H(3A)	795	3181	2077	48
H(3B)	-1282	3402	2073	48
H(3C)	88	4333	2079	48
H(4)	-246	3901	-1472	34
H(5)	2096	4446	-2505	38
H(6)	4841	4824	-1587	34
H(8A)	6858	4590	254	32
H(8B)	5896	4560	1404	32
H(10A)	8731	6001	1264	49
H(10B)	7506	6032	2302	49
H(10C)	7794	7046	1585	49
H(11A)	7381	6603	-1782	57
H(11B)	7934	5615	-1045	57

H(11C)	8706	6713	-676	57
H(13A)	3075	7719	349	29
H(13B)	2337	6623	-91	29
H(14A)	5602	7649	3089	42
H(14B)	3984	8210	2414	42
H(17A)	1344	9448	5413	48
H(17B)	3272	9969	5400	48
H(18)	3852	8593	6689	44
H(19A)	868	7797	5962	68
H(19B)	2421	6986	6301	68
H(20A)	916	7356	4115	65
H(20B)	2393	6503	4463	65
H(22A)	6616	6868	4980	86
H(22B)	4913	6542	5611	86
H(22C)	6446	7203	6261	86
H(23A)	6863	9058	5707	60
H(23B)	5744	9475	4607	60
H(23C)	7174	8588	4496	60

Table 6: Torsion angles [deg] for camphor sulfonamide **10-CS**.

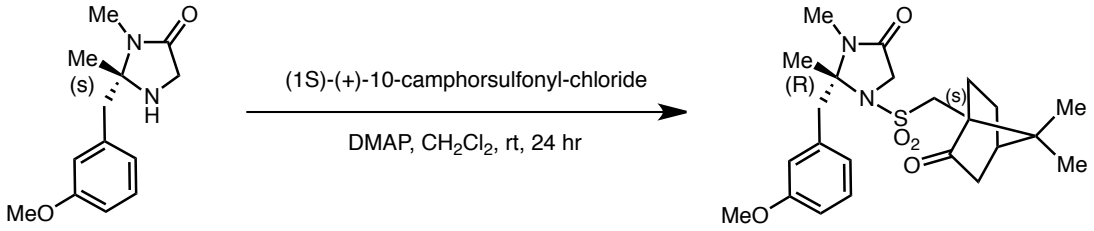
C(7)-C(1)-C(2)-O(1)	178.99(18)
C(7)-C(1)-C(2)-C(4)	-0.1(3)
C(1)-C(2)-O(1)-C(3)	6.9(3)
C(4)-C(2)-O(1)-C(3)	-174.03(18)
O(1)-C(2)-C(4)-C(5)	-178.81(19)
C(1)-C(2)-C(4)-C(5)	0.3(3)
C(2)-C(4)-C(5)-C(6)	0.3(3)
C(4)-C(5)-C(6)-C(7)	-1.2(3)
C(5)-C(6)-C(7)-C(1)	1.5(3)
C(5)-C(6)-C(7)-C(8)	-175.58(19)
C(2)-C(1)-C(7)-C(6)	-0.8(3)
C(2)-C(1)-C(7)-C(8)	176.37(18)
C(6)-C(7)-C(8)-C(9)	76.5(2)
C(1)-C(7)-C(8)-C(9)	-100.6(2)
C(7)-C(8)-C(9)-N(1)	-64.0(2)
C(7)-C(8)-C(9)-N(2)	45.9(2)

C(7)-C(8)-C(9)-C(10)	172.09(18)
N(2)-C(9)-N(1)-C(12)	-12.5(2)
C(10)-C(9)-N(1)-C(12)	-130.70(19)
C(8)-C(9)-N(1)-C(12)	105.1(2)
N(2)-C(9)-N(1)-C(11)	175.33(18)
C(10)-C(9)-N(1)-C(11)	57.1(3)
C(8)-C(9)-N(1)-C(11)	-67.1(2)
C(11)-N(1)-C(12)-O(2)	-1.9(3)
C(9)-N(1)-C(12)-O(2)	-174.2(2)
C(11)-N(1)-C(12)-C(13)	178.10(19)
C(9)-N(1)-C(12)-C(13)	5.9(2)
O(2)-C(12)-C(13)-N(2)	-176.1(2)
N(1)-C(12)-C(13)-N(2)	3.9(2)
C(12)-C(13)-N(2)-C(9)	-12.0(2)
C(12)-C(13)-N(2)-S(1)	171.91(14)
N(1)-C(9)-N(2)-C(13)	14.7(2)
C(10)-C(9)-N(2)-C(13)	131.70(18)
C(8)-C(9)-N(2)-C(13)	-102.8(2)
N(1)-C(9)-N(2)-S(1)	-169.57(15)
C(10)-C(9)-N(2)-S(1)	-52.5(2)
C(8)-C(9)-N(2)-S(1)	73.0(2)
C(13)-N(2)-S(1)-O(3)	158.38(16)
C(9)-N(2)-S(1)-O(3)	-17.0(2)
C(13)-N(2)-S(1)-O(4)	28.00(19)
C(9)-N(2)-S(1)-O(4)	-147.43(18)
C(13)-N(2)-S(1)-C(14)	-85.36(18)
C(9)-N(2)-S(1)-C(14)	99.21(19)
O(3)-S(1)-C(14)-C(15)	-73.2(2)
O(4)-S(1)-C(14)-C(15)	57.9(2)
N(2)-S(1)-C(14)-C(15)	171.04(19)
S(1)-C(14)-C(15)-C(16)	-127.10(19)
S(1)-C(14)-C(15)-C(21)	117.9(2)
S(1)-C(14)-C(15)-C(20)	-6.0(3)
C(14)-C(15)-C(16)-O(5)	18.2(3)
C(21)-C(15)-C(16)-O(5)	143.6(2)
C(20)-C(15)-C(16)-O(5)	-111.4(3)
C(14)-C(15)-C(16)-C(17)	-160.48(19)
C(21)-C(15)-C(16)-C(17)	-35.0(2)
C(20)-C(15)-C(16)-C(17)	70.0(2)

O(5)-C(16)-C(17)-C(18)	-178.2(2)
C(15)-C(16)-C(17)-C(18)	0.4(2)
C(16)-C(17)-C(18)-C(19)	-72.9(2)
C(16)-C(17)-C(18)-C(21)	34.6(2)
C(17)-C(18)-C(19)-C(20)	70.3(3)
C(21)-C(18)-C(19)-C(20)	-37.4(3)
C(18)-C(19)-C(20)-C(15)	2.9(3)
C(16)-C(15)-C(20)-C(19)	-71.1(3)
C(14)-C(15)-C(20)-C(19)	163.8(3)
C(21)-C(15)-C(20)-C(19)	32.5(3)
C(16)-C(15)-C(21)-C(22)	172.3(2)
C(14)-C(15)-C(21)-C(22)	-66.4(3)
C(20)-C(15)-C(21)-C(22)	65.7(3)
C(16)-C(15)-C(21)-C(23)	-63.9(2)
C(14)-C(15)-C(21)-C(23)	57.5(3)
C(20)-C(15)-C(21)-C(23)	-170.5(2)
C(16)-C(15)-C(21)-C(18)	53.3(2)
C(14)-C(15)-C(21)-C(18)	174.7(2)
C(20)-C(15)-C(21)-C(18)	-53.2(2)
C(17)-C(18)-C(21)-C(22)	-174.4(2)
C(19)-C(18)-C(21)-C(22)	-63.4(3)
C(17)-C(18)-C(21)-C(23)	62.0(2)
C(19)-C(18)-C(21)-C(23)	173.0(2)
C(17)-C(18)-C(21)-C(15)	-54.9(2)
C(19)-C(18)-C(21)-C(15)	56.1(2)

Supporting Information Available: Crystallographic data and details for camphor sulfonamide **10-CS**. This material is available free of charge via the Internet at http://pubs.acs.org

Synthesis of (*R*)-1-(((1*S*,4*R*)-7,7-dimethyl-2-oxobicyclo[2.2.1]heptan-1-yl)methylsulfonyl)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (*R, S*)-10-CS

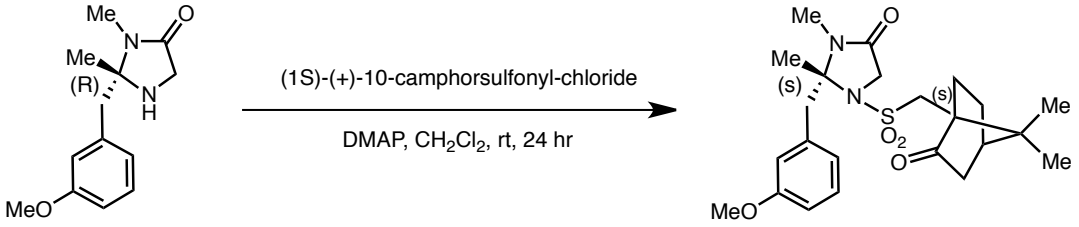


(+)–**10** **(*R, S*)-10-CS**

To a stirred solution of (+)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (25.0 mg, 0.107 mmol, 1.0 equiv) in anhydrous CH_2Cl_2 (0.6 mL) at room temperature was added DMAP (26.1 mg, 0.213 mmol, 2.0 equiv) followed by (1*S*)-(+)-10-camphor-sulfonyl chloride (26.8 mg, 0.107 mmol, 1.0 equiv). The reaction mixture was stirred for 24 h at room temperature before being quenched by the addition of aqueous citric acid (10 wt.%, 0.5 mL). The reaction mixture was poured into water (2 mL) and extracted with EtOAc (2 x 10 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (10 mL) and brine (10 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. Purification by flash chromatography on silica (50% EtOAc/hexanes + 5% MeOH) provided the pure title compound (24 mg, 50% yield, >95 : 5 dr) as a colorless viscous oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20 (t, 1H, *J* = 7.8 Hz, Ar**H**), 6.85 (s, 1H, Ar**H**), 6.81 (d, 1H, *J* = 8.2 Hz, Ar**H**), 6.77 (d, 1H, *J* = 7.3 Hz, Ar**H**), 3.79 (s, 3H, OC**H**$_3$), 3.61 (d, 1H, *J* = 14.4 Hz, COC**H**$_2$NH), 3.45-3.38 (m, 2H, SO_2C**H**$_2$ + ArC**H**$_2$), 3.03 (d, 1H, *J* = 14.4 Hz, COC**H**$_2$NH), 2.97 (s, 3H, NC**H**$_3$), 2.96-2.90 (m, 2H, ArC**H**$_2$ + SO_2C**H**$_2$), 2.52 (t, 1H, *J* = 12.3 Hz, CH_2C**H**$_2$CH), 2.39 (d, 1H, *J* = 18.5 Hz, COC**H**H), 2.13 (s, 1H, $COCH_2$C**H**), 2.09 (m, 1H, CC**H**$_2$$CH_2$CH), 2.01-1.94 (m, 4H, CC**H**$_3$ + COC**H**H), 1.75 (m, 1H, CH_2C**H**$_2$CH), 1.46 (t, 1H, *J* = 10.9 Hz, CC**H**$_2$$CH_2$CH), 1.12 (s, 3H, C**H**$_3$$CCH_3$), 0.86 (s, 3H, CH_3CC**H**$_3$); ^{13}C NMR (125 MHz,

$CDCl_3$) δ 214.7, 166.2, 159.6, 135.8, 129.4, 122.3, 115.5, 113.6, 83.8, 58.4, 55.2, 50.2, 49.6, 47.8, 43.4, 42.7, 42.5, 26.9, 25.5, 25.1, 24.0, 19.9, 19.7.

Synthesis of (*S*)-1-(((1*S*,4*R*)-7,7-dimethyl-2-oxobicyclo[2.2.1]heptan-1-yl)methylsulfonyl)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (*S, R*)-10-CS



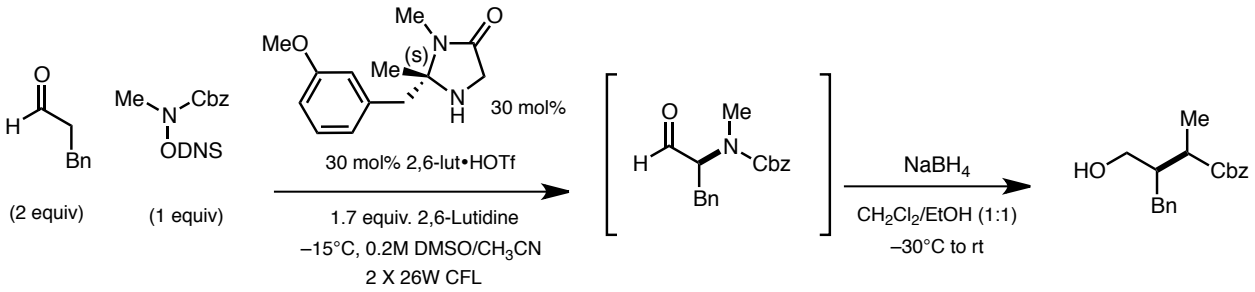
(–)–**10** **(*S, R*)-10-CS**

To a stirred solution of (−)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (25.0 mg, 0.107 mmol, 1.0 equiv) in anhydrous CH_2Cl_2 (0.6 mL) at room temperature was added DMAP (26.1 mg, 0.213 mmol, 2.0 equiv) followed by (1*S*)-(+)-10-camphor-sulfonyl chloride (26.8 mg, 0.107 mmol, 1.0 equiv). The reaction mixture was stirred for 24 h at room temperature before being quenched by the addition of aqueous citric acid (10 wt.%, 0.5 mL). The reaction mixture was poured into water (2 mL) and extracted with EtOAc (2 x 10 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (10 mL) and brine (10 mL), dried (Mg_2SO_4) and concentrated *in vacuo*. Purification by flash chromatography on silica gel (50% EtOAc/hexanes + 5% MeOH) provided the pure title compound (33 mg, 68% yield, >95 : 5 dr) as white crystals. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.20 (t, 1H, *J* = 7.9 Hz, Ar**H**), 6.88 (s, 1H, Ar**H**), 6.82 (d, 1H, *J* = 8.2 Hz, Ar**H**), 6.78 (d, 1H, *J* = 7.4 Hz, Ar**H**), 3.80 (s, 3H, OC**H**$_3$), 3.63 (d, 1H, *J* = 14.6 Hz, COC**H**$_2$NH), 3.48 (d, 1H, *J* = 14.6 Hz, SO_2C**H**$_2$), 3.41 (d, 1H, *J* = 14.1 Hz, ArC**H**$_2$), 2.98 (s, 3H, NC**H**$_3$), 2.97-2.89 (m, 3H, ArC**H**$_2$ + COC**H**$_2$NH + SO_2C**H**$_2$), 2.48 (t, 1H, *J* = 12.6 Hz, CH_2C**H**$_2$CH), 2.39 (d, 1H, *J* = 18.5 Hz, COC**H**H), 2.13 (s, 1H, $COCH_2$C**H**), 2.07 (m, 1H, CC**H**$_2$$CH_2$CH), 1.97-1.90 (m, 4H, CC**H**$_3$ + COCH**H**), 1.65 (m, 1H, CH_2C**H**$_2$CH), 1.44 (m, 1H, CC**H**$_2$$CH_2$CH), 1.17 (s, 3H, C**H**$_3$$CCH_3$), 0.92 (s, 3H, CH_3CC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 215.3, 166.4, 159.5, 135.7, 129.4, 122.4, 115.5, 113.8, 83.6, 58.8, 55.2, 51.4, 49.6, 48.0, 43.6, 42.9, 42.5, 26.9, 25.5, 25.4, 23.7, 20.0, 19.8.

Comparison of the ^{1}H and ^{13}C NMR spectra of diasteromeric camphor sulfonamide **(*S, R*)-10-CS** and **(*R, S*)-10-CS** with spectral data of camphor sulfonamide **10-CS** characterized by single-crystal X-ray diffraction, revealed an excellent correlation with structure **(*S, R*)-10-CS**, thus assigning the absolute configuration of imidazolidinone catalyst (−)-**(*R, S*)-10-CS** and (+)-**(*S, R*)-10-CS** to (*R*)- and (*S*)- respectively.

VIII. Structural Correlation between 2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one and 2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one

Synthesis of (2*S*)-Benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate

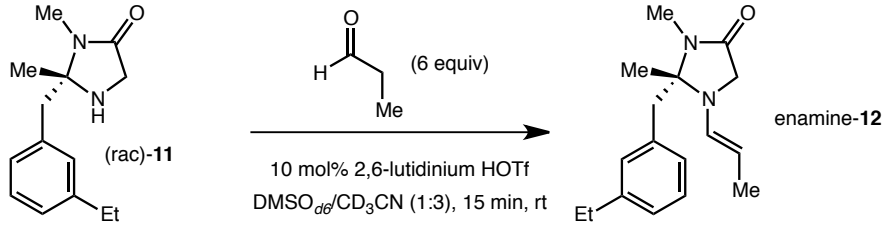


General α-amination procedure (including an in situ reduction, Section III) was followed using (+)-(2*S*)-2-(3-methoxybenzyl)-2,3-dimethylimidazolidin-4-one (18.7 mg, 0.080 mmol, 0.30 equiv), 2,6-lutidinium triflate (20.6 mg, 0.080 mmol, 0.30 equiv), benzyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate **10** (109.7 mg, 0.2667 mmol, 1.0 equiv), 2,6-lutidine (52 μL, 0.453 mmol, 1.7 equiv) and 3-phenylpropanal (70 μL, 0.533 mmol, 2.0 equiv) in DMSO/CH_3CN (1:3, 1.32 mL, 0.2 M). After 16 h, the reaction mixture was directly added via syringe to a stirred suspension of $NaBH_4$ (~30 mg, 3 equiv) in a 1:1 mixture of CH_2Cl_2/EtOH (1.6 mL) at −30 °C. The reaction mixture was stirred for 15 min at −30 °C then allowed to warm to 0 °C for 20 min before being quenched by the careful addition of aqueous citric acid (10 wt.%, 0.6 mL). Finally, the reaction mixture was subjected to the workup protocol outlined in the general procedure and purified by flash chromatography on silica gel (10% EtOAc/CH_2Cl_2 + 1% MeOH) to provide the pure title compound (52 mg, 65% yield, 88% ee) as a colorless oil.

All spectroscopic data (^{1}H and ^{13}C NMR), including chiral-HPLC analysis, and the specific rotation ($[\alpha]_D^{20}$) for (2*S*)-Benzyl 1-hydroxy-3-phenylpropan-2-yl(methyl)carbamate were in agreement with those previously obtained with catalyst (+)-**11** (Section III), thus assigning its absolute configuration to (*S*)- by analogy.

IX. Structural Studies on the Enamine by ^{1}H NMR and 2D NOESY

Preparation of a sample of (2*S*,*E*)-2-(3-ethylbenzyl)-2,3-dimethyl-1-(prop-1-enyl)imidazolidin-4-one for ^{1}H NMR Analysis



To an oven-dried 8 mL vial equipped with a magnetic stir bar and Teflon septum was added (*rac*)-2-(3-ethylbenzyl)-2,3-dimethylimidazolidin-4-one (10.0 mg, 43.0 μmol, 1.0 equiv), 2,6-lutidinium triflate (1.1 mg, 4.3 μmol, 0.10 equiv), and a 1:3 mixture of DMSO-d6/CD_3CN (0.4 mL). The mixture was stirred at room temperature till complete dissolution of solids and then propionaldehyde (19.0 μL, 0.258 mmol, 6.0 equiv) was added via syringe. After 15 min stirring at room temperature, the reaction mixture was transferred via syringe to an NMR tube for NMR analysis (^{1}H NMR analysis indicates >90% conv.). ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.16 (t, 1H, *J* = 7.4 Hz, Ar**H$_3$**), 7.09 (d, 1H, *J* = 7.5 Hz, Ar**H$_2$**), 7.00 (s, 1H, Ar**H$_1$**), 6.91 (d, 1H, *J* = 7.5 Hz, Ar**H$_4$**), 6.53 (d, 1H, *J* = 13.5 Hz, H_1), 3.99 (m, 1H, H_2), 3.27 (d, 1H, *J* = 14.7 Hz, COC**H**$_a$H$_b$NH), 3.07 (d, 1H, *J* = 14.4 Hz, ArC**H**$_2$), 3.02 (d, 1H, *J* = 14.4 Hz, ArC**H**$_2$), 2.87 (s, 3H, NC**H**$_3$), 2.69 (d, 1H, *J* = 14.7 Hz, COCH$_a$**H**$_b$NH), 2.59 (q, 2H, *J* = 7.6 Hz, ArC**H**$_2$CH$_3$), 1.77 (d, 3H, *J* = 6.3 Hz, =CHC**H**$_3$), 1.54 (s, 3H, CC**H**$_3$), 1.20 (t, 3H, *J* = 7.7 Hz, ArCH$_2$C**H**$_3$).

The numbering system adopted for the ^{1}H NMR assignment of enamine **12** is shown in Figure 3.

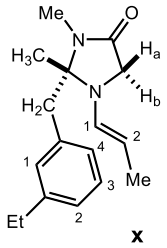


Figure 3: Numbering system for enamine **12**

2D NOESY Spectra of Enamine 12

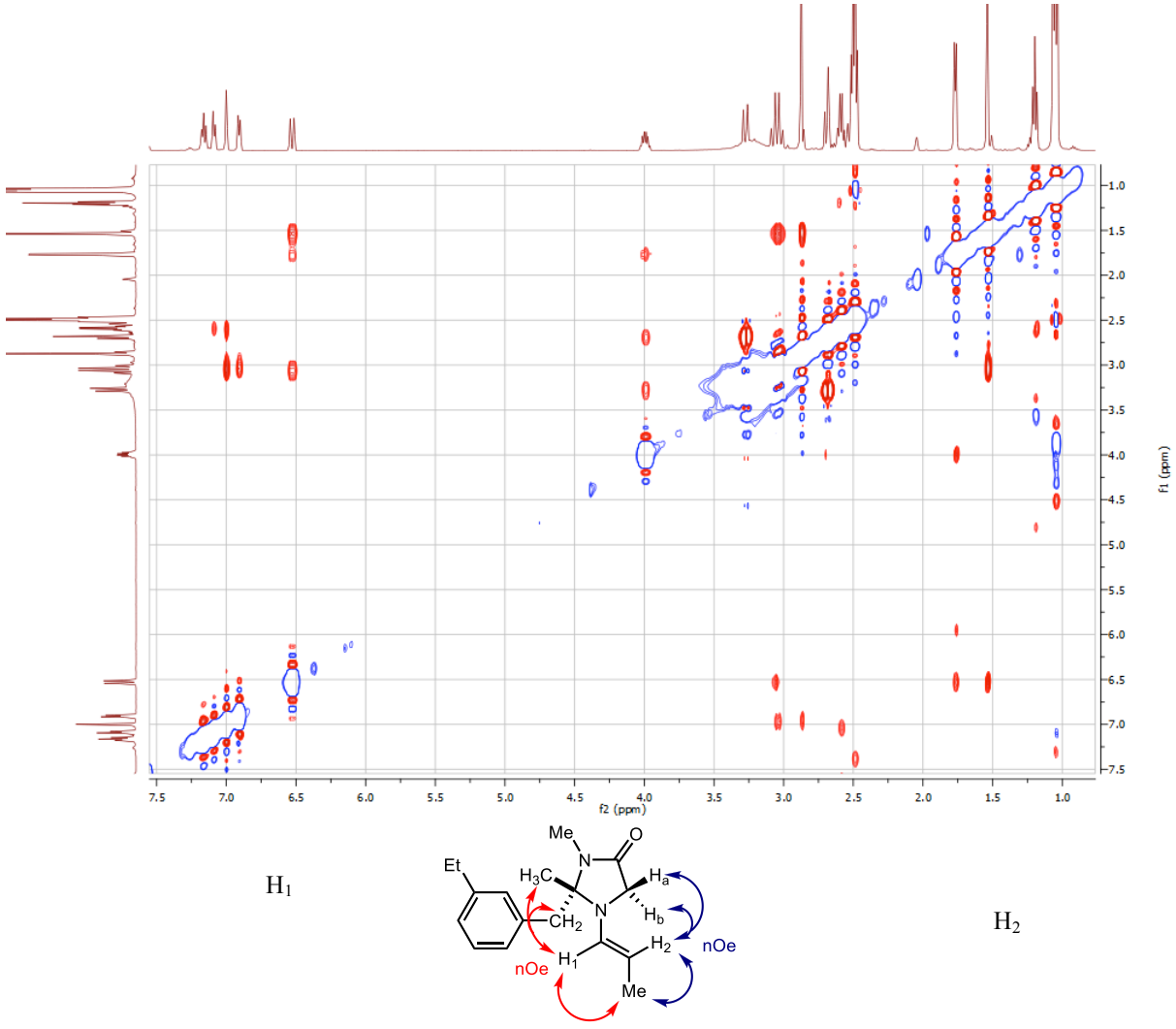
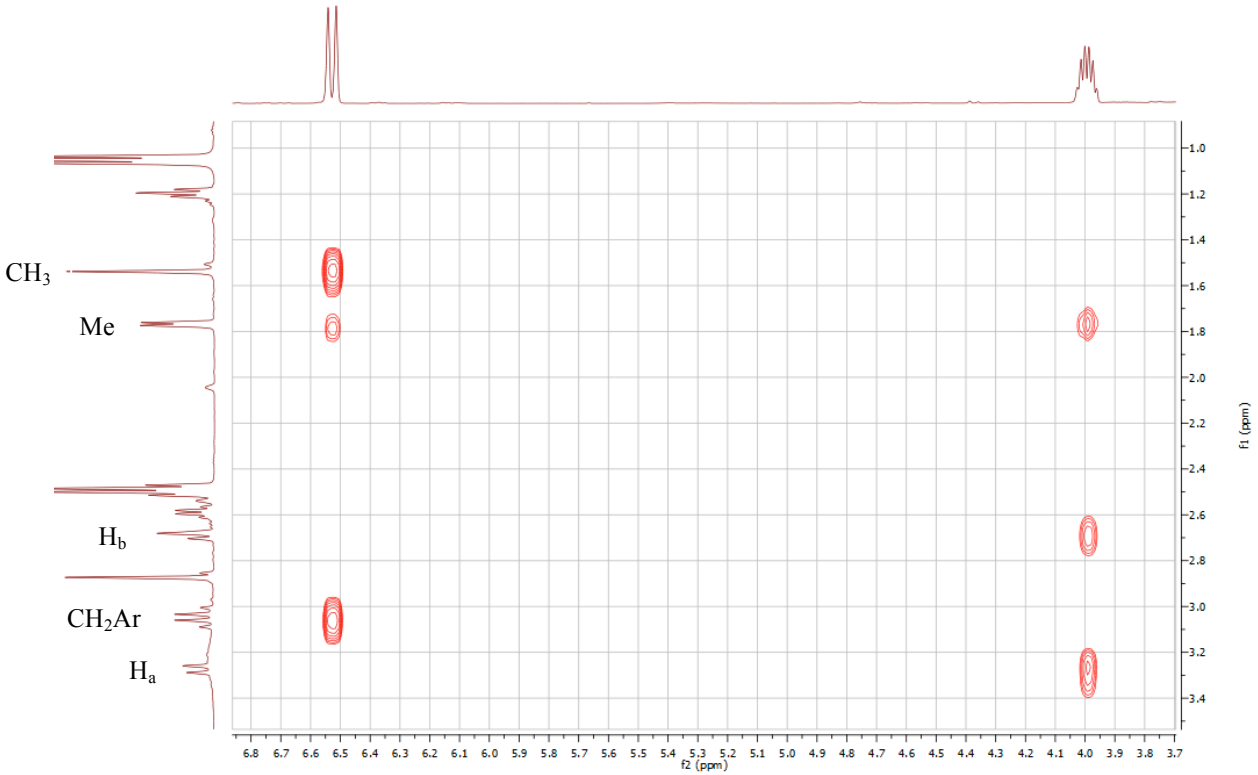


Figure 4: Main NOE correlations of enamine **12**



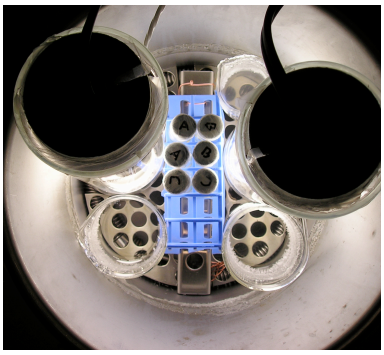
The structure of the enamine 12 was further correlated with a DFT minimized structure calculated on Gaussian 3. The calculation was performed at the B3LYP/6–31G* level of theory, and the structure is reported in the manuscript Figure 1.[15]

X. Cryogenic Reaction Set-up & Safety Procedures

[15] Frisch, M. J.; Trucks, G. W.; Schlegel, H. B.; Scuseria, G. E.; Robb, M. A.; Cheeseman, J. R.; Montgomery, Jr., J. A.; Vreven, T.; Kudin, K. N.; Burant, J. C.; Millam, J. M.; Iyengar, S. S.; Tomasi, J.; Barone, V.; Mennucci, B.; Cossi, M.; Scalmani, G.; Rega, N.; Petersson, G. A.; Nakatsuji, H.; Hada, M.; Ehara, M.; Toyota, K.; Fukuda, R.; Hasegawa, J.; Ishida, M.; Nakajima, T.; Honda, Y.; Kitao, O.; Nakai, H.; Klene, M.; Li, X.; Knox, J. E.; Hratchian, H. P.; Cross, J. B.; Bakken, V.; Adamo, C.; Jaramillo, J.; Gomperts, R.; Stratmann, R. E.; Yazyev, O.; Austin, A. J.; Cammi, R.; Pomelli, C.; Ochterski, J. W.; Ayala, P. Y.; Morokuma, K.; Voth, G. A.; Salvador, P.; Dannenberg, J. J.; Zakrzewski, V. G.; Dapprich, S.; Daniels, A. D.; Strain, M. C.; Farkas, O.; Malick, D. K.; Rabuck, A. D.; Raghavachari, K.; Foresman, J. B.; Ortiz, J. V.; Cui, Q.; Baboul, A. G.; Clifford, S.; Cioslowski, J.; Stefanov, B. B.; Liu, G.; Liashenko, A.; Piskorz, P.; Komaromi, I.; Martin, R. L.; Fox, D. J.; Keith, T.; Al-Laham, M. A.; Peng, C. Y.; Nanayakkara, A.; Challacombe, M.; Gill, P. M. W.; Johnson, B.; Chen, W.; Wong, M. W.; Gonzalez, C.; and Pople, J. A.; Gaussian 03, Revision C.02, Gaussian, Inc., Wallingford CT, 2004.

In a typical experiment, a −15 °C acetone containing cryocool was employed to maintain constant cryogenic temperatures. Use of the cryocool at lower temperatures than −15 °C has no additional beneficial effect for reaction yields and/or higher enantioselectivities. Furthermore, many compact fluorescence light bulbs tested were found to be operationally unreliable below −18 °C. As a light source, compact fluorescent light (CFL) bulbs can be conveniently used due to their large availability, low-cost, long average life, and ease of use. Ultimately, a 26 W compact fluorescent light bulb (daylight, colour = 5000-6500K,[16] 1600-1750 lumens), was chosen because of the combination of its intense luminosity and compact size (Figure 5).[17] Controlled experiments conducted under selective irradiation conditions (Tab 1, entry 3) in combination with UV/Vis data obtained for amine reagent (**1**-**4**, Section XII) highlight the importance of UVB (281-315 nm) light in the photoredox process. This explains our preferential use of cool-white (>5000K) fluorescent bulbs as they have been shown[18] to emit UVB light in low intensity. For our convenience, the CFL bulb could be simply encased within a Pyrex glass tube, sealed with a rubber stopper (as shown below), and placed at approximately 3 cm from the reaction vials. This ensured efficient photo-excitation, with minimal warming effects. ***CAUTION: When using an electrical device near a cooling bath, be certain the outlet is equipped with a proper ground fault circuit interrupter (GFI or GFCI) to prevent severe or fatal electric shocks.***

26 W CFL
(Greenlite®, Overdrive™)



(Top view)

(Side view)

Figure 5: Cryogenic reaction set-up

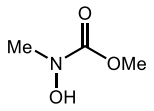
XI. Synthesis of Starting Material Amine Reagents

[16] Use of soft-white (2700 K) fluorescent bulbs produced diminished reaction yields.

[17] A variety of bulbs purchased from different providers have been successfully employed for our purposes (amongst these: Greenlite®, Overdrive™, Figure 5).

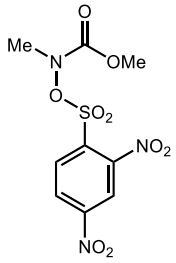
[18] Chignell, C. F.; Sik, R. H.; Bilski, P. J. *Photochemistry and Photobiology*, **2008**, *84*, 1291.

Methyl hydroxy(methyl)carbamate



To a stirred suspension of *N*-methylhydroxylamine hydrochloride (10.0 g, 120 mmol, 1.0 equiv) in THF (200 mL) and H_2O (20 mL) was added $NaHCO_3$ (20.0 g, 240 mmol, 2.0 equiv) and methylchloroformate (10.0 mL, 132 mmol, 1.1 equiv). The resulting clear suspension was stirred overnight at room temperature, then diluted with H_2O (100 mL) and extracted with CH_2Cl_2 (3 x 100 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo* to yield the title compound (11.6 g, 92% yield) as a colorless oil which was used without further purification. IR (thin film) 3268, 2956, 1723, 1455, 1367, 1255, 1194, 1145, 1062, 1030, 974, 908, 869, 838, 741 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.17 (br s, 1H, O**H**), 3.76 (s, 3H, OC**H**$_3$), 3.21 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 158.7, 53.4, 38.1; HRMS (ESI-TOF) calculated for $C_3H_8NO_3$ $[M+H]^+$ m/z 106.0499, found 106.0501.

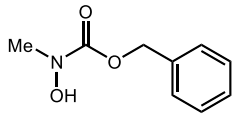
Methyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (Table 2, entry 1)



To a stirred solution of methyl hydroxy(methyl)carbamate (3.0 g, 28.5 mmol, 1.0 equiv) in CH_2Cl_2 (200 mL) at 0 °C was added NEt_3 (5.1 mL, 37.1 mmol, 1.3 equiv) and 2,4-dinitrobenzenesulfonyl chloride (8.0 g, 29.9 mmol, 1.05 equiv). The resulting orange solution was stirred at 0 °C for 3 h, then diluted with 0.5 M aqueous citric acid (100 mL) and extracted with CH_2Cl_2 (2 x 100 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (100 mL) and brine (100 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant orange solid was collected by filtration on a sintered funnel, then triturated and washed with Et_2O

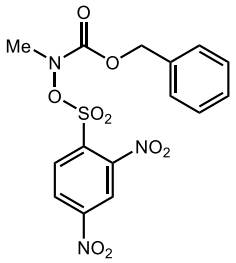
(2 x 100 mL) and toluene (2 x 100 mL) to provide the title compound (7.1 g, 74% yield) as light yellow crystals. IR (thin film) 3115, 3092, 1744, 1609, 1560, 1538, 1447, 1388, 1347, 1320, 1195, 1133, 1106, 1002, 913, 840, 828, 807, 768, 747, 736, 706, 662 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.69 (s, 1H, Ar**H**), 8.55 (d, 1H, *J* = 8.6 Hz, Ar**H**), 8.42 (d, 1H, *J* = 8.6 Hz, Ar**H**), 3.61 (s, 3H, OC**H**$_3$), 3.39 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.1, 151.0, 149.0, 134.5, 132.9, 126.3, 120.2, 54.5, 41.0; HRMS (ESI-TOF) calculated for $C_9H_{10}N_3O_9S$ $[M+H]^+$ m/z 336.0132, found 336.0132.

Benzyl hydroxy(methyl)carbamate



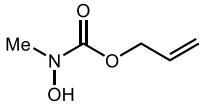
To a stirred suspension of *N*-methylhydroxylamine hydrochloride (5.0 g, 59.9 mmol, 1.2 equiv) in THF (100 mL) and H_2O (10 mL) were added $NaHCO_3$ (10.0 g, 120 mmol, 2.0 equiv) and benzyl chloroformate (7.1 mL, 49.9 mmol, 1.0 equiv). The resulting clear suspension was stirred overnight at room temperature, then diluted with H_2O (50 mL) and extracted with CH_2Cl_2 (3 x 50 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo* to yield the title compound (9.0 g, 99% yield) as a colorless oil that was used without further purification. IR (thin film) 3250, 2945, 1670, 1498, 1455, 1425, 1390, 1347, 1238, 1157, 1082, 1036, 990, 914, 876, 802, 752, 696 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.39-7.36 (m, 5H, Ar**H**), 5.19 (s, 2H, OC**H**$_2$Ph), 3.22 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.9, 135.8, 128.4 (2C), 128.2 (2C), 127.9, 67.8, 38.0; HRMS (ESI-TOF) calculated for $C_9H_{12}NO_3$ $[M+H]^+$ m/z 182.0812, found 182.0810.

Benzyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (Table 2, entry 2)



To a stirred solution of benzyl hydroxy(methyl)carbamate (3.5 g, 19.0 mmol, 1.1 equiv) in CH_2Cl_2 (100 mL) at 0 °C was added NEt_3 (3.1 mL, 22.5 mmol, 1.3 equiv) and 2,4-dinitrobenzenesulfonyl chloride (4.6 g, 17.3 mmol, 1.0 equiv). The resulting orange solution was stirred at 0 °C for 3 h, then diluted with 0.5 M aqueous citric acid (50 mL) and extracted with CH_2Cl_2 (2 x 50 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (50 mL) and brine (50 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant yellow solid was purified by flash chromatography on silica gel (30% EtOAc/hexanes) to provide the pure title compound (5.2 g, 73% yield) as light yellow crystals. IR (thin film) 3114, 2947, 2887, 1719, 1611, 1544, 1503, 1456, 1414, 1400, 1384, 1344, 1307, 1230, 1219, 1199, 1181, 1144, 1127, 1097, 1046, 990, 965, 949, 903, 870, 836, 816, 805, 796, 765, 756, 733, 696, 654 cm^{-1}; ^1H NMR (500 MHz, DMSO-d6) δ 8.87 (d, 1H, *J* = 2.0 Hz, Ar**H**), 8.50 (dd, 1H, *J* = 8.7, 2.1 Hz, Ar**H**), 8.39 (d, 1H, *J* = 8.7 Hz, Ar**H**), 7.33-7.28 (m, 3H, Ar**H**), 7.20-7.15 (m, 2H, Ar**H**), 5.01 (s, 2H, OC**H**$_2$Ph), 3.32 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.6, 150.4, 148.4, 133.9, 132.3, 130.7, 129.3, 129.0 (2C), 128.5 (2C), 125.7, 120.1, 69.4, 40.9; HRMS (ESI-TOF) calculated for $C_{15}H_{14}N_3O_9S$ $[M+H]^+$ m/z 412.0445, found 412.0449.

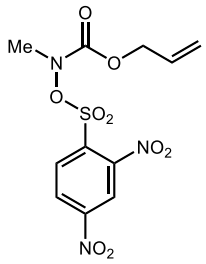
Allyl hydroxy(methyl)carbamate



To a stirred suspension of *N*-methylhydroxylamine hydrochloride (4.0 g, 48.7 mmol, 1.0 equiv) in THF (100 mL) and H_2O (10 mL) was added $NaHCO_3$ (8.2 g, 97.4 mmol, 2.0 equiv) and allyl chloroformate (5.7 mL, 53.6 mmol, 1.2 equiv). The resulting clear suspension was stirred overnight at room temperature, then diluted with H_2O (50 mL) and extracted with EtOAc (2 x 50 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo* to yield

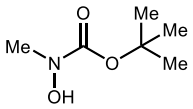
the title compound as an orange oil (6.37 g, 99% yield) which was used without further purification. IR (thin film) 3267, 2947, 1700, 1649, 1416, 1386, 1337, 1273, 1240, 1162, 1036, 993, 930, 847, 759 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 5.92-5.86 (m, 1H, C**H**=CH_2), 5.30-5.19 (m, 2H, CH=C**H**$_2$), 4.59-4.58 (m, 2H, OC**H**$_2$CH=CH_2), 3.20 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.7, 132.1, 118.0, 66.8, 38.0; HRMS (ESI-TOF) calculated for $C_5H_{10}NO_3$ $[M+H]^+$ m/z 132.0655, found 132.0655.

Allyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (Table 2, entry 3)



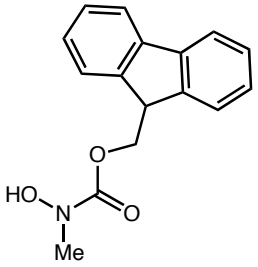
To a stirred solution of allyl hydroxy(methyl)carbamate (1.0 g, 7.7 mmol, 1.0 equiv) in CH_2Cl_2 (60 mL) at 0 °C was added NEt_3 (1.4 mL, 10.0 mmol, 1.3 equiv) and 2,4-dinitrobenzenesulfonyl chloride (2.3 g, 8.4 mmol, 1.1 equiv). The resulting orange solution was stirred at 0 °C temperature for 30 min, then diluted with 0.5 M aqueous citric acid (50 mL) and extracted with CH_2Cl_2 (2 x 50 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (50 mL) and brine (50 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant yellow solid was purified by flash chromatography on silica (20% EtOAc/hexanes) to provide the pure title compound (1.99 g, 71% yield) as yellow crystals. IR (thin film) 3106, 3034, 2956, 1735, 1607, 1556, 1538, 1465, 1401, 1388, 1375, 1307, 1204, 1179, 1130, 1106, 991, 969, 950, 907, 841, 830, 811, 765, 747, 734, 709, 661 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.62 (d, 1H, J = 2.2 Hz, Ar**H**), 8.53 (dd, 1H, J = 8.6, 2.2 Hz, Ar**H**), 8.40 (d, 1H, J = 8.6 Hz, Ar**H**), 5.68-5.63 (m, 1H, CH_2C**H**=CH_2), 5.17-5.14 (m, 2H, CH_2CH=C**H**$_2$), 4.42 (ap dt, 2H, J = 6.0, 1.1 Hz, OC**H**$_2$CH=CH_2), 3.43 (s, 3H, NC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 156.3, 151.0, 148.9, 134.5, 132.6, 130.6, 126.2, 120.3, 119.9, 68.3, 40.9; HRMS (ESI-TOF) calculated for $C_{11}H_{12}N_3O_9S$ $[M+H]^+$ m/z 362.0289, found 362.0289.

***tert*-Butyl hydroxy(methyl)carbamate**



To a stirred suspension of *N*-methylhydroxylamine hydrochloride (5.0 g, 59.9 mmol, 1.0 equiv) in THF (100 mL) and H_2O (10 mL) was added $NaHCO_3$ (10.0 g, 120 mmol, 2.0 equiv) and di-*tert*-butyl dicarbonate (15.7 g, 71.8 mmol, 1.2 equiv). The resulting clear suspension was stirred overnight at room temperature, then diluted with H_2O (50 mL) and extracted with CH_2Cl_2 (3 x 50 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo* to yield the title compound (8.8 g, 99% yield) as an orange oil which was used without further purification. IR (thin film) 3247, 2981, 2937, 1782, 1733, 1692, 1608, 1560, 1543, 1475, 1455, 1365, 1320, 1256, 1200, 1189, 1140, 1110, 1027, 920, 905, 830, 808, 772, 755, 713, 641, 609 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.21 (br s, 1H, O**H**), 3.15 (s, 3H, OC**H**$_3$), 1.47 (s, 9H, C(C**H**$_3$)$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.6, 81.8, 37.8, 28.2 (3C); HRMS (ESI-TOF) calculated for $C_6H_{14}NO_3$ $[M+H]^+$ m/z 148.0968, found 148.0971.

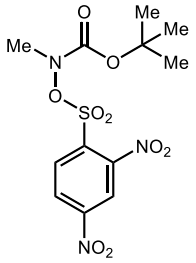
9-fluorenyl hydroxy(methyl)carbamate



To a stirred suspension of *N*-methylhydroxylamine hydrochloride (0.208g, 2.5mmol, 1.0 equiv) in THF (16 mL) and H_2O (1.0 mL) was added $NaHCO_3$ (0.420g, 5 mmol, 2.0 equiv) and 9-fluorenyl chloroformate (0.525g, 0.8 mmol, 0.8 equiv). The resulting clear suspension was stirred overnight at room temperature, then diluted with H_2O (10 mL) and extracted with EtOAc (3 x 20 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo* to yield the title compound (4.85g, 73% yield) as an clear oil which was used without further purification. IR (thin film) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.77 (d, 2H, J=7.48, Ar**H**), d7.58 (d, 2H, J=7.48 Ar**H**), 7.40 (t, 2H, J=7.58, 15.07, Ar**H**) 7.31 (t, 2H, J=7.58, 15.07, Ar**H**) 4.44 (d, 2H, J=7.11, $CO_2C\mathbf{H_2}$) 4.26 (t, 1H, J=7.01, 14.27, Ar**H**) 3.24 (s, 3H, N**Me**); ^{13}C NMR (125 MHz,

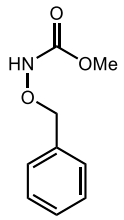
$CDCl_3$) δ 158, 144, 141.31, 127.16, 127.88, 125.05, 120.11, 68.37, 46.99, 37.90; HRMS (ESI-TOF) calculated for $C_6H_{14}NO_3$ $[M+H]^+$ m/z 148.0968, found 148.0971.

tert-Butyl 2,4-dinitrophenylsulfonyloxy(methyl)carbamate (Table 2, entry 5)



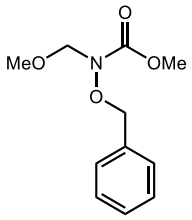
To a stirred solution of *tert*-butyl hydroxy(methyl)carbamate (1.1 g, 7.4 mmol, 1.1 equiv) in CH_2Cl_2 (50 mL) at 0 °C was added NEt_3 (1.1 mL, 8.2 mmol, 1.2 equiv) and 2,4-dinitrobenzenesulfonyl chloride (2.6 g, 6.2 mmol, 1.0 equiv). The resulting orange solution was stirred at 0 °C for 2 h, then diluted with 0.5 M aqueous citric acid (30 mL) and extracted with CH_2Cl_2 (2 x 30 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (30 mL) and brine (30 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant orange solid was collected by filtration on a sintered funnel, then triturated and washed with EtOH (2 x 20 mL) and Et_2O (2 x 20 mL) to provide the title compound (1.9 g, 82% yield) as light yellow crystals. IR (thin film) 3115, 3090, 2993, 2949, 1734, 1609, 1560, 1543, 1473, 1390, 1373, 1352, 1320, 1260, 1202, 1190, 1134, 1109, 1051, 967, 906, 830, 809, 773, 754, 747, 732, 713, 660, 610 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.62 (s, 1H, J = 2.2 Hz, Ar**H**), 8.55 (dd, 1H, J = 8.6, 2.2 Hz, Ar**H**), 8.42 (dd, 1H, J = 8.6, 2.2 Hz, Ar**H**), 3.32 (s, 3H, OC**H**$_3$), 1.29 (s, 9H, C(C**H**$_3$)$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 155.3, 150.1, 149.2, 134.6, 132.9, 125.9, 120.0, 84.7, 41.0, 27.7 (3C); HRMS (ESI-TOF) calculated for $C_{12}H_{16}N_3O_9S$ $[M+H]^+$ m/z 378.0602, found 378.0600.

Methyl benzyloxycarbamate



To a stirred suspension of *O*-benzylhydroxylamine hydrochloride (11.4 g, 71.4 mmol, 1.0 equiv) in THF (150 mL) and H_2O (15 mL) was added $NaHCO_3$ (12.0 g, 142.8 mmol, 2.0 equiv) and methylchloroformate (6.2 mL, 78.6 mmol, 1.1 equiv). The resulting clear suspension was stirred overnight at room temperature, then diluted with H_2O (50 mL) and extracted with EtOAc (3 x 50 mL). The combined organic extracts were dried ($MgSO_4$) and concentrated *in vacuo* to yield the title compound as a colorless oil (13.0 g, 99% yield) which was used without further purification. IR (thin film) 3270, 2956, 1724, 1455, 1367, 1256, 1193, 1116, 1063, 1034, 972, 926, 909, 838, 743, 698 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.39-7.36 (m, 5H, Ar**H**), 7.23 (br s, 1H, N**H**), 4.88 (s, 2H, OC**H**$_2$Ph), 3.78 (s, 3H, OC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 157.9, 135.3, 129.1 (2C), 128.6, 128.5 (2C), 78.6, 52.8; HRMS (ESI-TOF) calculated for $C_9H_{12}NO_3$ $[M+H]^+$ m/z 182.0812, found 182.0809.

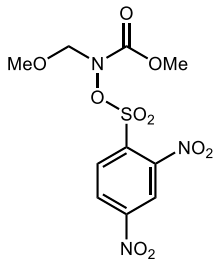
Methyl benzyloxy(methoxymethyl)carbamate



To a stirred solution of methyl benzyloxycarbamate (6.6 g, 36.2 mmol, 1.2 equiv) in DMF (150 mL) at 0 °C was added NaH (60% dispersion in oil, 1.6 g, 39.5 mmol, 1.3 equiv). The reaction mixture was stirred for 10 min at 0 °C, then chloro(methoxy)methane (2.5 mL 29.7 mmol, 1.0 equiv) was added dropwise. The resulting white suspension was stirred at room temperature for 4 h before being quenched by the careful addition of 0.5 M aqueous citric acid (100 mL). The mixture was poured into a separatory funnel and extracted with EtOAc (3 x 100 mL). The combined organic extracts were washed with H_2O (3 x 100 mL), dried ($MgSO_4$)

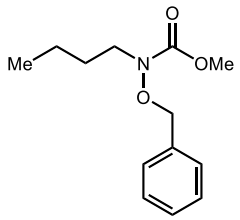
and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (hexanes→20% EtOAc/hexanes) to provide the pure title compound (5.13 g, 77% yield) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42-7.36 (m, 5H, Ar**H**), 4.93 (s, 2H, OC**H**$_2$OMe), 4.88 (s, 2H, OC**H**$_2$Ph), 3.82 (s, 3H, OC**H**$_3$), 3.39 (s, 3H, OC**H**$_3$).

Methyl 2,4-dinitrophenylsulfonyloxy(methoxymethyl)carbamate (Table 2, entry 6)



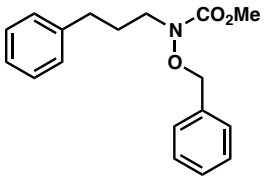
To a solution of methyl benzyloxy(2-methoxymethyl)carbamate (5.1 g, 22.8 mmol, 1.0 equiv) in EtOH (180 mL), was added $Pd(OH)_2/C$ (~0.4 g, 20 wt.%) and the resulting suspension was purged by evacuation and then back filled with a stream of hydrogen (balloon) for three times. The mixture was stirred for 16 h at room temperature under hydrogen atmosphere and then filtered directly through a pad of celite. The filter cake was rinsed with EtOH (2 x 30 mL) and the filtrate was concentrate *in vacuo* to give a colorless oil. The crude product was dissolved in CH_2Cl_2 (150 mL), cooled to 0 °C, then NEt_3 (3.8 mL, 27.4 mmol, 1.2 equiv) and 2,4-dinitrobenzenesulfonyl chloride (6.7 g, 25.1 mmol, 1.1 equiv) were added. The resulting orange solution was stirred at 0 °C for 30 min, then diluted with 0.5 M aqueous citric acid (100 mL) and extracted with CH_2Cl_2 (3 x 50 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (50 mL) and brine (50 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant yellow solid was purified by flash chromatography on silica gel (30% EtOAc/hexanes) to provide the title compound (6.9 g, 83% yield) as light yellow crystals. IR (thin film) 3098, 2966, 1754, 1608, 1559, 1541, 1442, 1411, 1397, 1349, 1307, 1265, 1193, 1138, 1075, 1013, 938, 921, 870, 832, 819, 784, 760, 738, 718, 695, 660 cm^{-1}; ^{1}H NMR (500 MHz, $CDCl_3$) δ 8.68 (d, 1H, J = 2.1 Hz, Ar**H**), 8.57 (dd, 1H, J = 8.7, 2.2 Hz, Ar**H**), 8.41 (d, 1H, J = 8.7 Hz, Ar**H**), 5.00 (s, 2H, OC**H**$_2$OMe), 3.74 (s, 3H, OC**H**$_3$), 3.41 (s, 3H, OC**H**$_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 155.5, 151.0, 148.9, 134.3, 133.2, 126.3, 120.3, 83.8, 58.3, 54.8; HRMS (ESI-TOF) calculated for $C_{10}H_{12}N_3O_{10}S$ $[M+H]^+$ m/z 366.0238, found 366.0240.

Methyl benzyloxy(butyl)carbamate



To a stirred solution of methyl benzyloxycarbamate (2.0 g, 11.0 mmol, 1.0 equiv) in DMF (60 mL) at 0 °C was added NaH (60% dispersion in oil, 0.66 g, 16.5 mmol, 1.5 equiv). The reaction mixture was stirred for 10 min at 0 °C then 1-butylbromide (1.6 mL, 14.4 mmol, 1.3 equiv) and TBAI (0.4 g, 1.1 mmol, 0.1 equiv) were added. The resulting suspension was stirred at room temperature for 4 h before being quenched by the careful addition of 0.5 M aqueous citric acid (50 mL). The mixture was poured into a separatory funnel and extracted with MTBE (3 x 50 mL). The combined organic extracts were washed with brine (50 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (hexanes→15% EtOAc/hexanes) to provide the pure title compound (2.1 g, 78% yield) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.40-7.34 (m, 5H, Ar**H**), 4.85 (s, 2H, OC**H**$_2$Ph), 3.45-3.42 (m, 2H, NC**H**$_2$CH$_2$CH$_2$CH$_3$), 1.58-1.57 (m, 2H, NCH$_2$C**H**$_2$CH$_2$CH$_3$), 1.31 (dt, 2H, J = 7.5 Hz, NCH$_2$CH$_2$C**H**$_2$CH$_3$), 0.90 (t, 3H, J = 7.5 Hz, NCH$_2$CH$_2$CH$_2$C**H**$_3$).

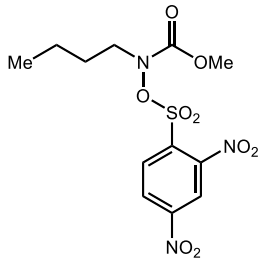
Methyl benzyloxy(propylphenyl)carbamate



To a stirred solution of methyl benzyloxycarbamate (1.0 g, 5.52.0 mmol, 1.0 equiv) in DMF (19 mL) at 0 °C was added NaH (60% dispersion in oil, 0.255 g, 9.38 mmol, 1.7 equiv). The reaction mixture was stirred for 10 min at 0 °C then 1-bromo-3-phenylpropane (1.17 mL, 7.7mmol, 1.4 equiv) and TBAI (0.408 g, 1.1 mmol, 0.2 equiv) were added. The resulting suspension was stirred at room temperature for 3 h before being quenched by the careful addition

of 0.5 M aqueous citric acid (50 mL). The mixture was poured into a separatory funnel and extracted with MTBE (3 x 50 mL). The combined organic extracts were washed with brine (50 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The residue was purified by flash chromatography on silica gel (hexanes→15% EtOAc/hexanes) to provide the pure title compound (3.27g, 59% yield) as a colorless oil. ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.44 – 7.35 (m, 6H, Ar**H**), 7.33 – 7.27 (m, 6H, Ar**H**), 7.24 – 7.17 (m, 3H, Ar**H**), 4.91 – 4.83 (s, 2H, OC**H$_2$**Ph), 3.86 – 3.77 (s, 3H, CO_2**Me**), 3.55 – 3.45 (t, *J* = 7.2 Hz, 2H, C**H$_2$**N), 2.69 – 2.60 (t, *J* = 7.8 Hz, 2H, C**H$_2$**Ph), 2.01 – 1.89 (m, 2H, CH_2C**H$_2$**CH_2Ph). HRMS (ESI-TOF) calculated for $C_{18}H_{21}NNaO_3$ $[M+Na]^+$ m/z 299.1517, found 299.1521.

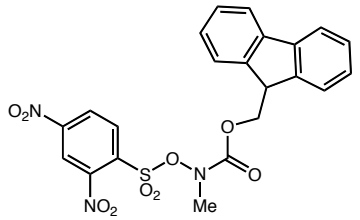
Methyl butyl(2,4-dinitrophenylsulfonyloxy)carbamate (Table 2, entry 4)



To a solution of methyl benzyloxy(butyl)carbamate (1.0 g, 4.4 mmol, 1.0 equiv) in EtOH (25 mL), was added $Pd(OH)_2$/C (~0.2 g, 20 wt.%) and the resulting suspension was purged by evacuation and then back filled with a stream of hydrogen (balloon) for three times. The mixture was stirred for 16 h at room temperature under hydrogen atmosphere and then filtered directly through a pad of celite. The filter cake was rinsed with EtOH (2 x 10 mL) and the filtrate was concentrate *in vacuo* to give a colorless oil. The crude product was dissolved in CH_2Cl_2 (40 mL), cooled to 0 °C, then NEt_3 (0.8 mL, 5.7 mmol, 1.3 equiv) and 2,4-dinitrobenzenesulfonyl chloride (1.3 g, 4.8 mmol, 1.1 equiv) were added. The resulting orange solution was stirred at 0 °C for 30 min, then diluted with 0.5 M aqueous citric acid (30 mL) and extracted with CH_2Cl_2 (2 x 30 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (30 mL) and brine (30 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant yellow solid was purified by flash chromatography on silica gel (30% EtOAc/hexanes) to provide the pure title compound (1.15 g, 69% yield) as light yellow crystals. IR (thin film) 3105, 2964, 2876, 1720, 1538, 1469, 1444, 1407, 1345, 1292, 1195, 1111, 1020, 916, 832, 819, 810, 751, 735, 660, 619,

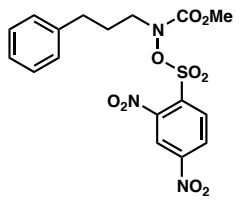
610, 587 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.67 (d, 1H, *J* = 2.2 Hz, Ar**H**), 8.56 (dd, 1H, *J* = 2.2, 8.6 Hz, Ar**H**), 8.41 (d, 1H, *J* = 8.6 Hz, Ar**H**), 3.62 (m, 2H, $NC\mathbf{H}_2CH_2CH_2CH_3$), 1.60 (m, 2H, $NCH_2C\mathbf{H}_2CH_2CH_3$), 1.27 (dt, 2H, *J* = 7.4 Hz, $NCH_2CH_2C\mathbf{H}_2CH_3$), 0.87 (t, 3H, *J* = 7.4 Hz, $NCH_2CH_2CH_2C\mathbf{H}_3$); ^{13}C NMR (125 MHz, $CDCl_3$) δ 155.5, 151.0, 148.9, 134.5, 133.3, 126.3, 120.2, 54.4, 53.8, 27.9, 19.7, 13.7; HRMS (ESI-TOF) calculated for $C_{12}H_{15}N_3NaO_9S$ $[M+Na]^+$ m/z 400.0421, found 400.0421.

***9-fluorenyl* 2,4-dinitrophenylsulfonyloxy(methyl)carbamate**



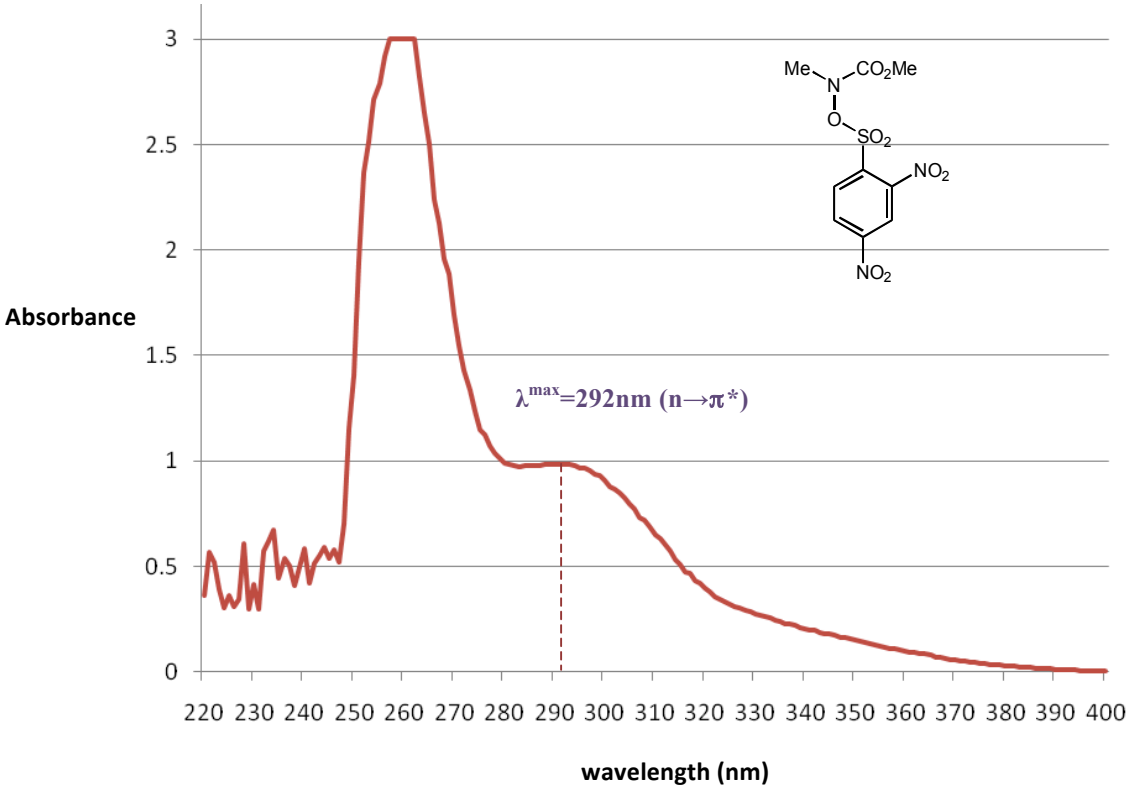
To a stirred solution of *9-fluorenyl* hydroxy(methyl)carbamate (0.485g, 1.8mmol, 1.1 equiv) in CH_2Cl_2 (6 mL) at 0 °C was added NEt_3 (0.324mL, 2.34mmol, 1.3 equiv) and 2,4-dinitrobenzenesulfonyl chloride (0.426g, 1.6 mmol, 1.0 equiv). The resulting orange solution was stirred at 0 °C for 3 h, then diluted with 0.75 M aqueous citric acid (10 mL) and extracted with CH_2Cl_2 (2 x 20 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (30 mL) and brine (30 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant orange oil was purified by flash chromatography on silica gel (5-30% EtOAc/hexanes) to provide the pure title compound as a yellow solid (466 mg, 58% yield). ^1H NMR (500mHz, $CDCl_3$) δ8.59 (s, 1H, J=2.01 Hz, ArH), δ8.49 (d, 1H, J=2.01, ArH), δ8.30 (d, 1H, J= 8.75, ArH), δ7.76 (d, 2H, J=7.53), δ7.48 (d, 2H, J=7.47), δ7.42 (d, 2H, J=7.49, 14.99), δ7.31 (d, 2H, J=7.66, 14.63), δ4.37 (d, 2H, J=6.46), δ4.13 (m, 1H, J=12.92, 6.46) δ3.35 (s, 1H, N-Me); ^{13}C NMR (125MHz, $CDCl_3$) 156.59, 150.96, 142.74, 141.34, 134.40, 132.31, 128.16, 127.27, 126.23, 124.75, 120.25, 69.46, 46.63, 41.11; HRMS (ESI-TOF) calculated for $C_{22}H_{17}N_3NaO_9S$ $[M+Na]^+$ m/z 499.06855, found 499.06765

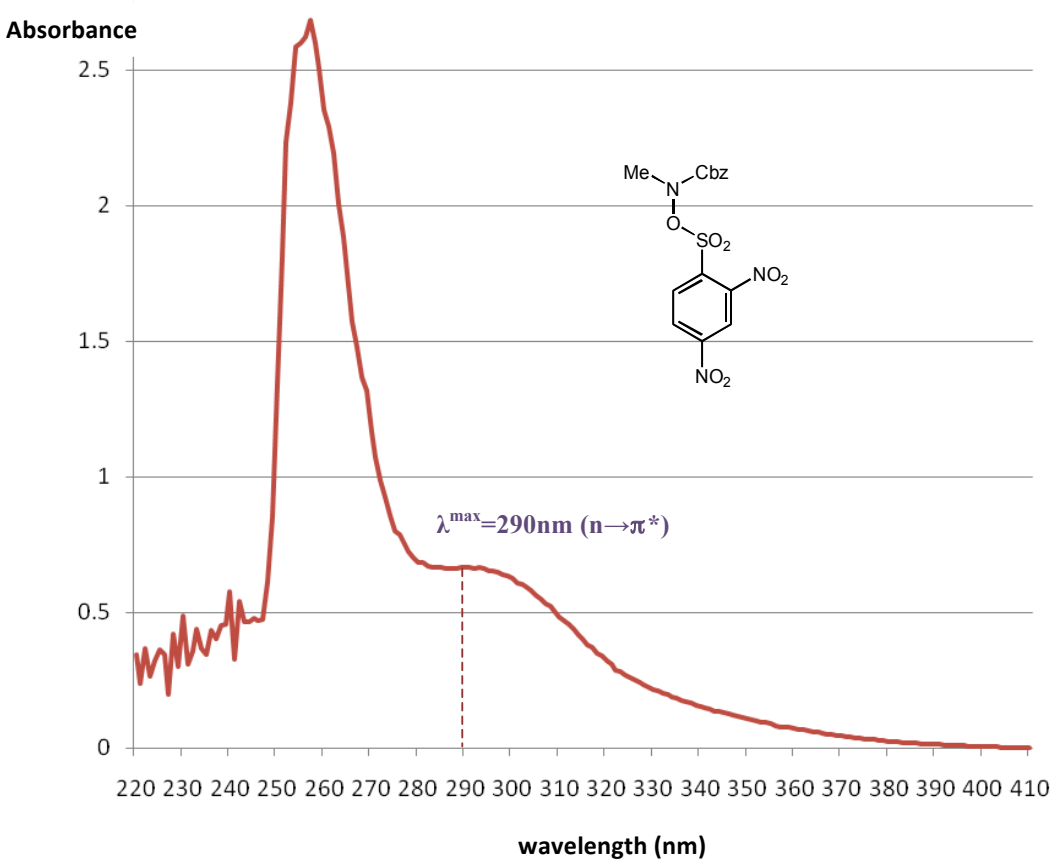
Methyl butyl(2,4-dinitrophenylsulfonyloxy)carbamate (Table 2, entry 8)

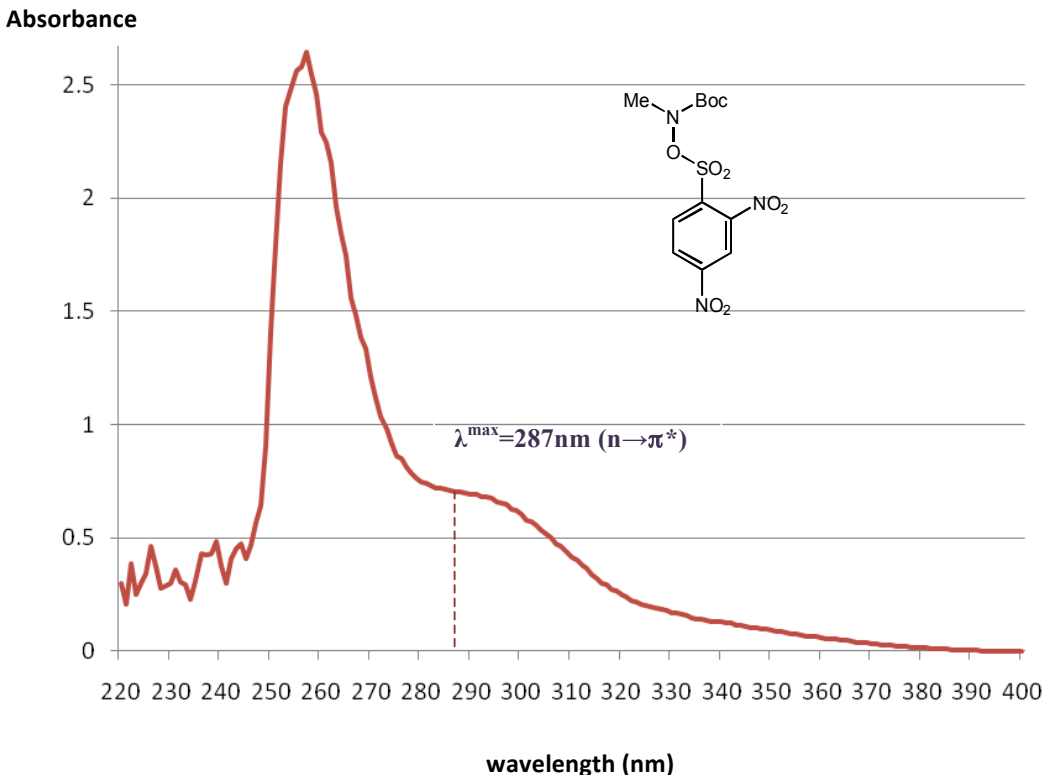


To a solution of methyl benzyloxy(propylphenyl)carbamate (3.86g, 12.89mmol, 1.0 equiv) in EtOH (43 mL), was added $Pd(OH)_2/C$ (~0.9 g, 20 wt.%) and the resulting suspension was purged by evacuation and then back filled with a stream of hydrogen (balloon) for three times. The mixture was stirred for 16 h at room temperature under hydrogen atmosphere and then filtered directly through a pad of celite. The filter cake was rinsed with EtOH (2 x 10 mL) and the filtrate was concentrate *in vacuo* to give a yellow oil. The crude product was dissolved in CH_2Cl_2 (27 mL), cooled to 0 °C, then NEt_3 (2.06 mL, 14.8mmol, 1.2 equiv) and 2,4-dinitrobenzenesulfonyl chloride (4.31g, 16mmol, 1.2 equiv) were added. The resulting orange solution was stirred at 0 °C for 30 min, then diluted with 0.5 M aqueous citric acid (50 mL) and extracted with CH_2Cl_2 (2 x 30 mL). The combined organic extracts were washed with saturated aqueous $NaHCO_3$ (30 mL) and brine (30 mL), dried ($MgSO_4$) and concentrated *in vacuo*. The resultant yellow solid was purified by flash chromatography on silica gel (10% EtOAc/hexanes) to provide the pure title compound (5.01g, 84% yield) as yellow oil. IR (thin film) 2966, 2232, 2013, 1734, 1541, 1348, 1194, 1054, 1013 cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 8.62 – 8.60 (d, J = 2.2 Hz, 1H, ArH), 8.55 – 8.50 (dd, J = 8.6, 2.2 Hz, 1H, ArH), 8.38 – 8.34 (d, J = 8.6 Hz, 1H, ArH), 7.30 – 7.24 (m, 3H, ArH), 7.22 – 7.17 (m, 1H, ArH), 7.16 – 7.12 (m, 2H, ArH), 3.68 – 3.58 (s over m, 5H, CO_2**Me** and C**H$_2$**N), 2.67 – 2.59 (t, J = 7.6 Hz, 2H, CH_2CH_2**CH$_2$**Ph), 2.06 – 1.95 (m, 3H), 1.59 – 1.53 (m, 2H, CH_2C**H$_2$**CH_2Ph). ^{13}C NMR (125 MHz, $CDCl_3$) δ 153.5, 148.8, 142.6, 140.3, 134.1, 128.4, 126.1, 120.3, 102.6, 54.5, 53.2, 32.5, 27.4; HRMS (ESI-TOF) calculated for $C_{17}H_{17}N_3NaO_9S$ $[M+Na]^+$ m/z 462.05655, found 462.05659.

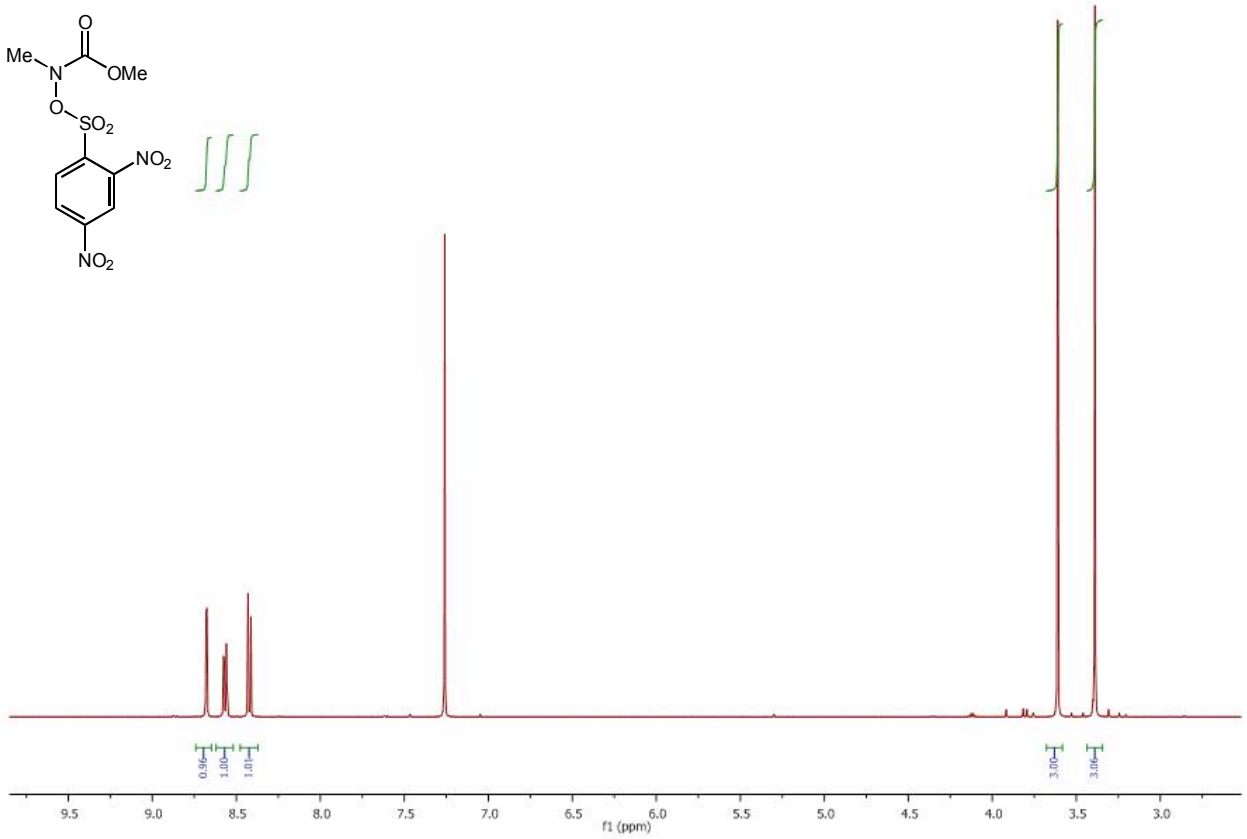
XII. Selected UV/Vis Spectra of Amine Reagents in a 1:3 DMSO/CH_3CN mixture at 0.15 mM

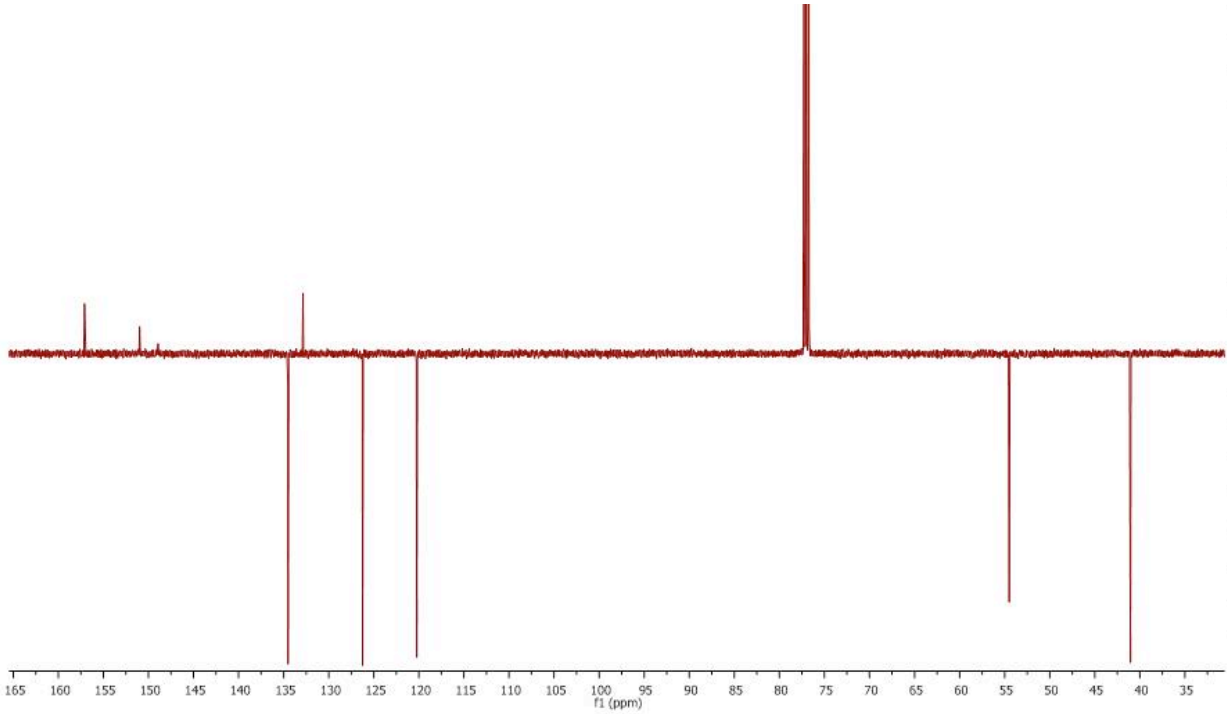


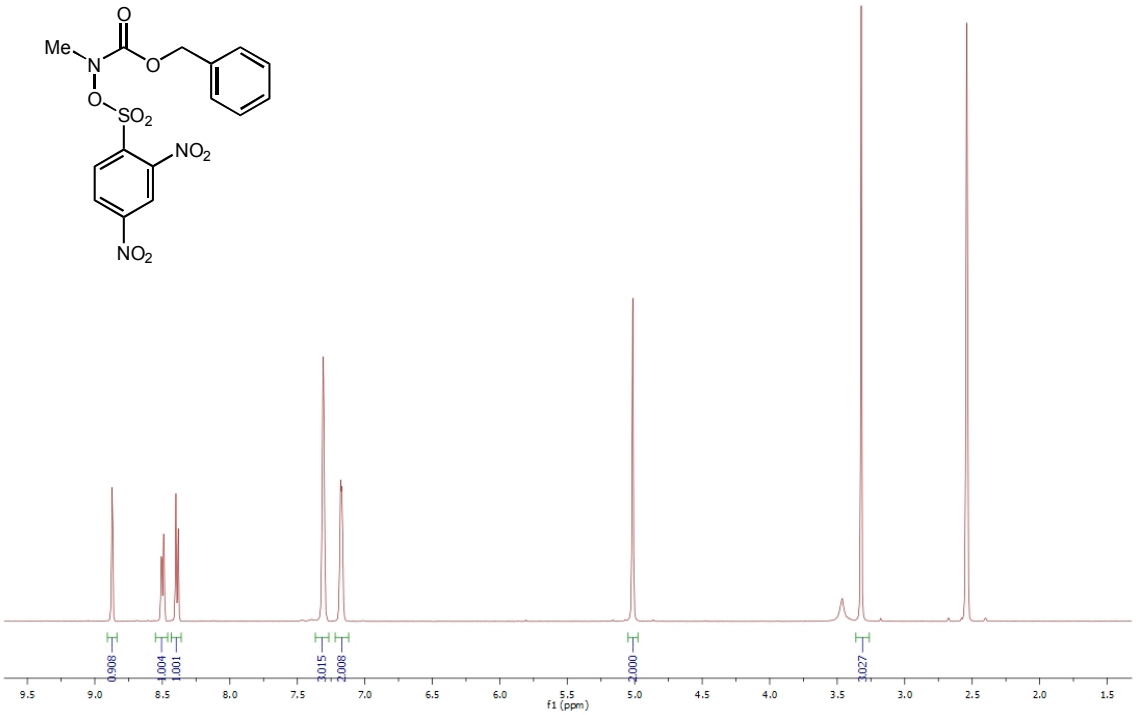

Absorbance
2.5
2
1.5
1
0.5
0
Me
N
Cbz
O
SO2
NO2
NO2
λmax=290nm (n→π*)
220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410
wavelength (nm)


Absorbance
2.5
2
1.5
1
0.5
0
Me
N
Boc
O
SO2
NO2
NO2
λmax=287nm (n→π*)
220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400
wavelength (nm)

XIII. Selected ^{1}H and ^{13}C NMR Spectra






Me
N
O
O
O
SO2
NO2
NO2
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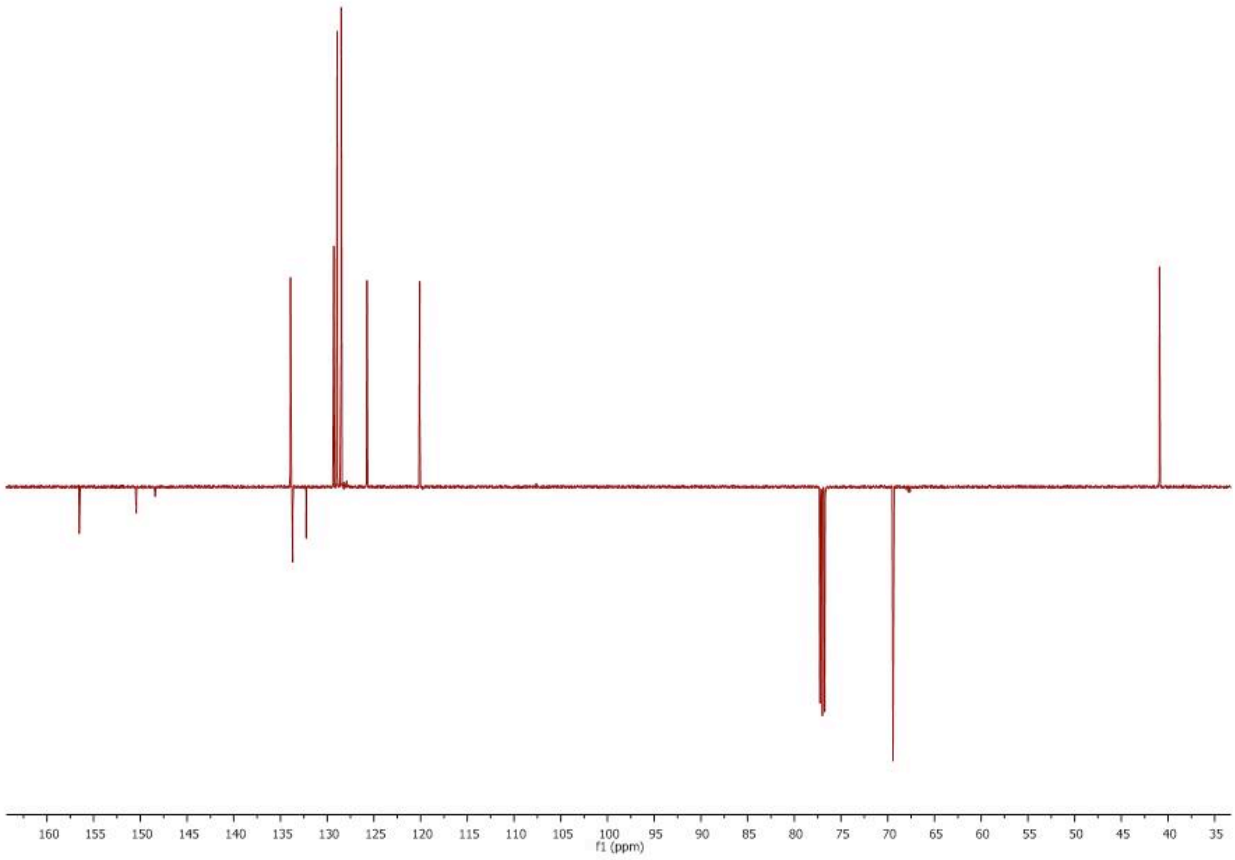
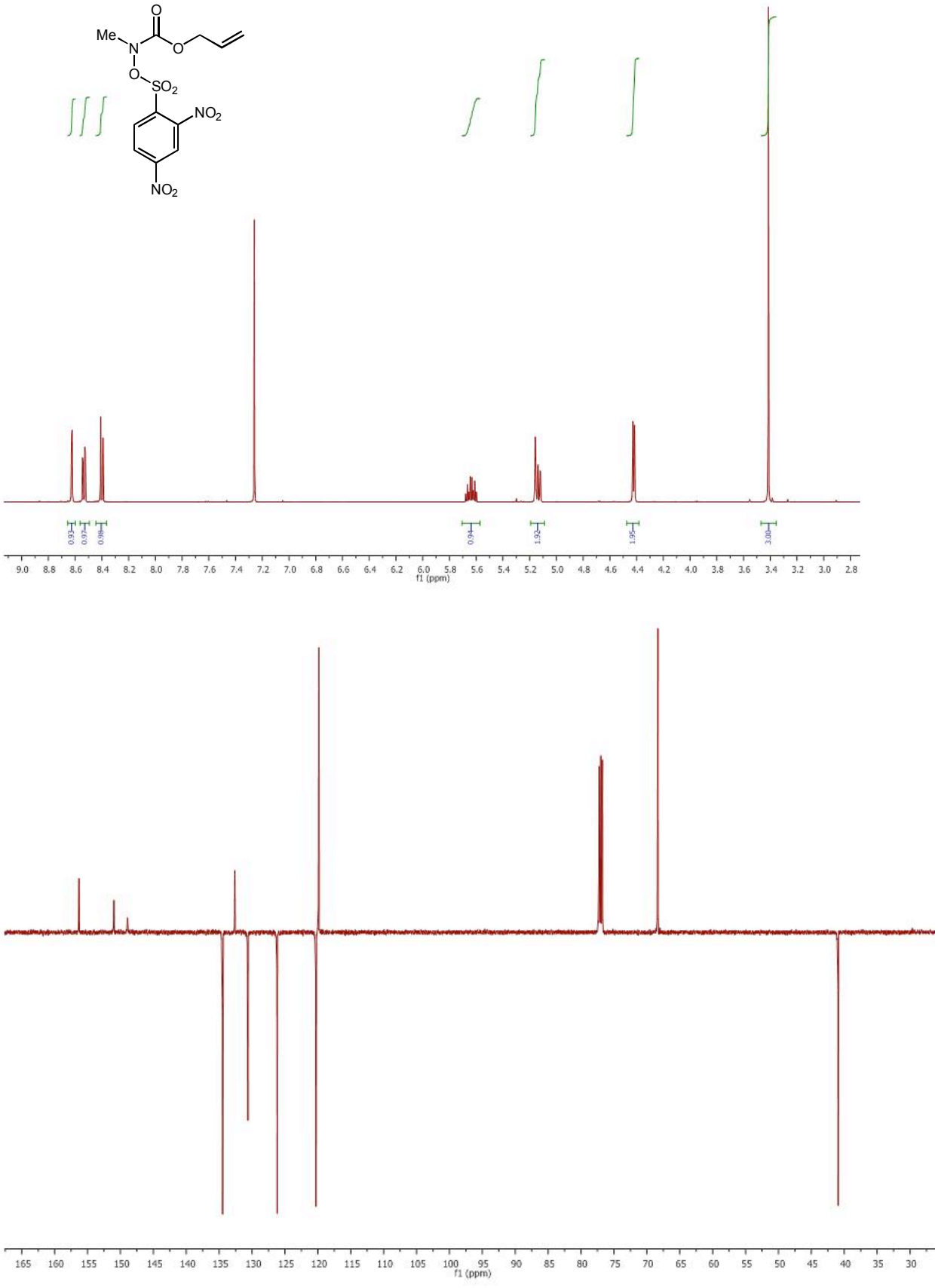
4.004
1.001
3.015
2.008
2.000
3.027
f1 (ppm)


f1 (ppm)


Me
N
O
O
O
SO2
NO2
NO2
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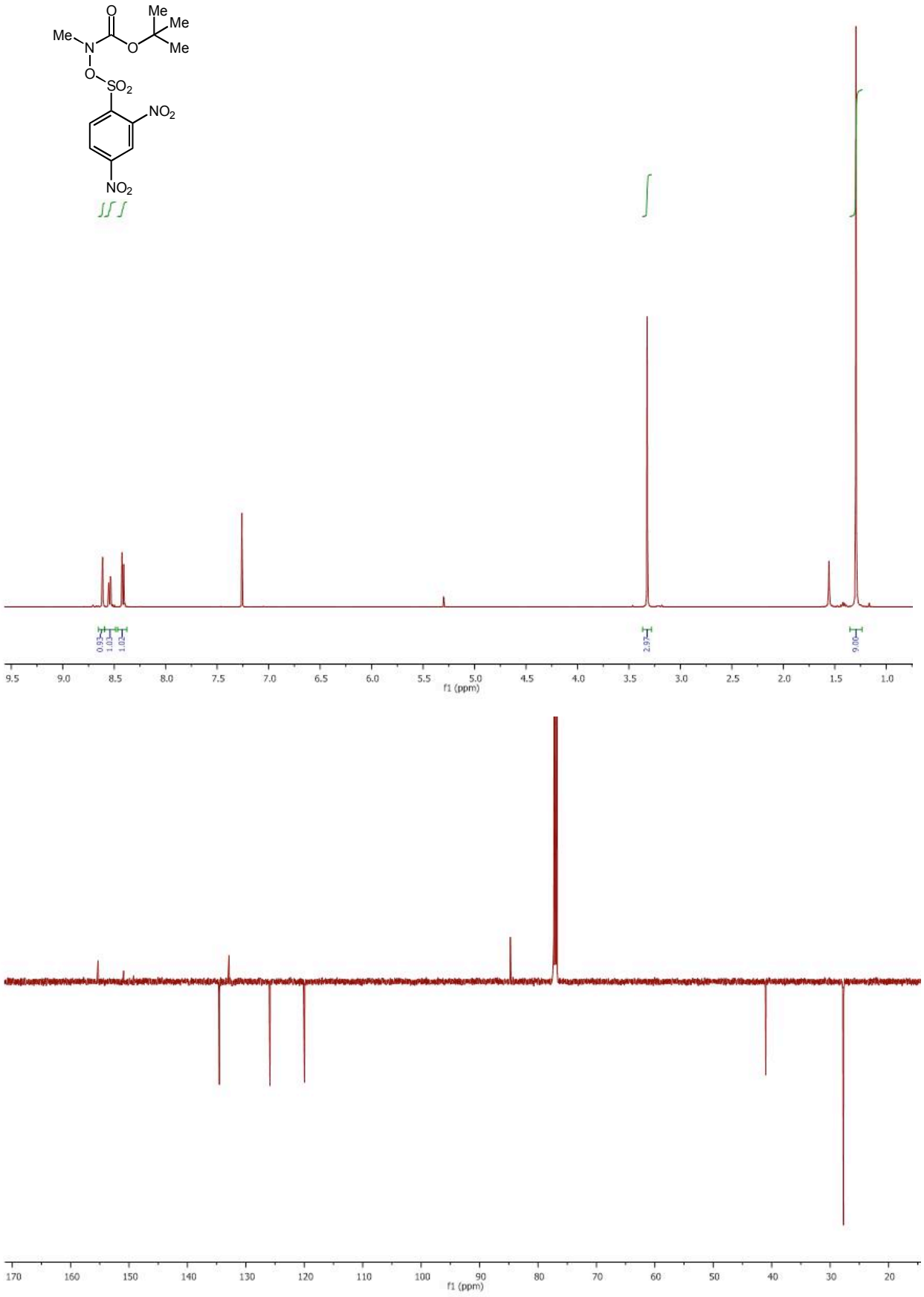
0.97
0.98
0.94
1.92
1.95
3.00
f1 (ppm)
f1 (ppm)


Me
Me
Me
O
N
O
O
Me
O
SO2
NO2
NO2
0.93
1.03
1.02
2.97
9.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
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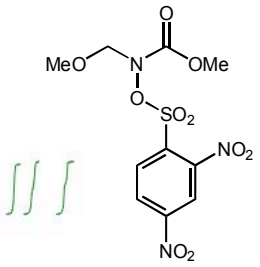
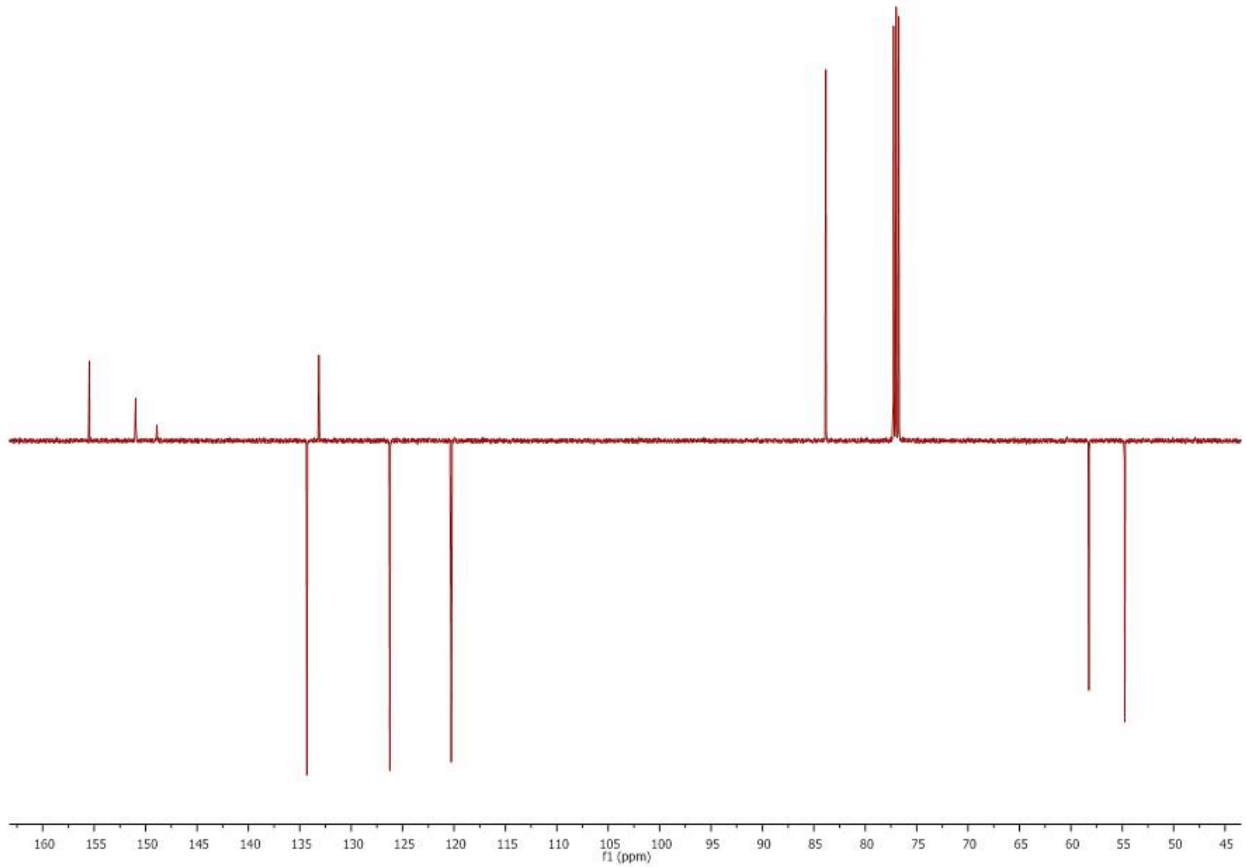
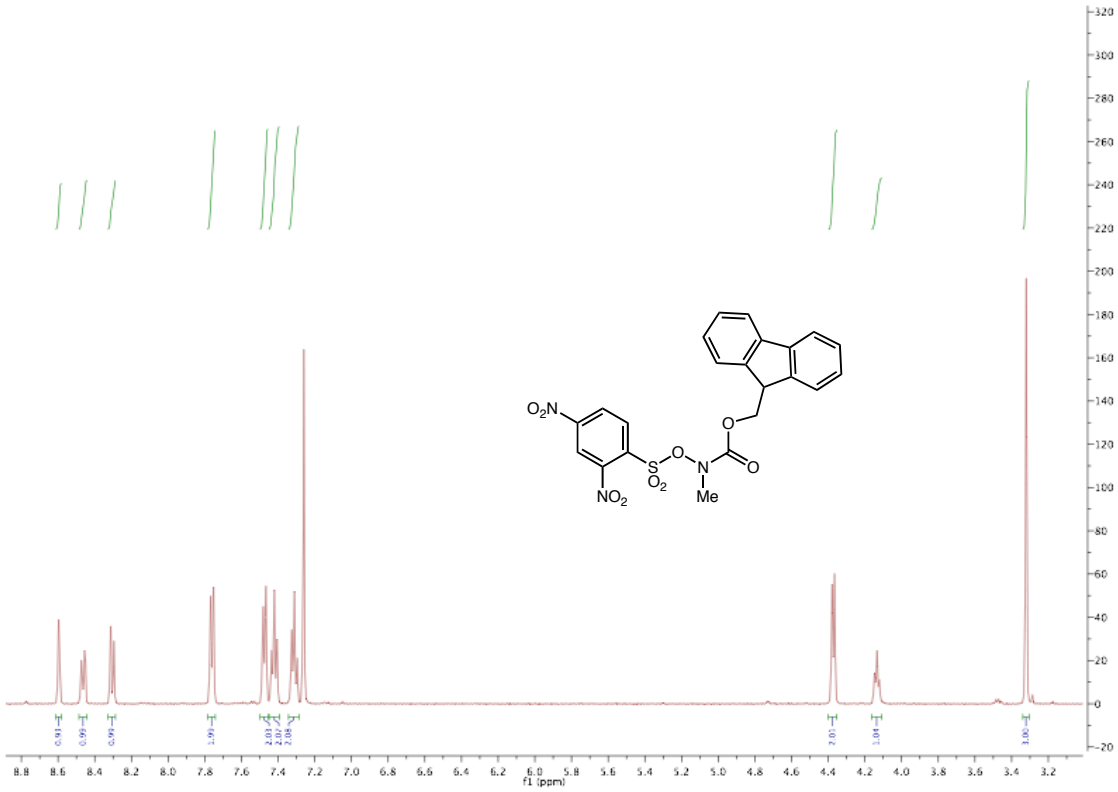
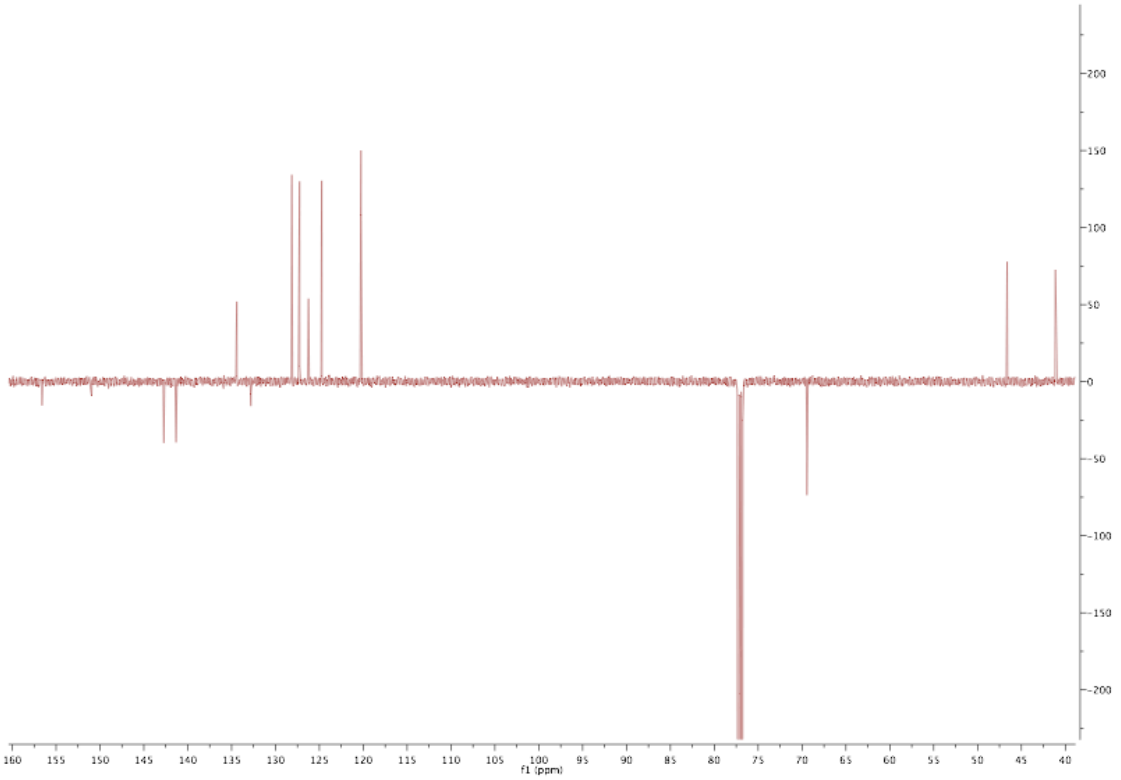
4.0
3.5
3.0
2.5
2.0
1.5
1.0
f1 (ppm)
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
f1 (ppm)

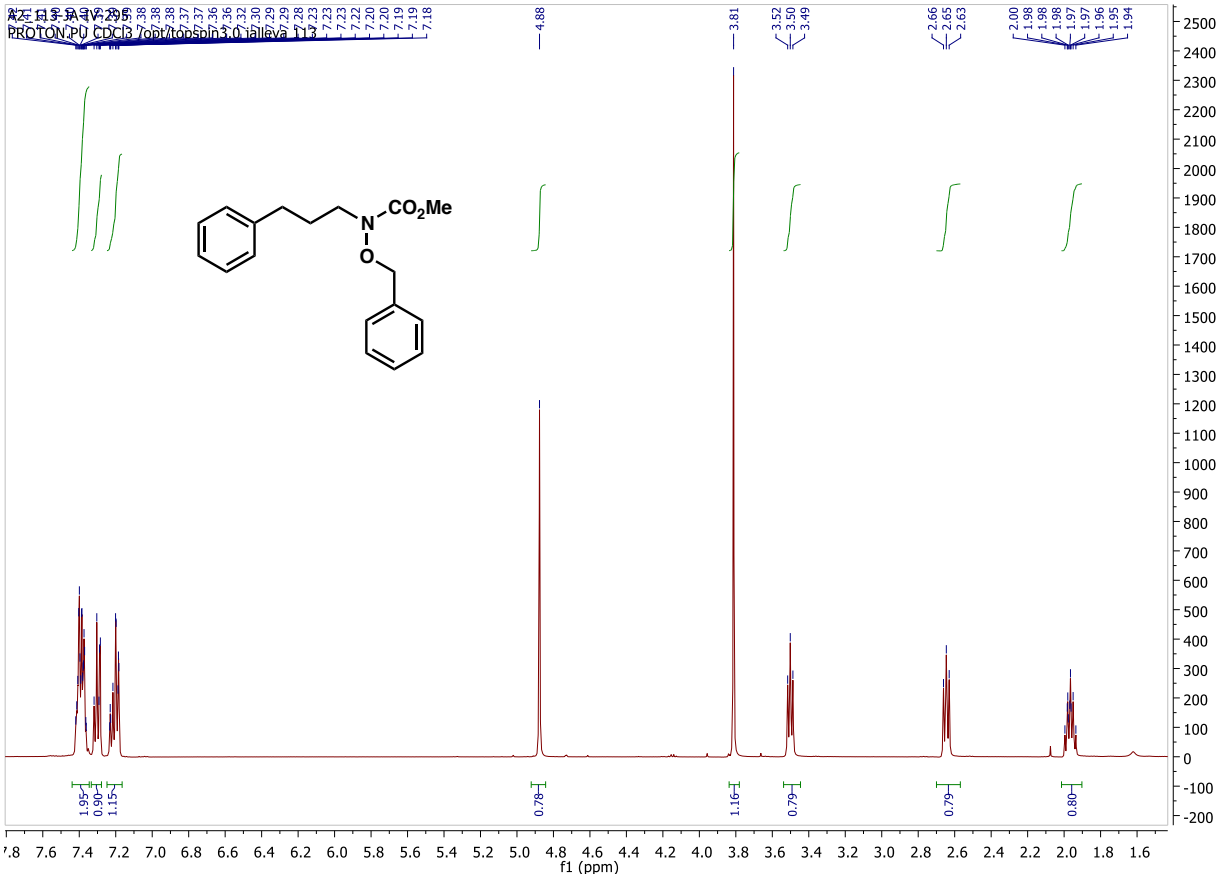

O
MeO
N
OMe
O
SO2
NO2
NO2

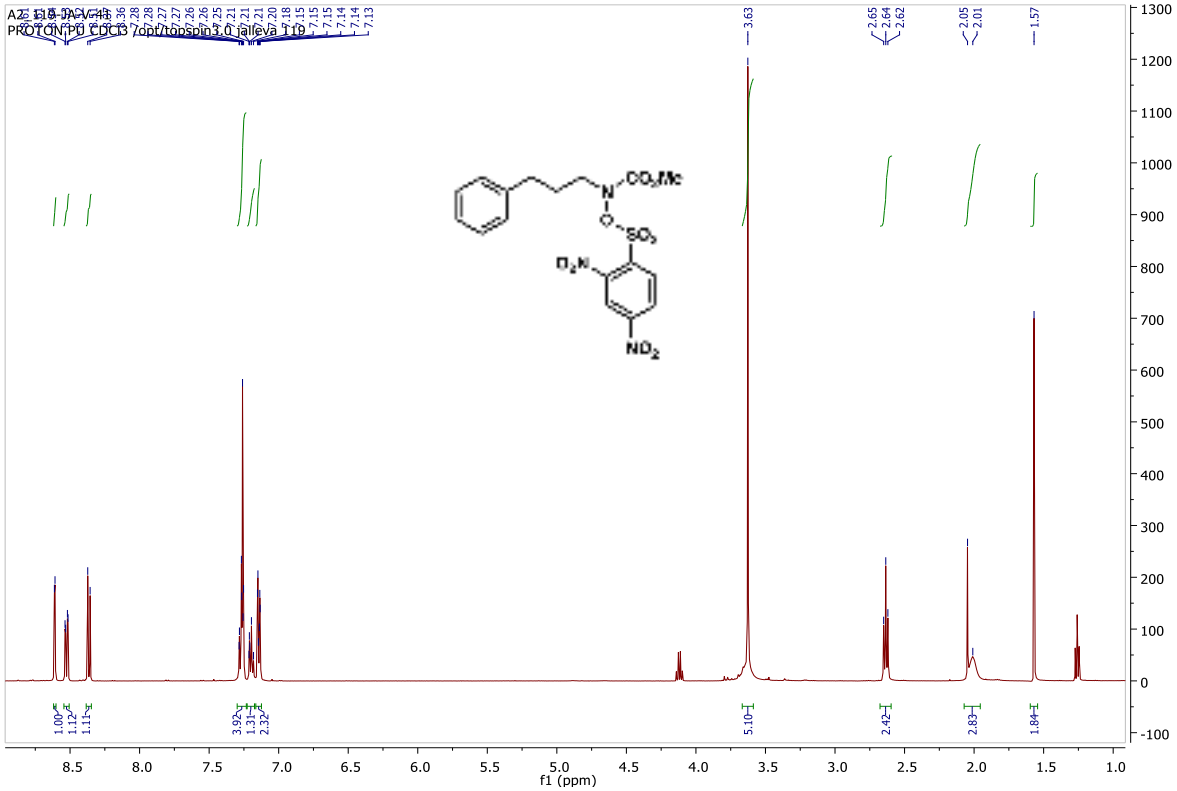
0.95
1.00
1.00
1.91
3.00
2.08
9.0 8.8 8.6 8.4 8.2 8.0 7.8 7.6 7.4 7.2 7.0 6.8 6.6 6.4 6.2 6.0 5.8 5.6 5.4 5.2 5.0 4.8 4.6 4.4 4.2 4.0 3.8 3.6 3.4 3.2
f1 (ppm)

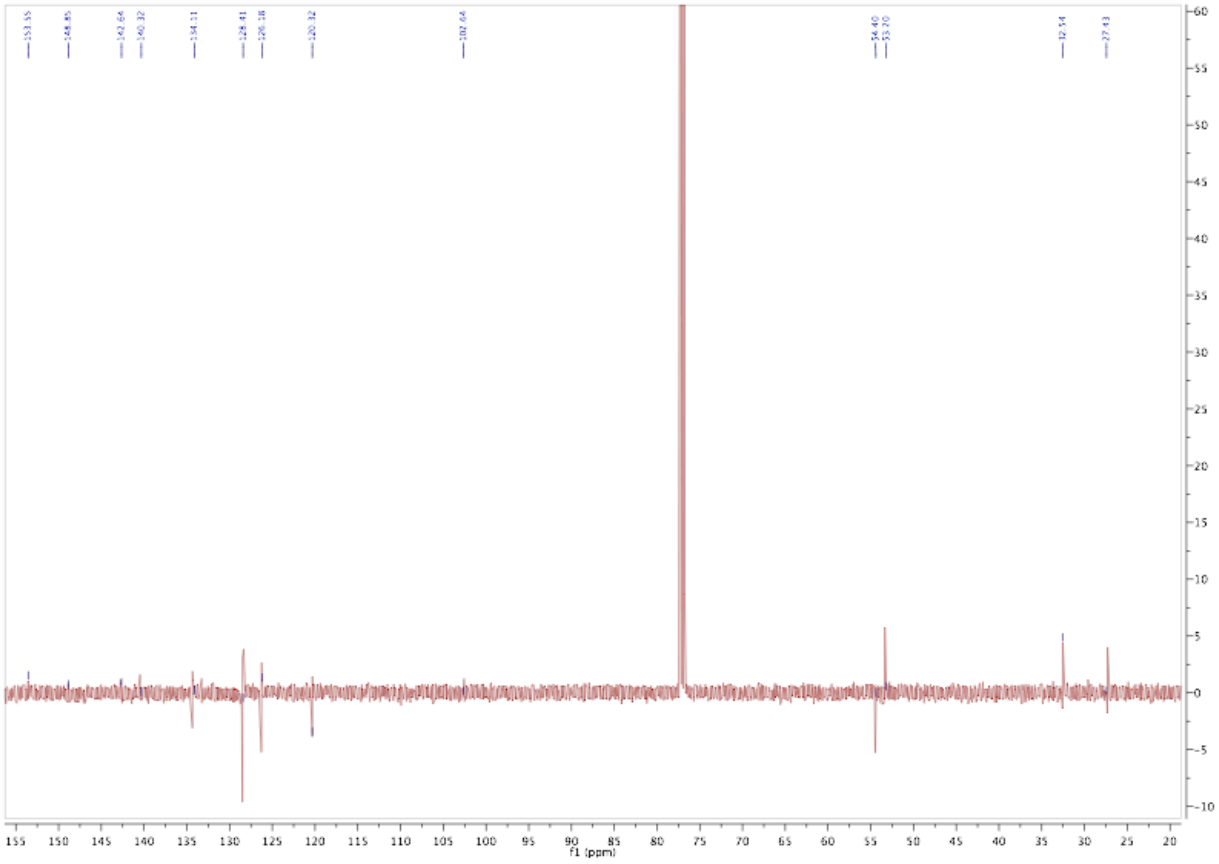

160 155 150 145 140 135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45
f1 (ppm)

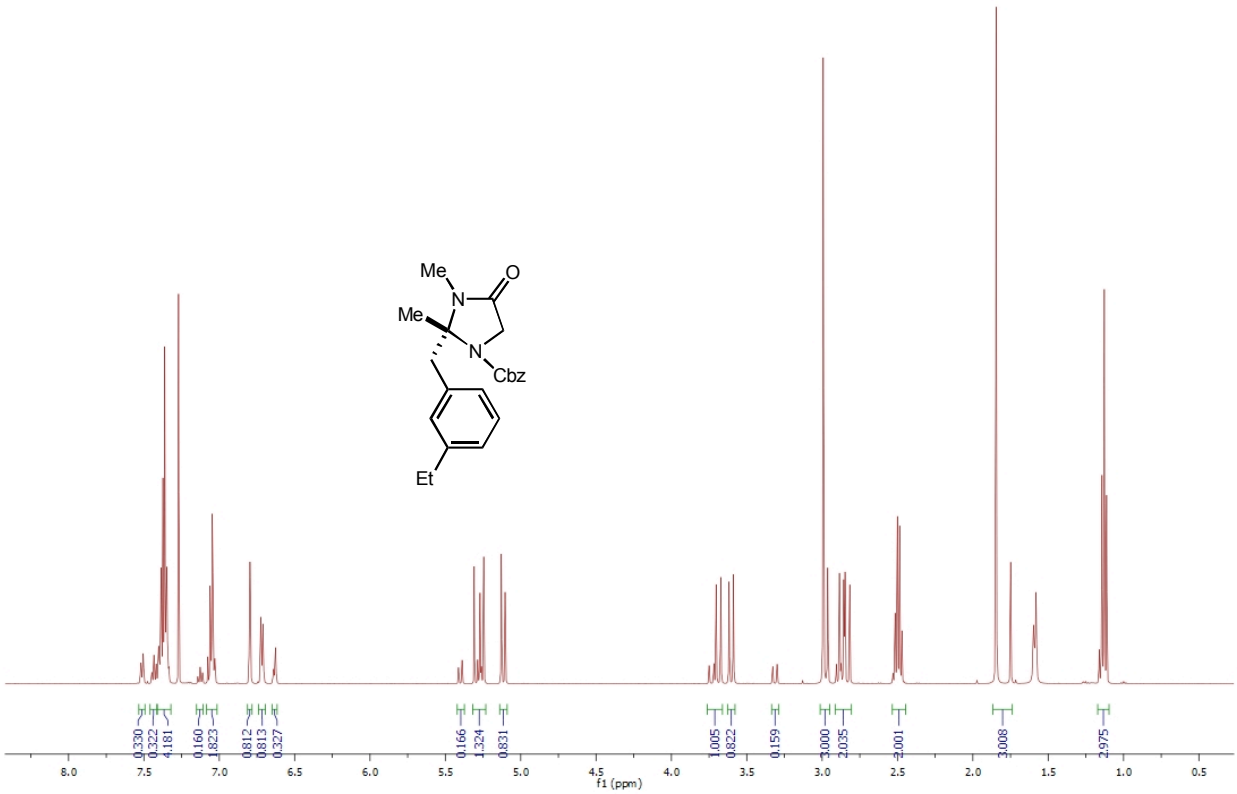

O2N
NO2
S
O2
O
N
Me
O
O
f1 (ppm)

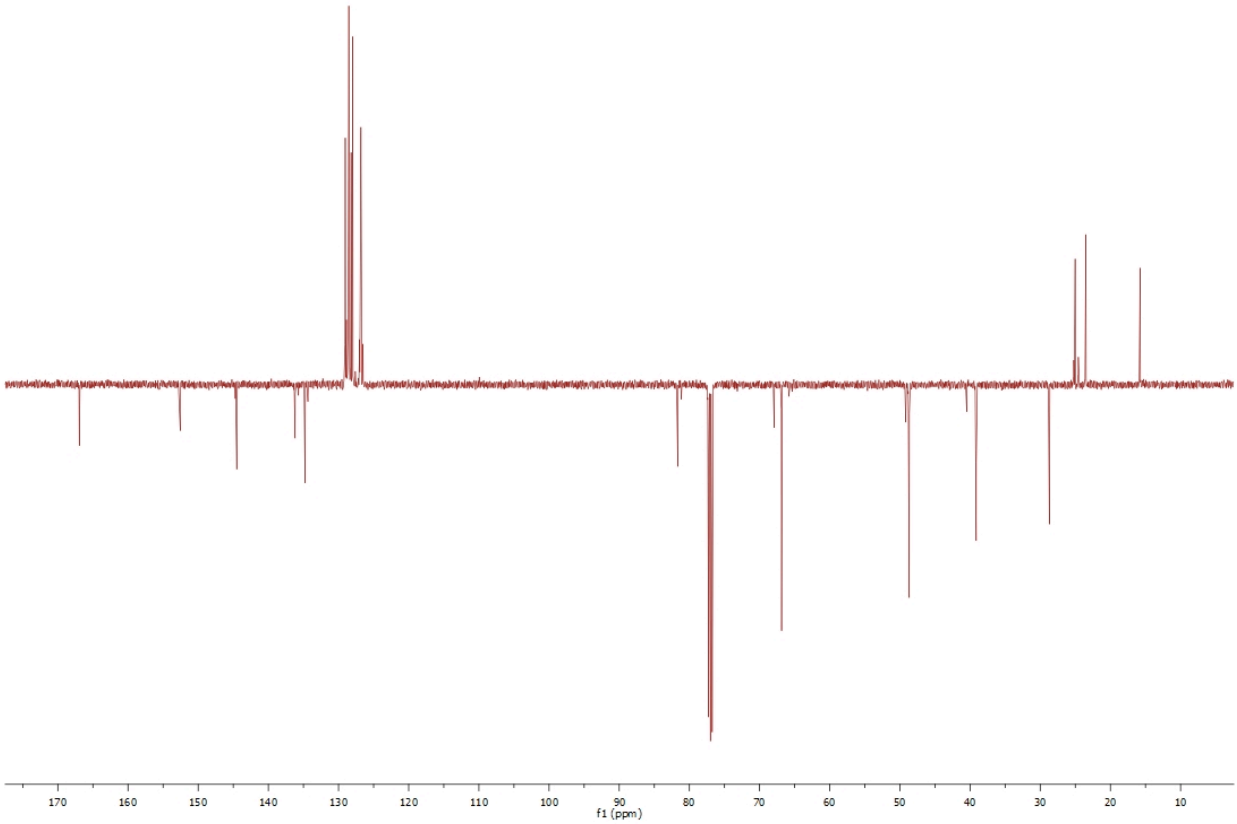

f1 (ppm)

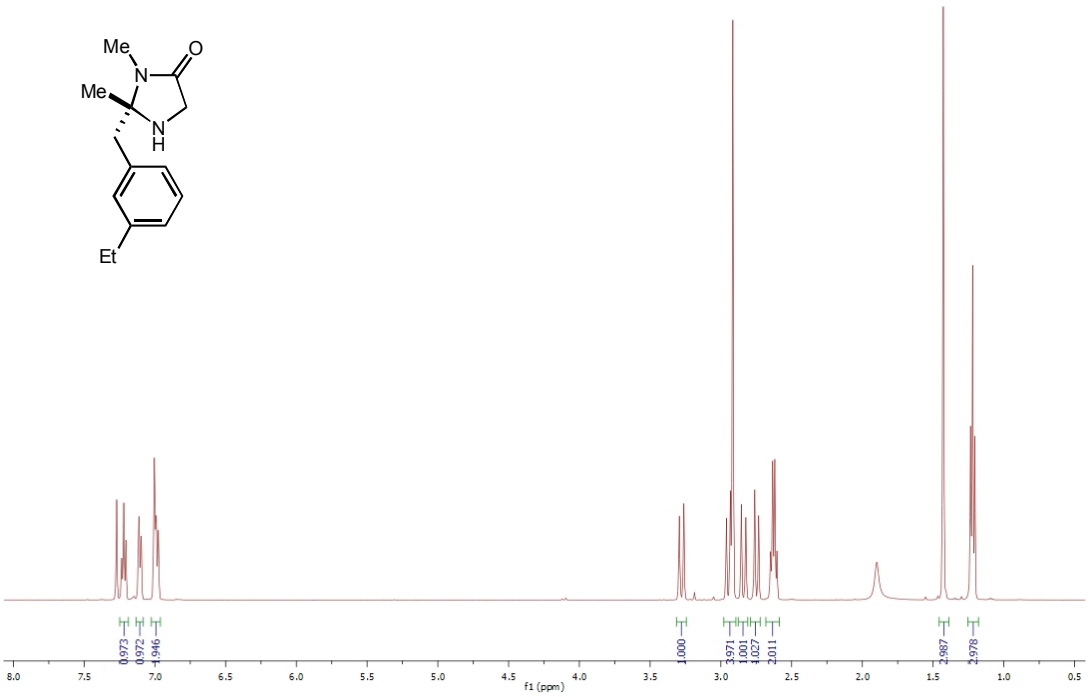

PROTON.PU CDCl3 /opt/topspin3.0 jalleva 113
4.88
3.81
3.52
3.50
3.49
2.66
2.65
2.63
2.00
1.98
1.98
1.98
1.97
1.97
1.96
1.95
1.94
CO2Me
N
O
1.95
0.90
1.15
0.78
1.16
0.79
0.79
0.80
f1 (ppm)

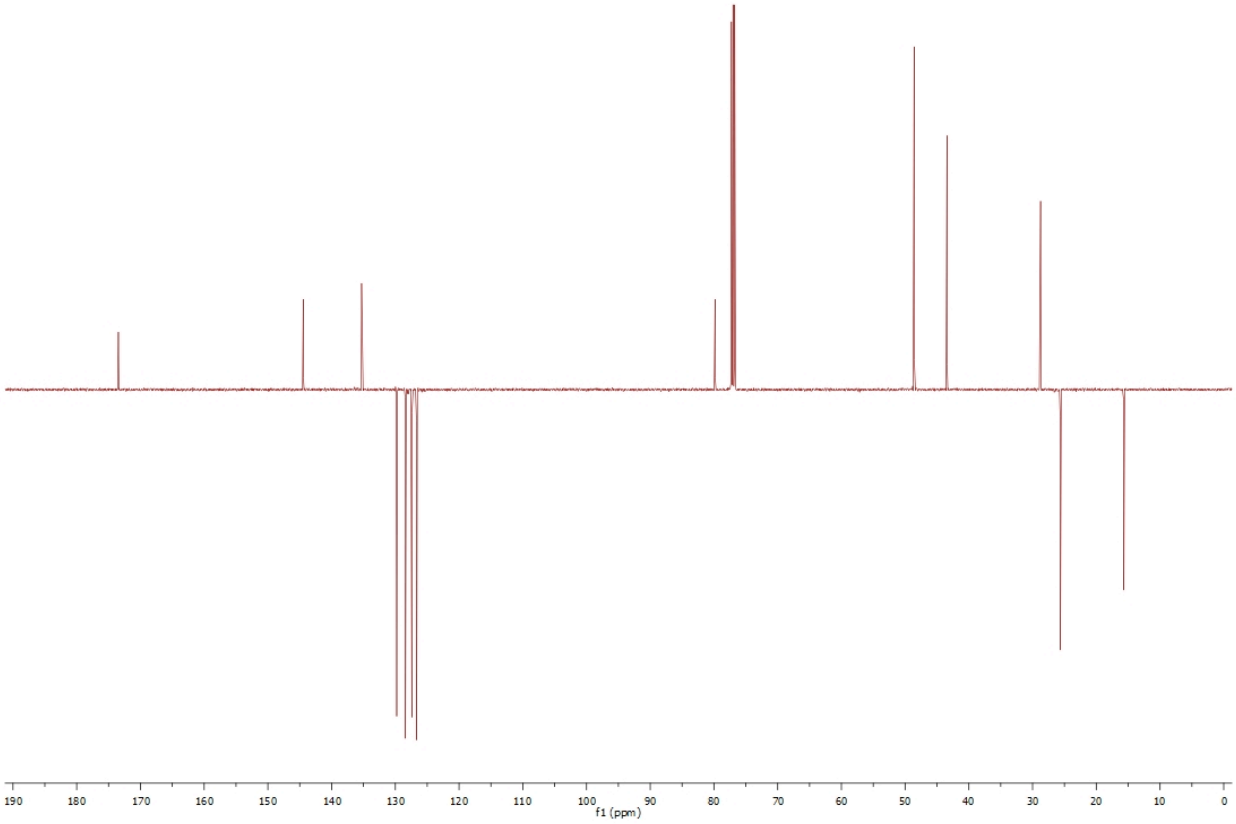

PROTON.PU CDCl3 /opt/topspin3.0 jalleva 119
3.63
2.65
2.64
2.62
2.05
2.01
1.57
CO2Me
N
O
SO2
O2N
NO2
1.00
1.12
1.11
3.92
1.31
2.32
5.10
2.42
2.83
1.84
f1 (ppm)

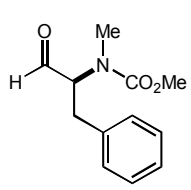

153.55
148.85
142.64
140.32
134.11
128.41
126.18
120.32
102.64
54.40
53.70
32.54
27.43
f1 (ppm)


Me
N
O
Me
N
Cbz
Et
0.330
0.322
4.181
0.160
1.823
0.812
0.813
0.327
0.166
1.324
0.831
1.005
0.822
0.159
3.000
2.035
2.001
3.008
2.975
f1 (ppm)

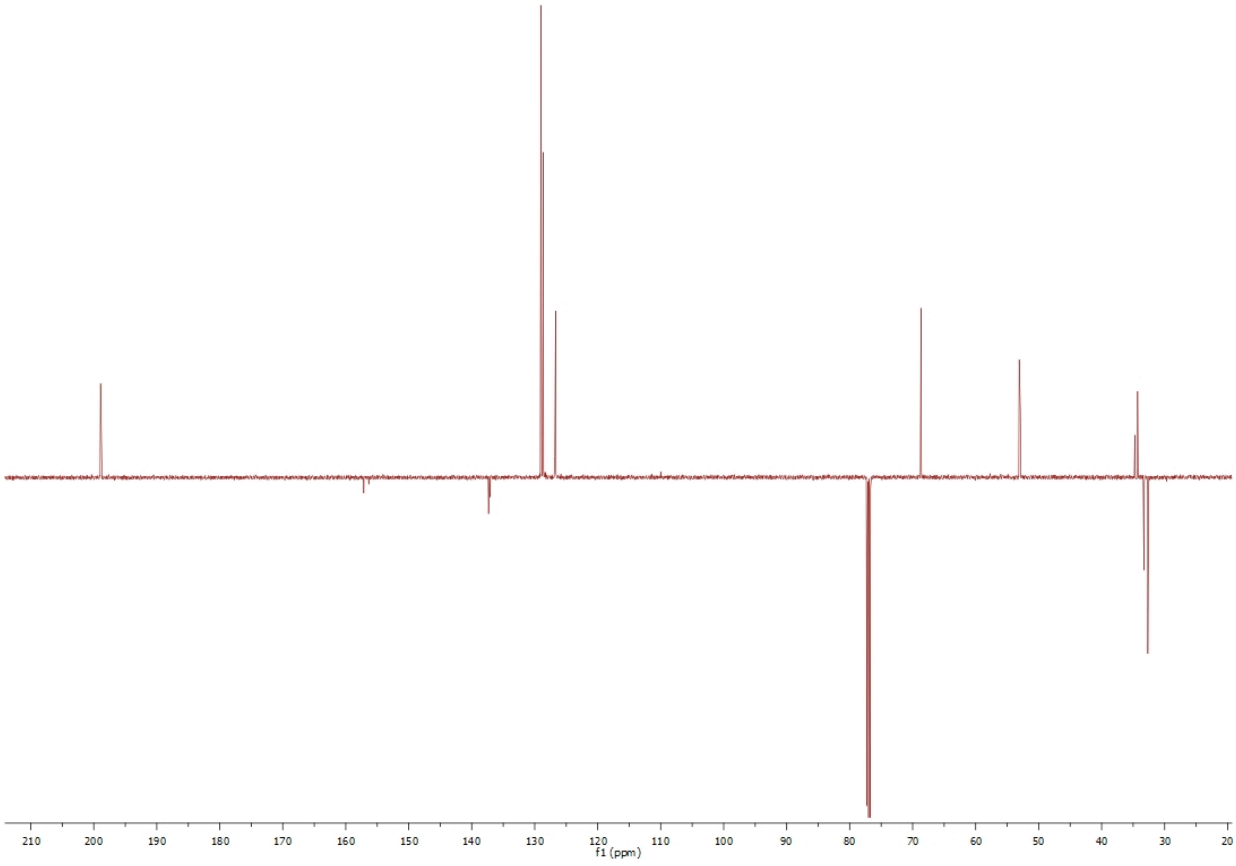

170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
f1 (ppm)

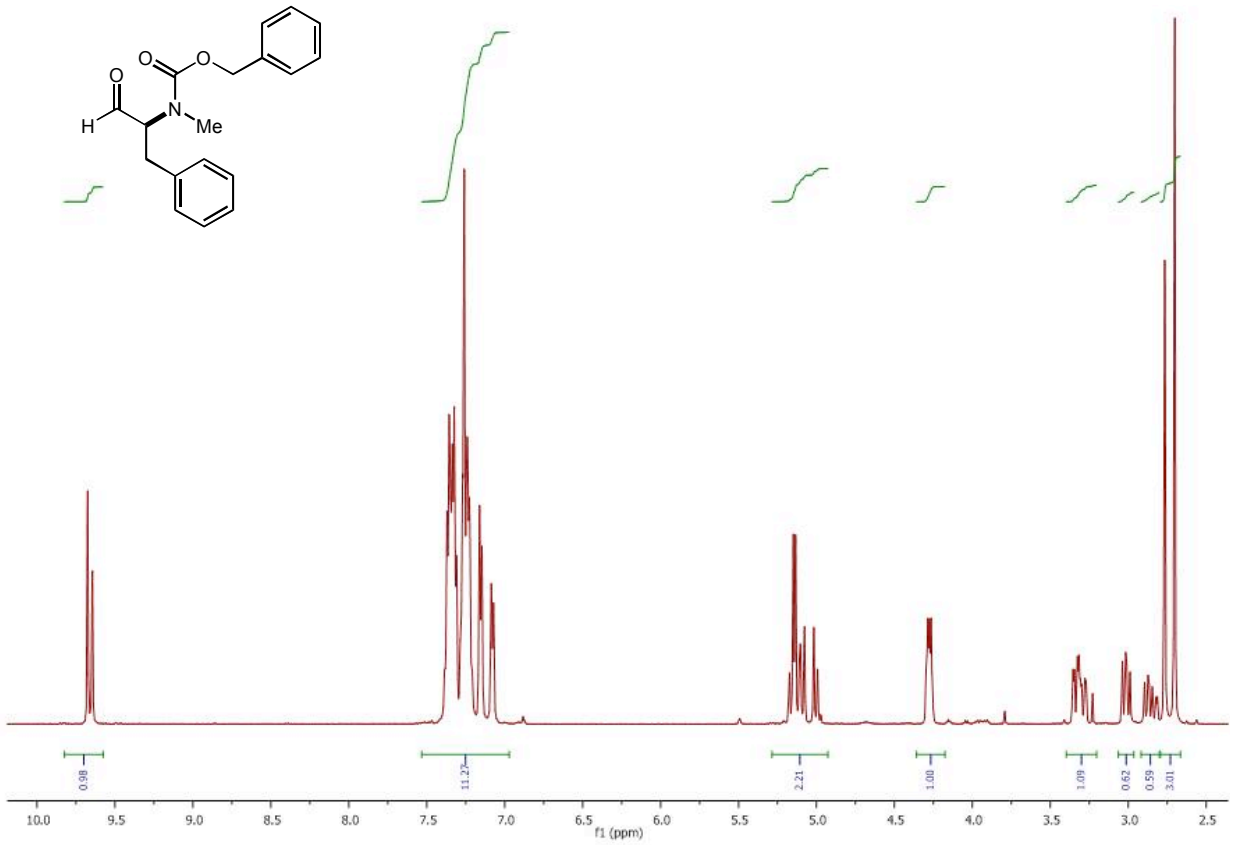

Me
N
O
Me
N
H
Et
0.973
0.972
1.946
1.000
2.971
1.001
1.027
2.011
2.987
2.978
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

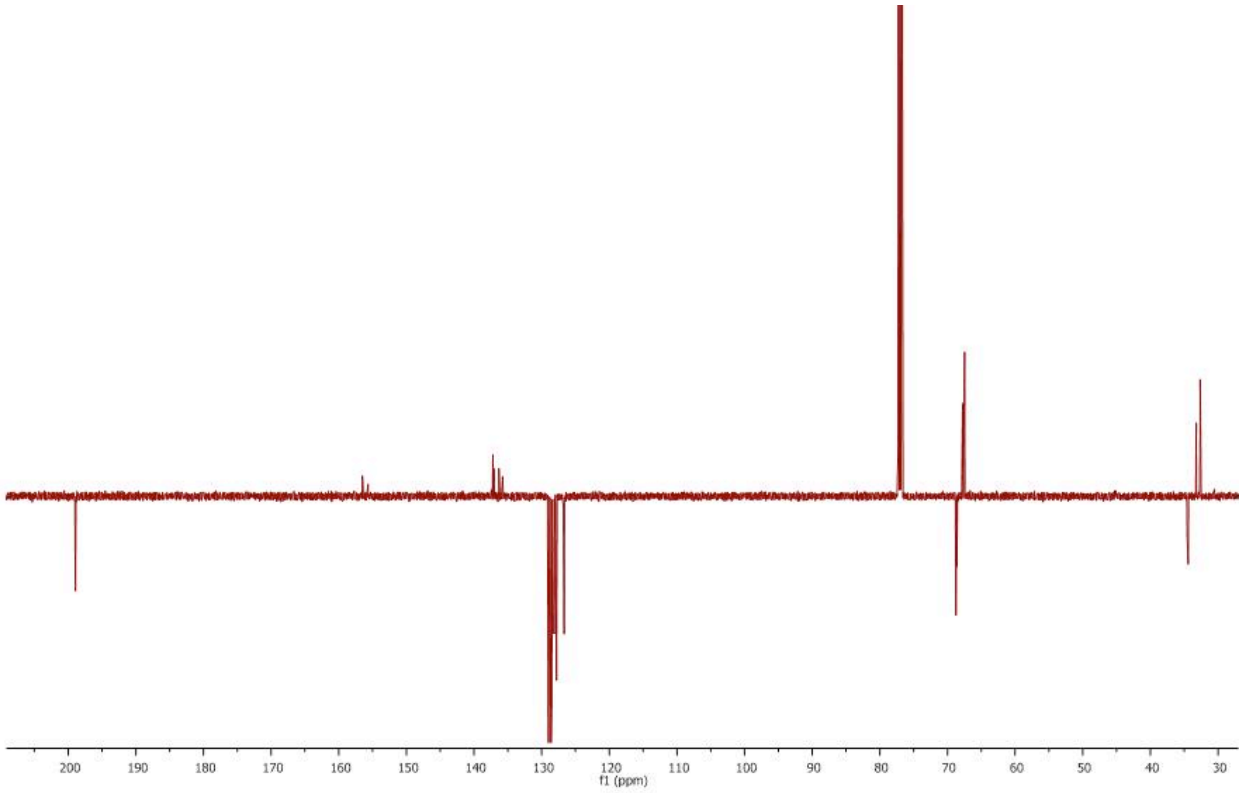

190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

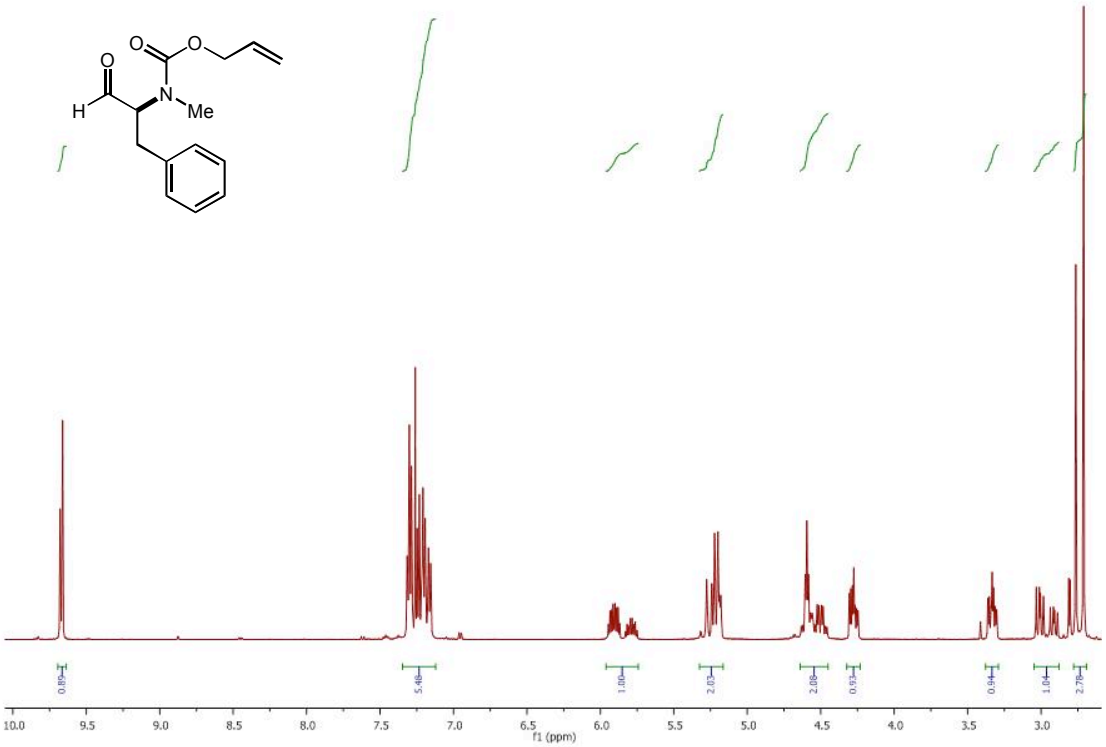

O
Me
H
N
CO2Me

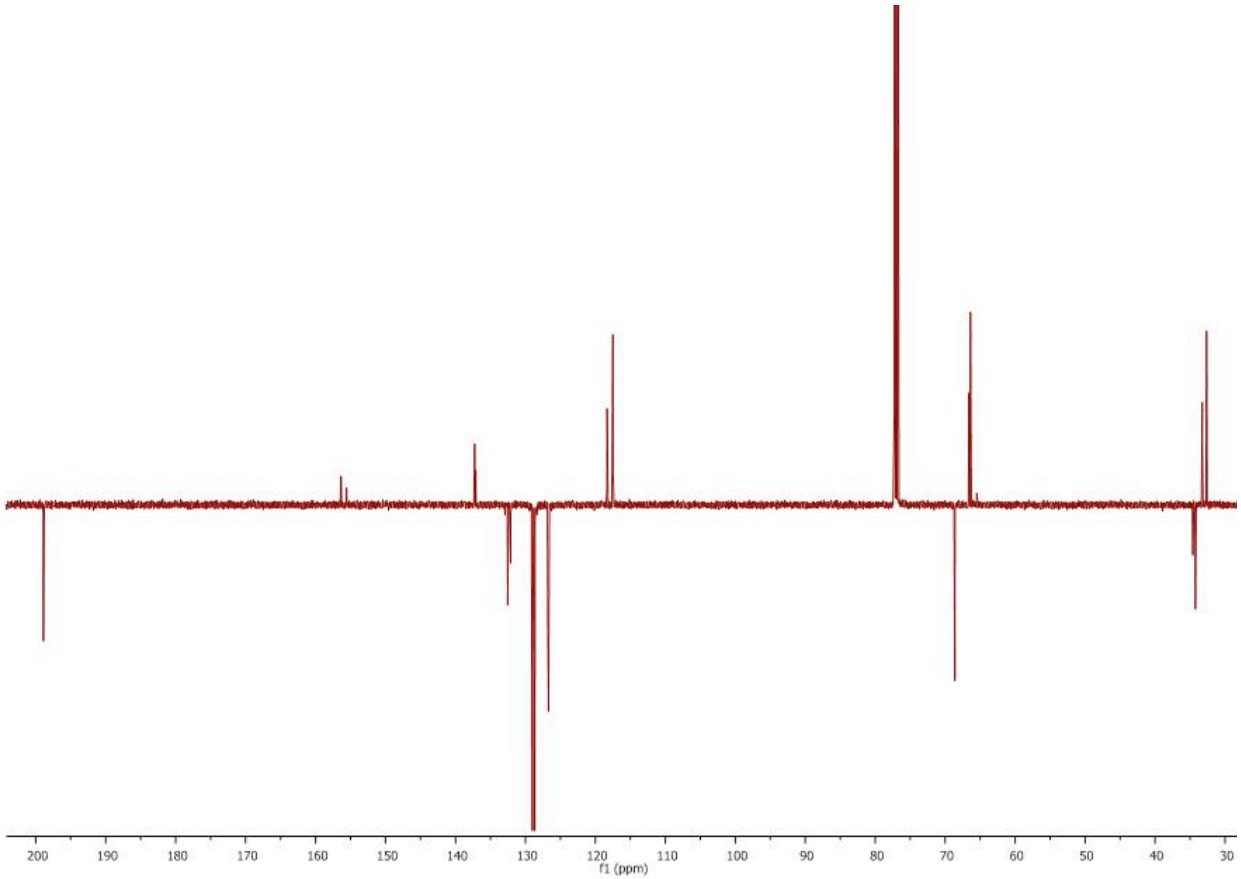
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

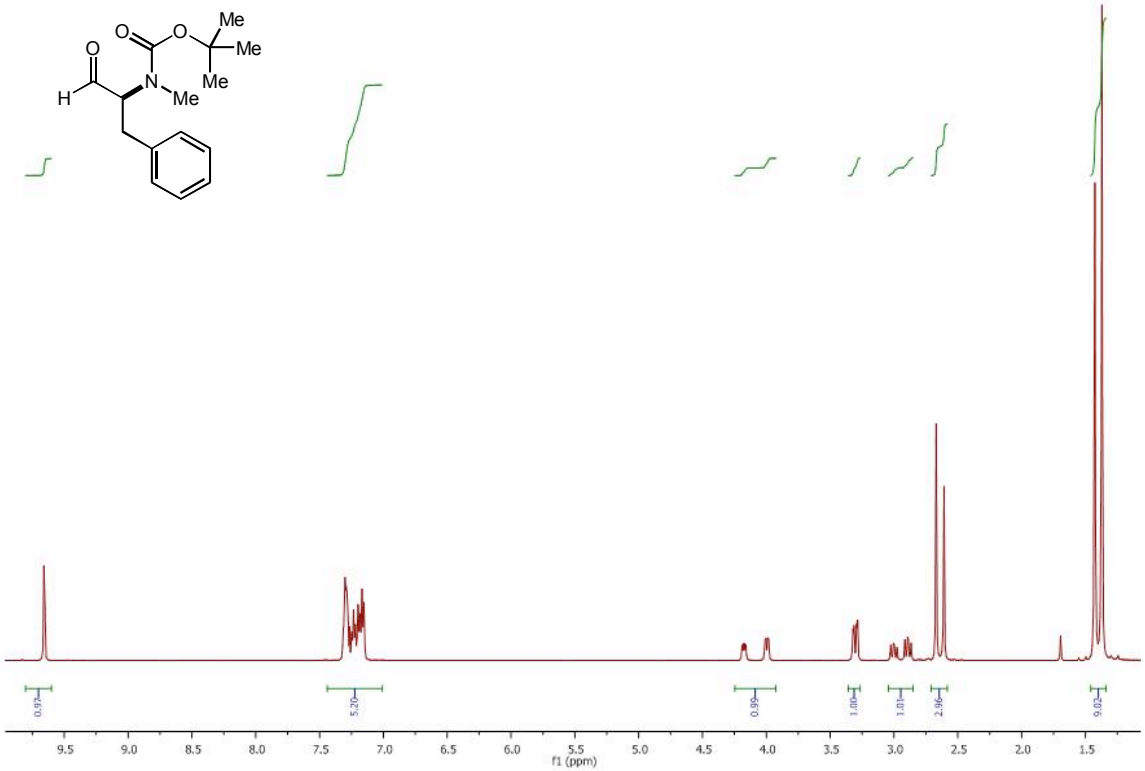

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
f1 (ppm)

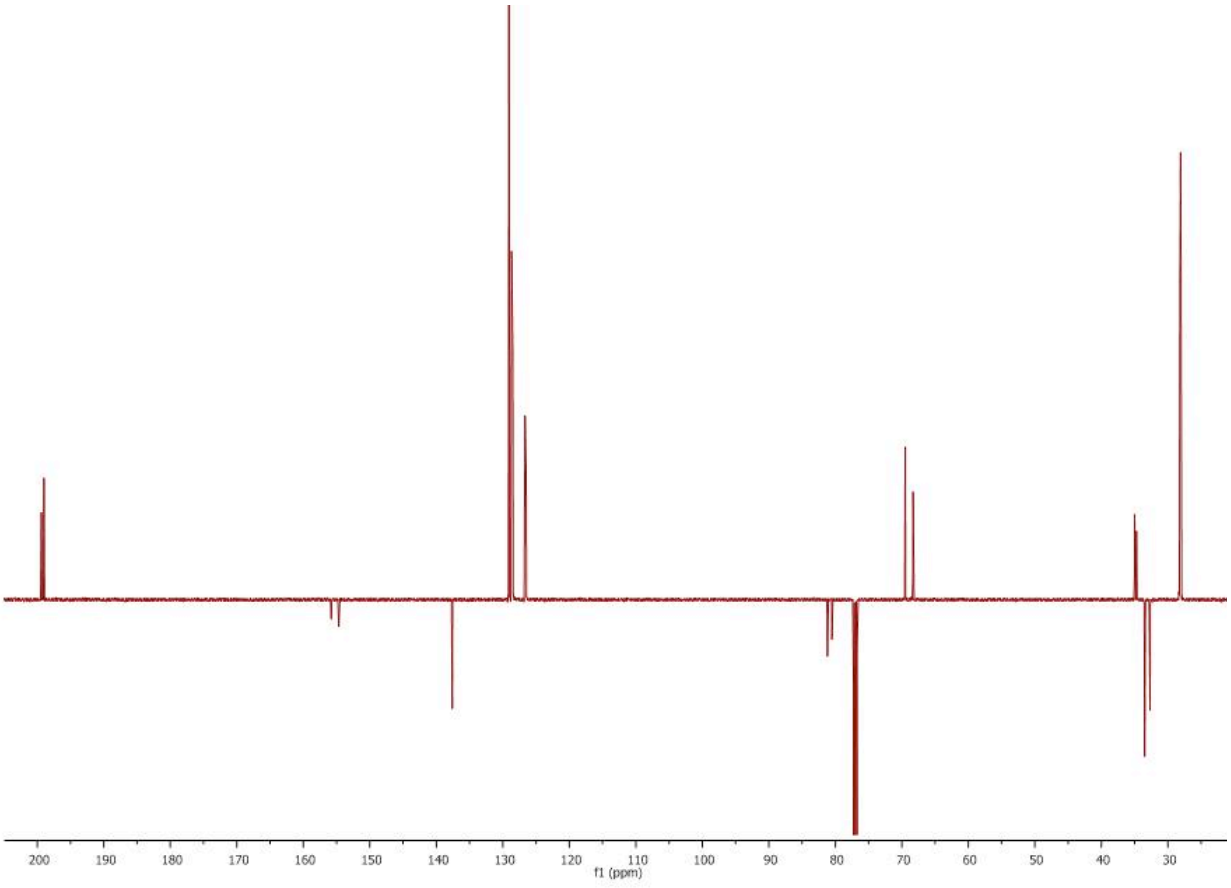

O
O
O
H
N
Me
0.98
11.27
2.21
1.00
1.09
0.62
0.59
3.01
10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5
f1 (ppm)

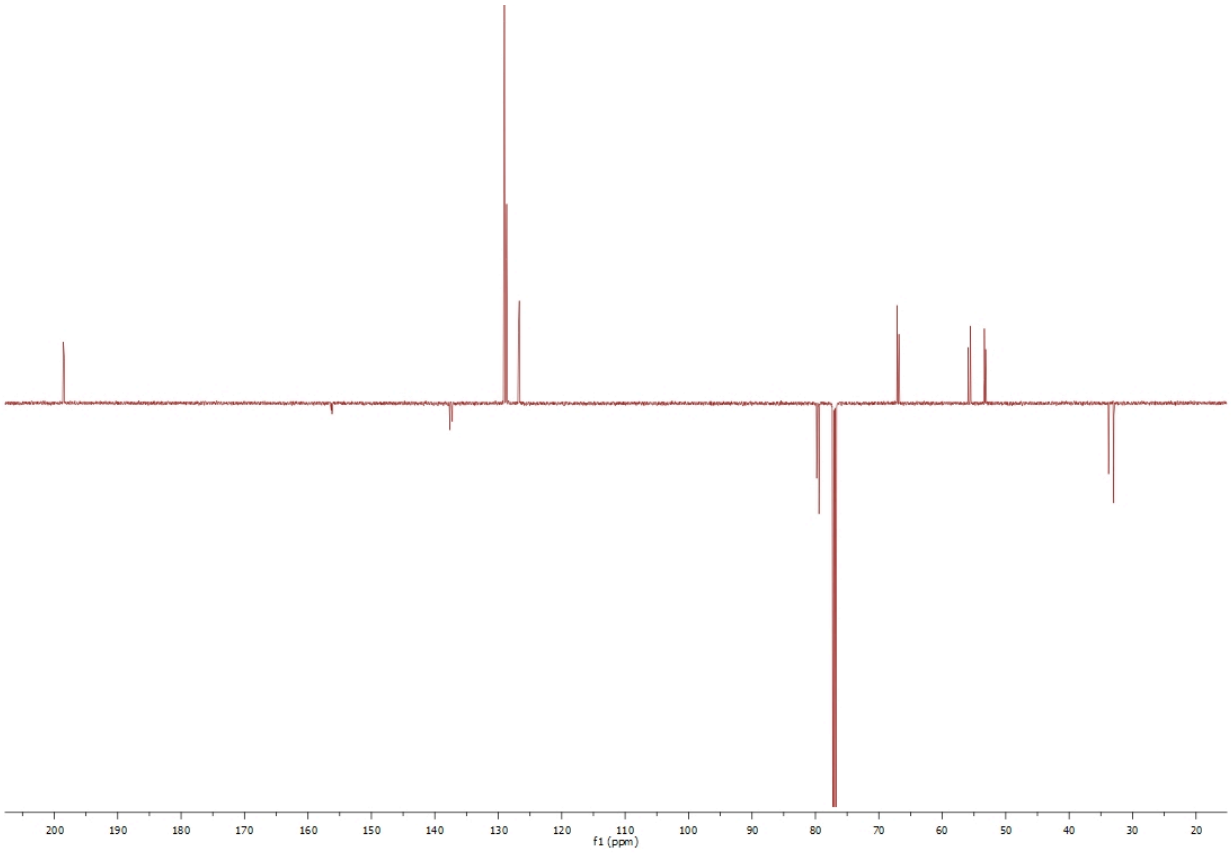

200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
f1 (ppm)

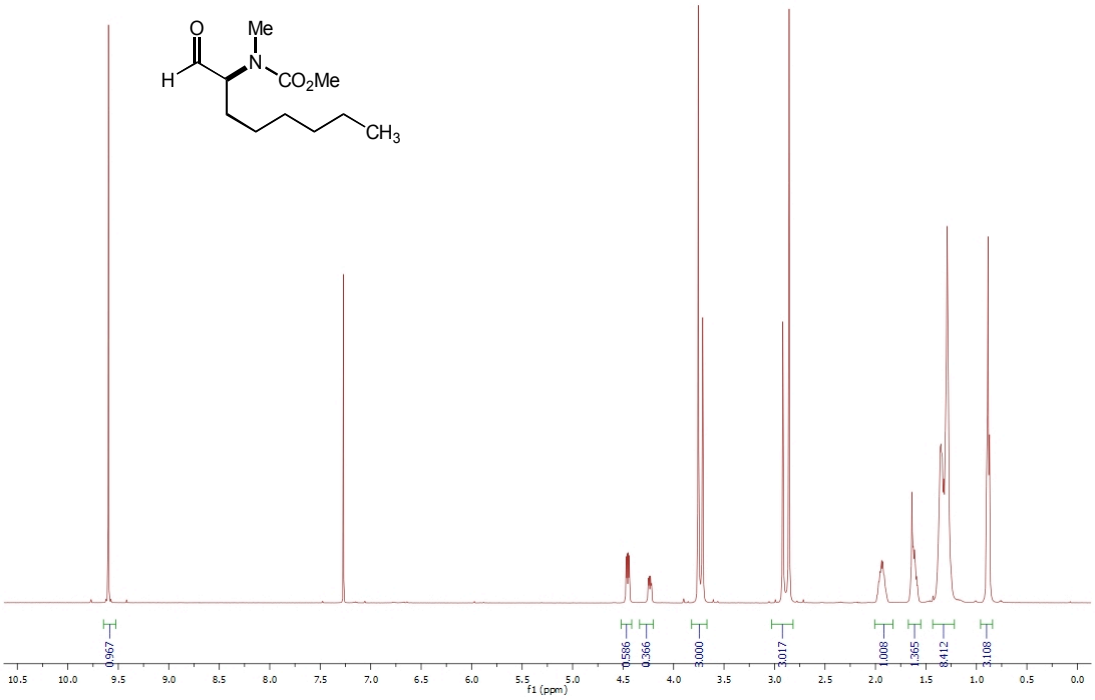

O
O
O
H
N
Me
0.89
5.48
1.00
2.03
2.08
0.93
0.94
1.04
2.78
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
f1 (ppm)

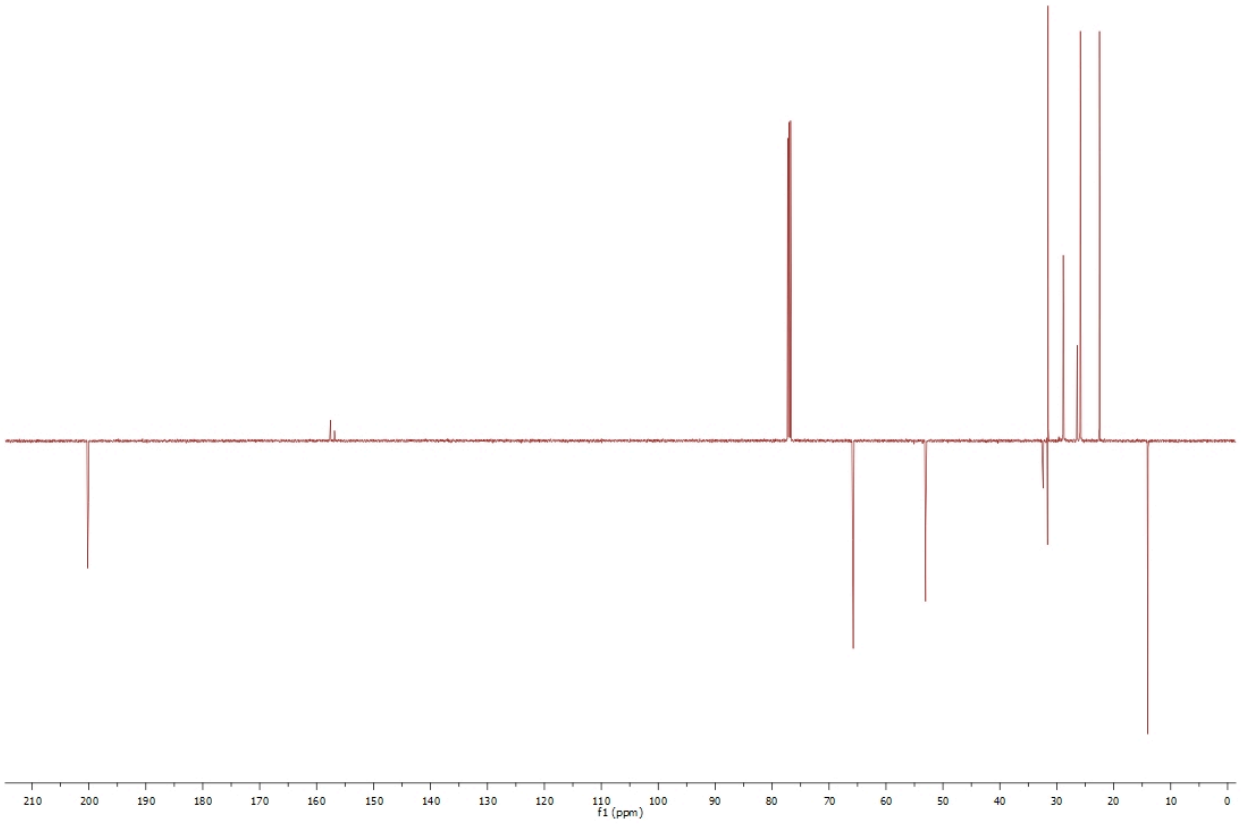

200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30
f1 (ppm)

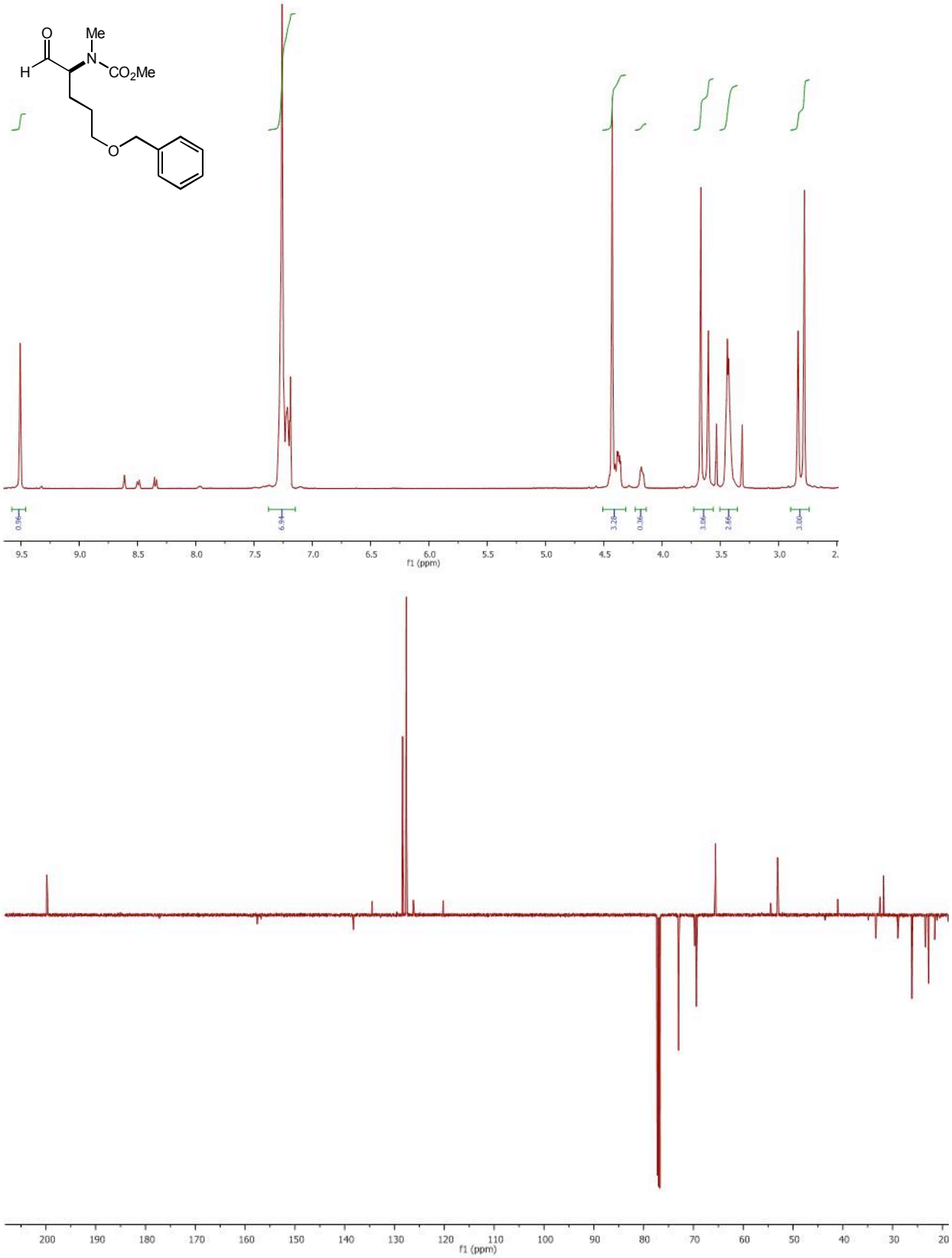

O
O
O
Me
Me
Me
N
Me
H
0.97
5.20
0.99
1.00
1.01
2.96
9.02
9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5
f1 (ppm)

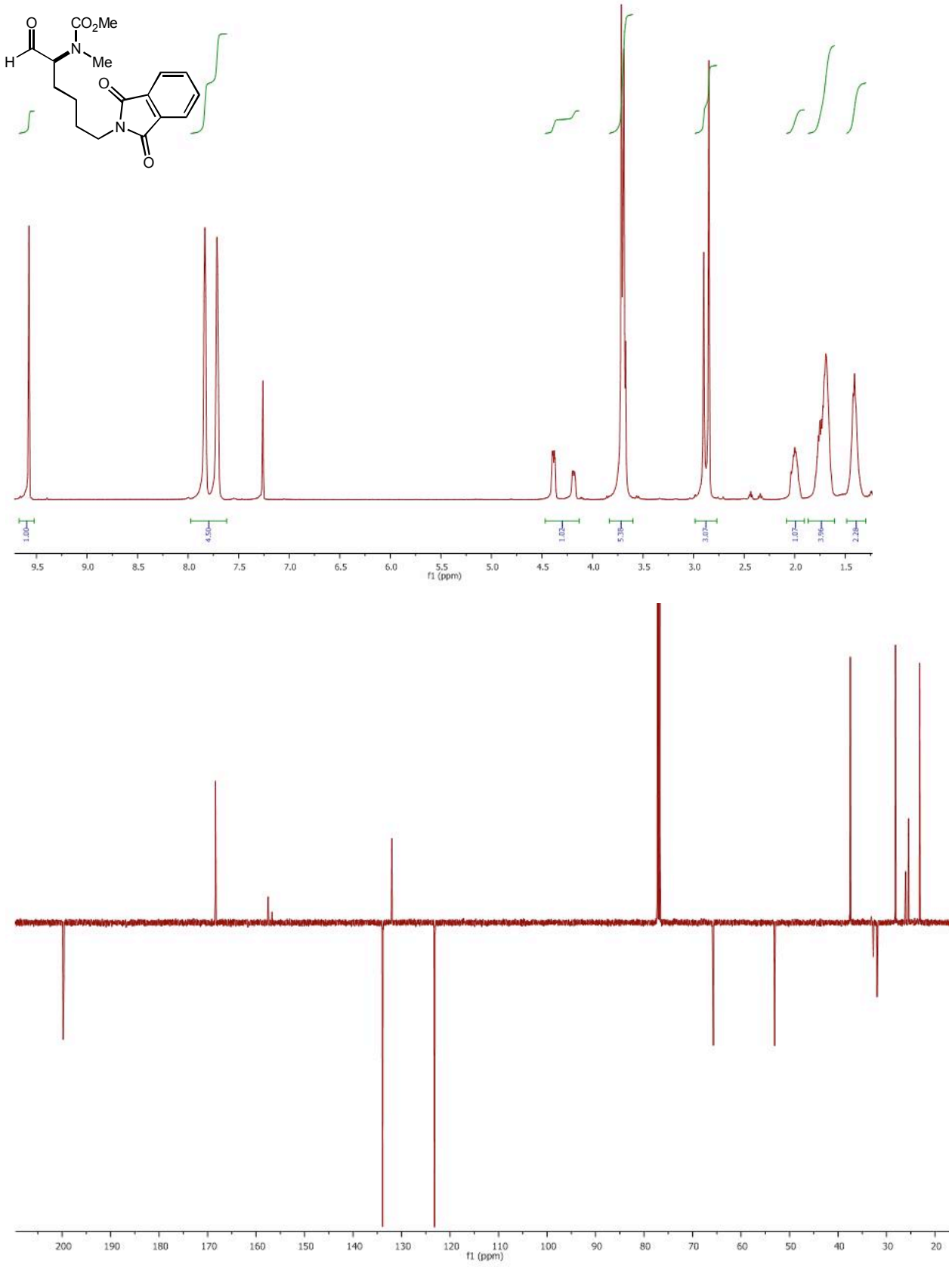

200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30
f1 (ppm)
O
H
N
OMe
CO2Me
1.000
1.900
2.078
0.447
0.570
1.016
1.047
3.103
1.045
3.075
0.593
0.462
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5
f1 (ppm)

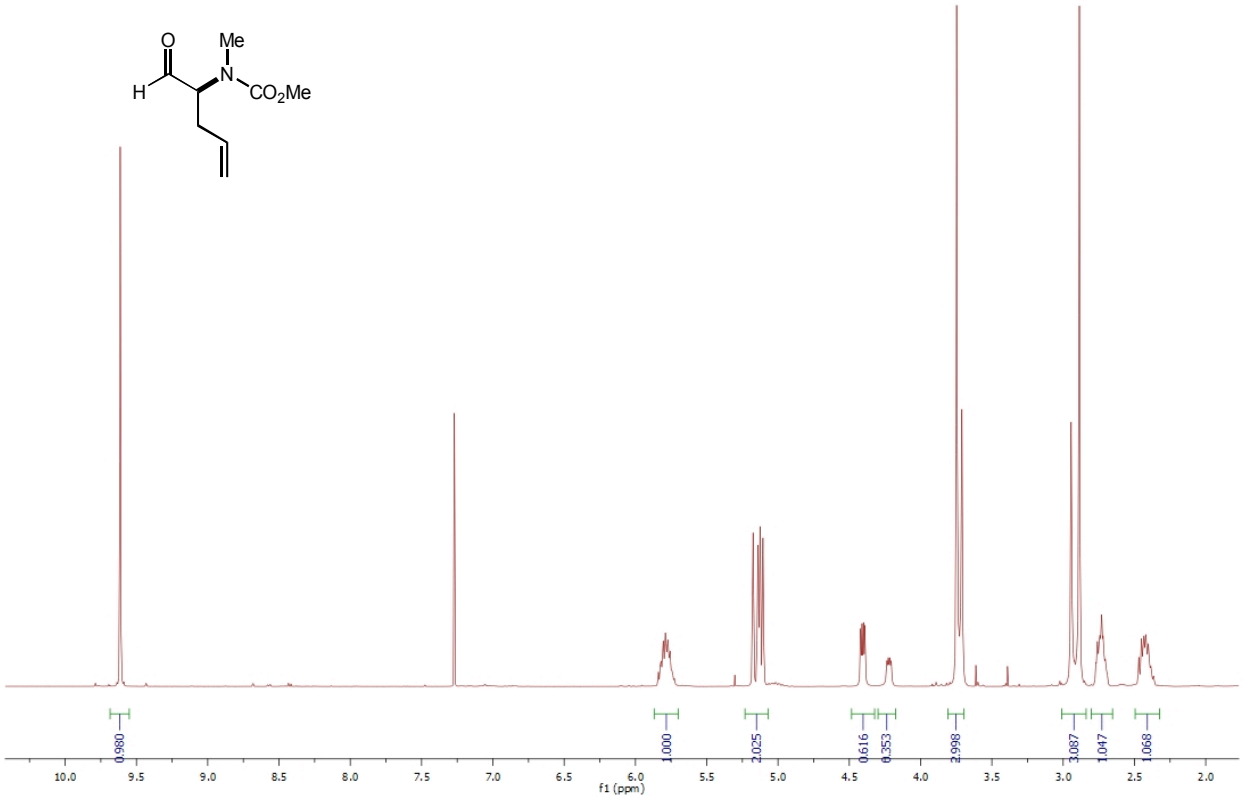

200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
f1 (ppm)

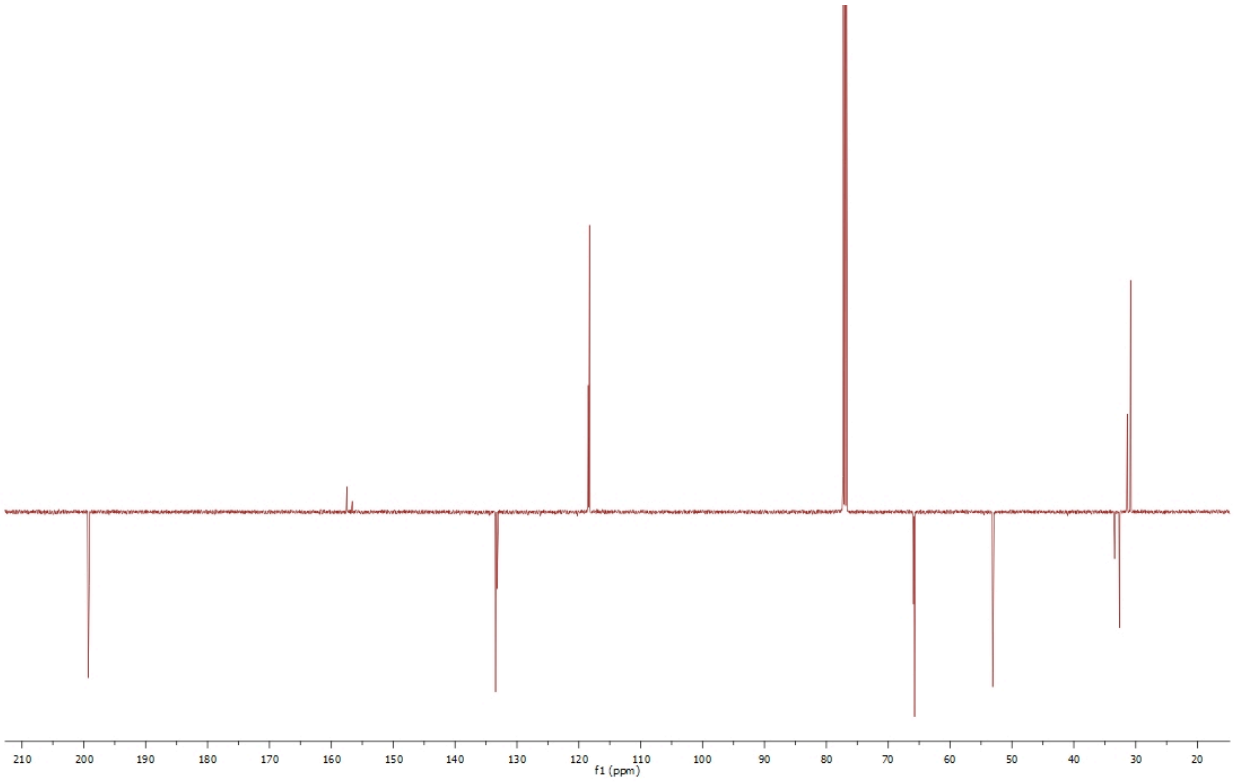

O
Me
N
H
CO2Me
CH3
0.967
0.586
0.366
3.000
3.017
1.008
1.365
3.412
3.108
f1 (ppm)

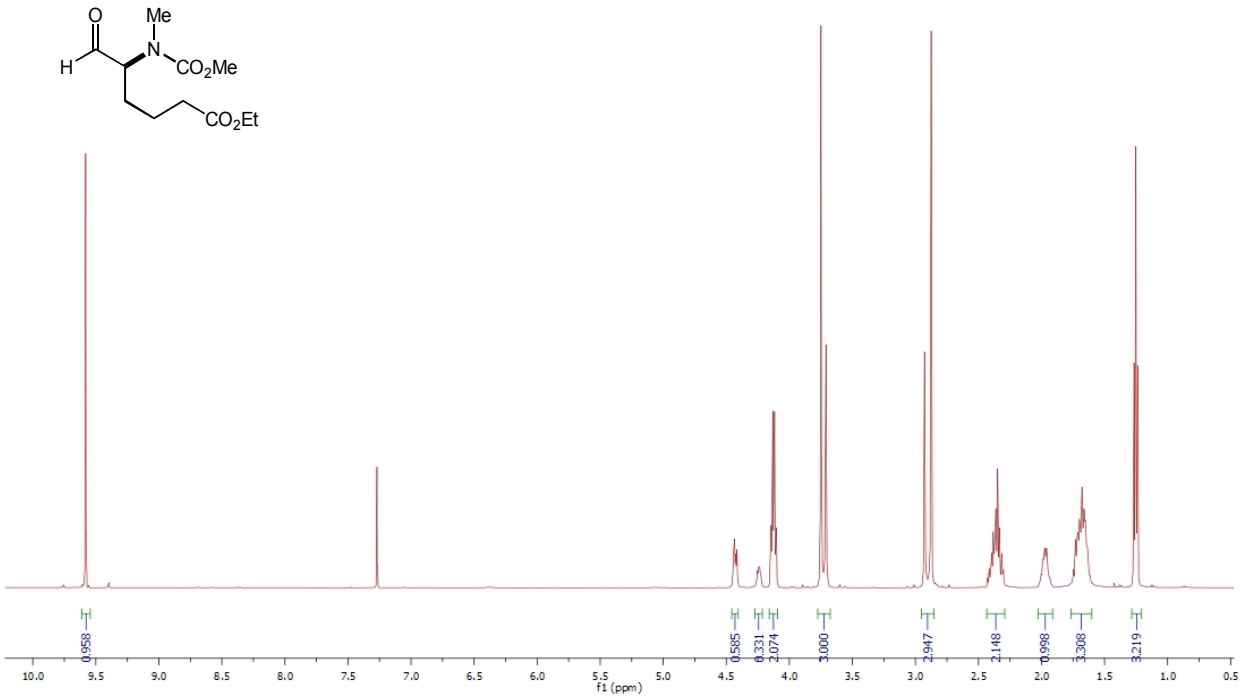

f1 (ppm)

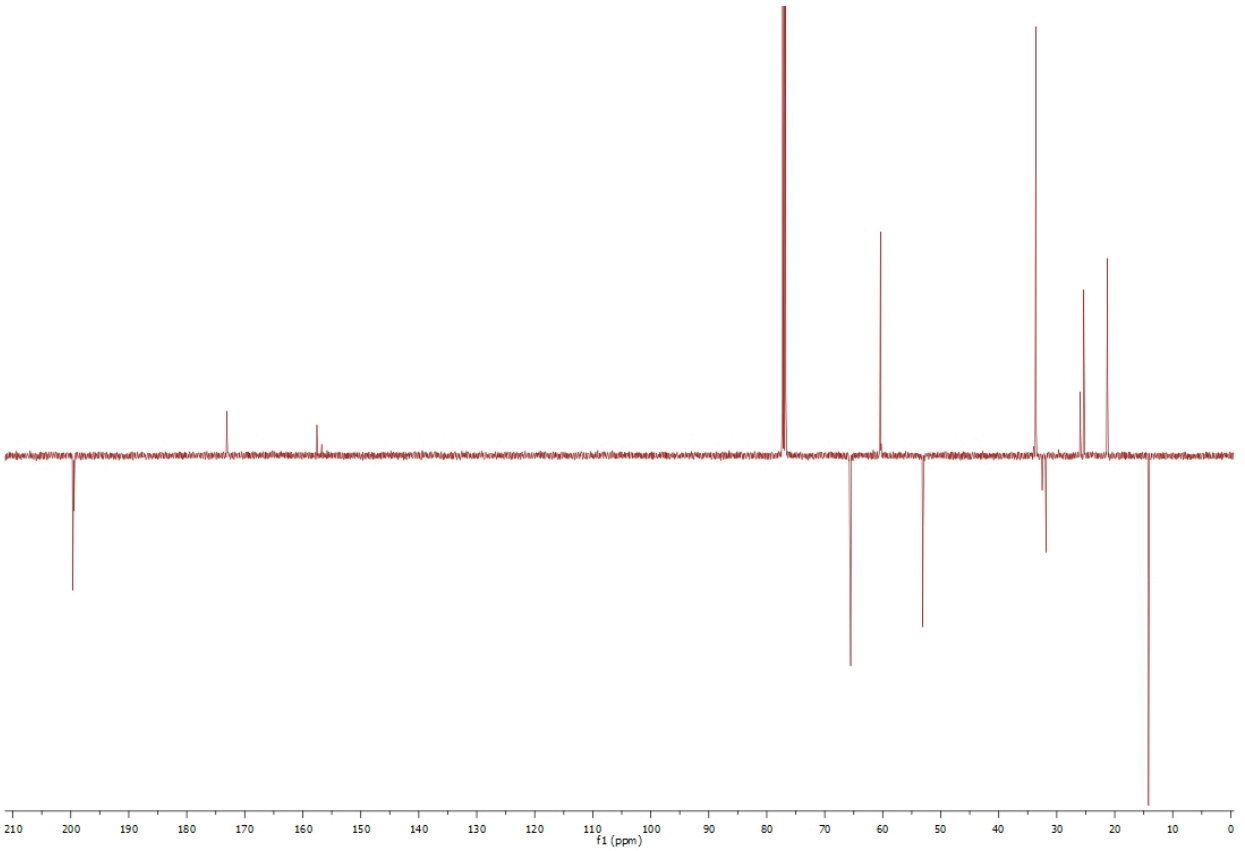

O
Me
N
H
CO2Me
O
0.96
6.94
3.28
0.36
3.06
2.66
3.00
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
f1 (ppm)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
f1 (ppm)

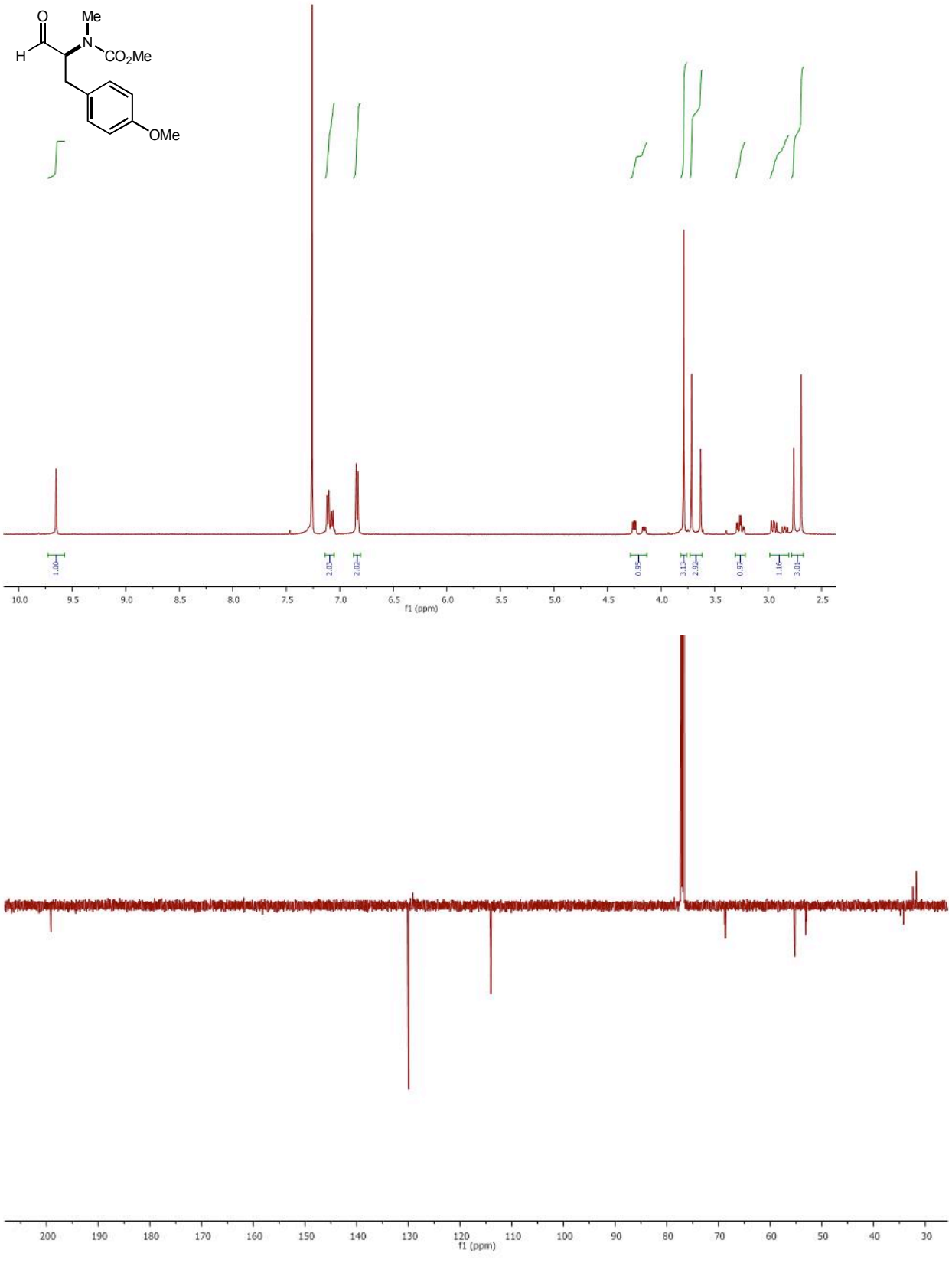

O
CO2Me
H
N
Me
O
N
O
1.00
4.50
1.02
5.38
3.07
1.07
3.96
2.28
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
f1 (ppm)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
f1 (ppm)

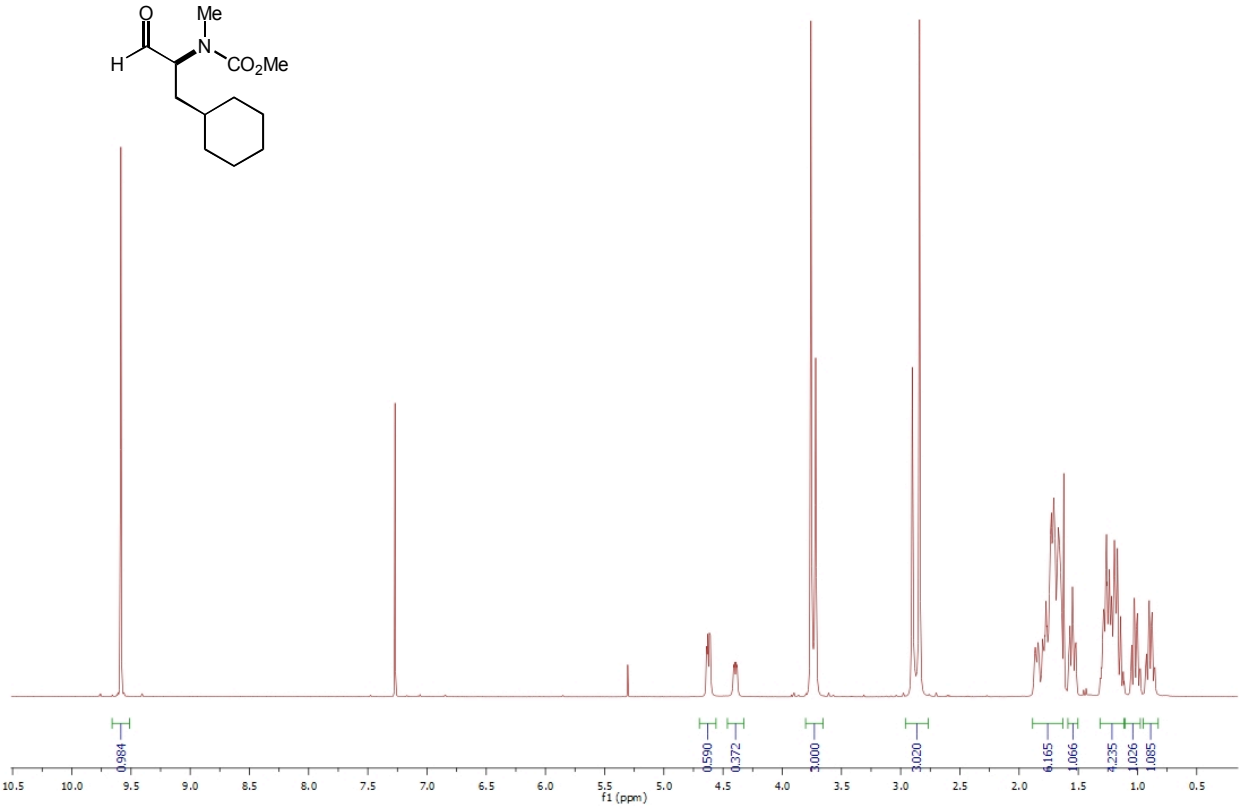

O
Me
N
H
CO2Me
0.980
1.000
2.025
0.616
0.353
2.998
3.087
1.047
1.068
f1 (ppm)

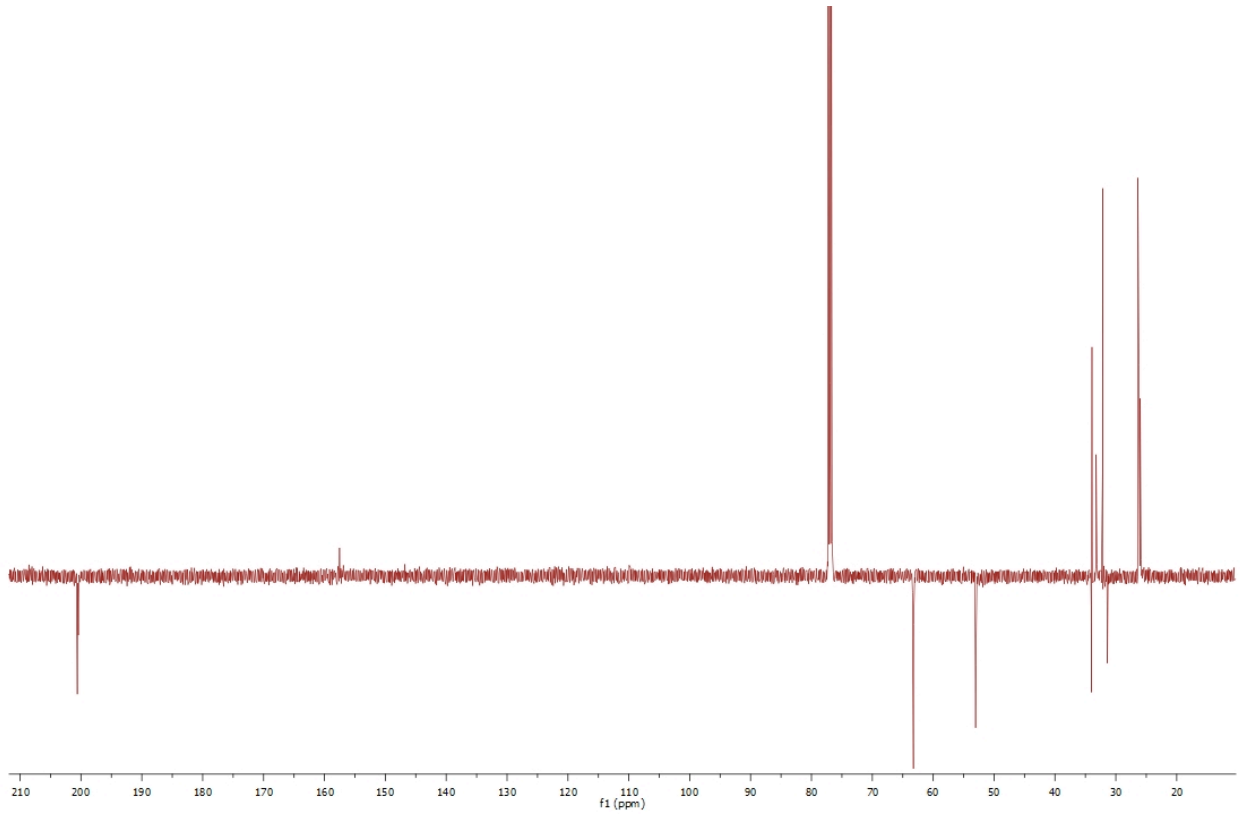

f1 (ppm)

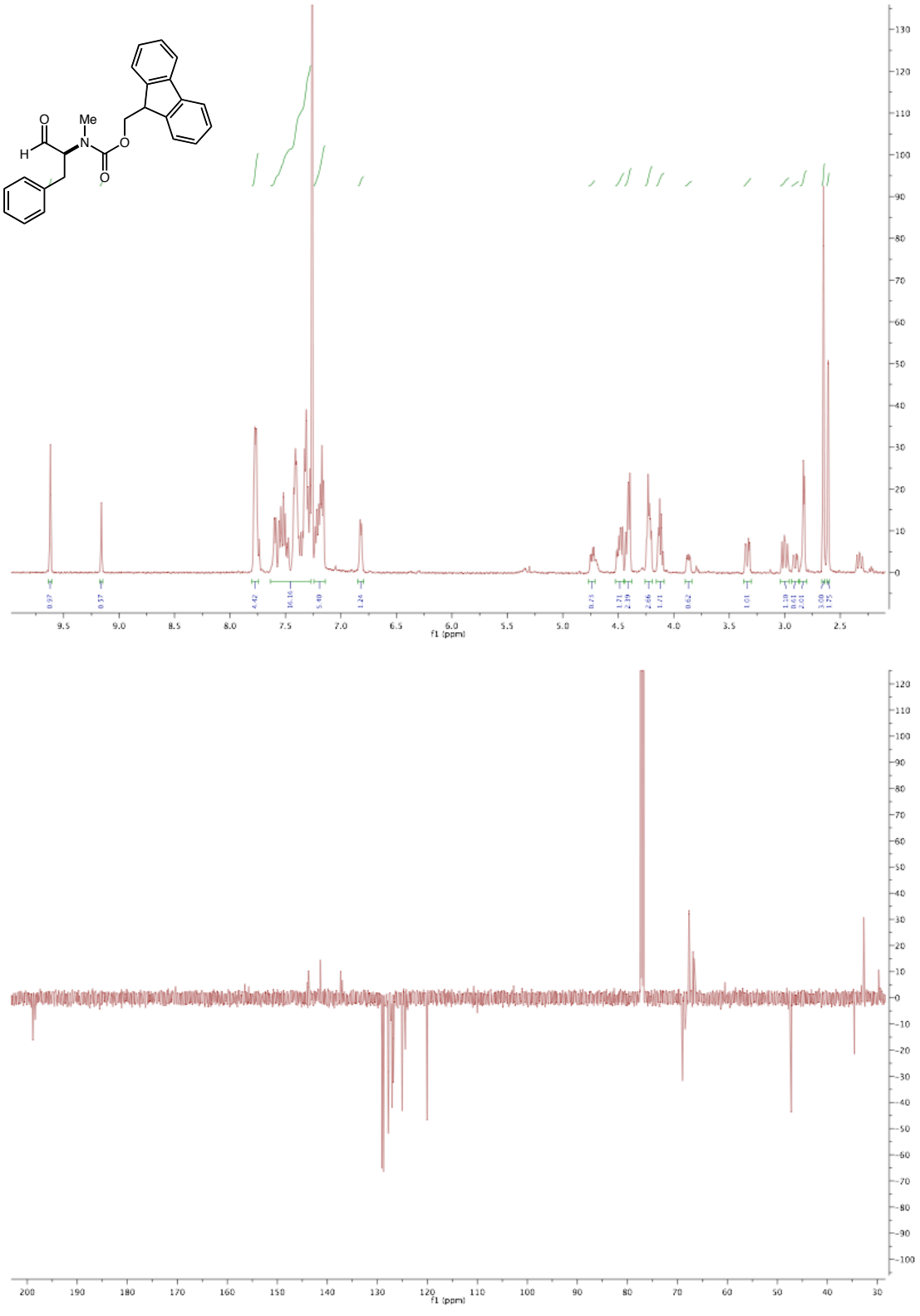

O
Me
H
N
CO2Me
CO2Et
0.958
0.585
0.331
2.074
3.000
2.947
2.148
0.998
3.308
3.219
f1 (ppm)

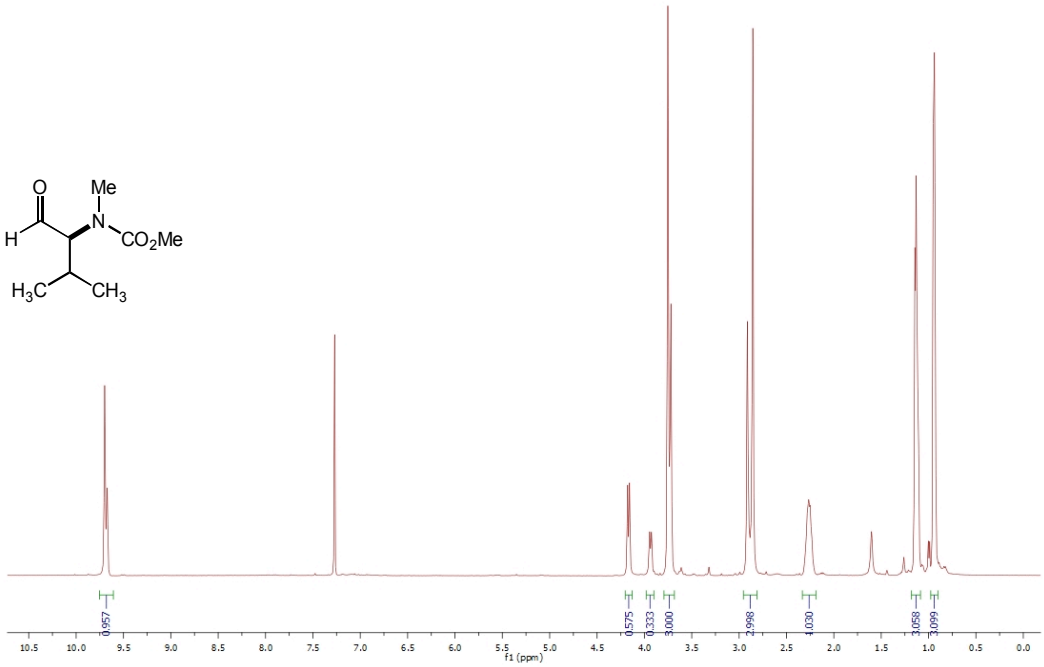

f1 (ppm)

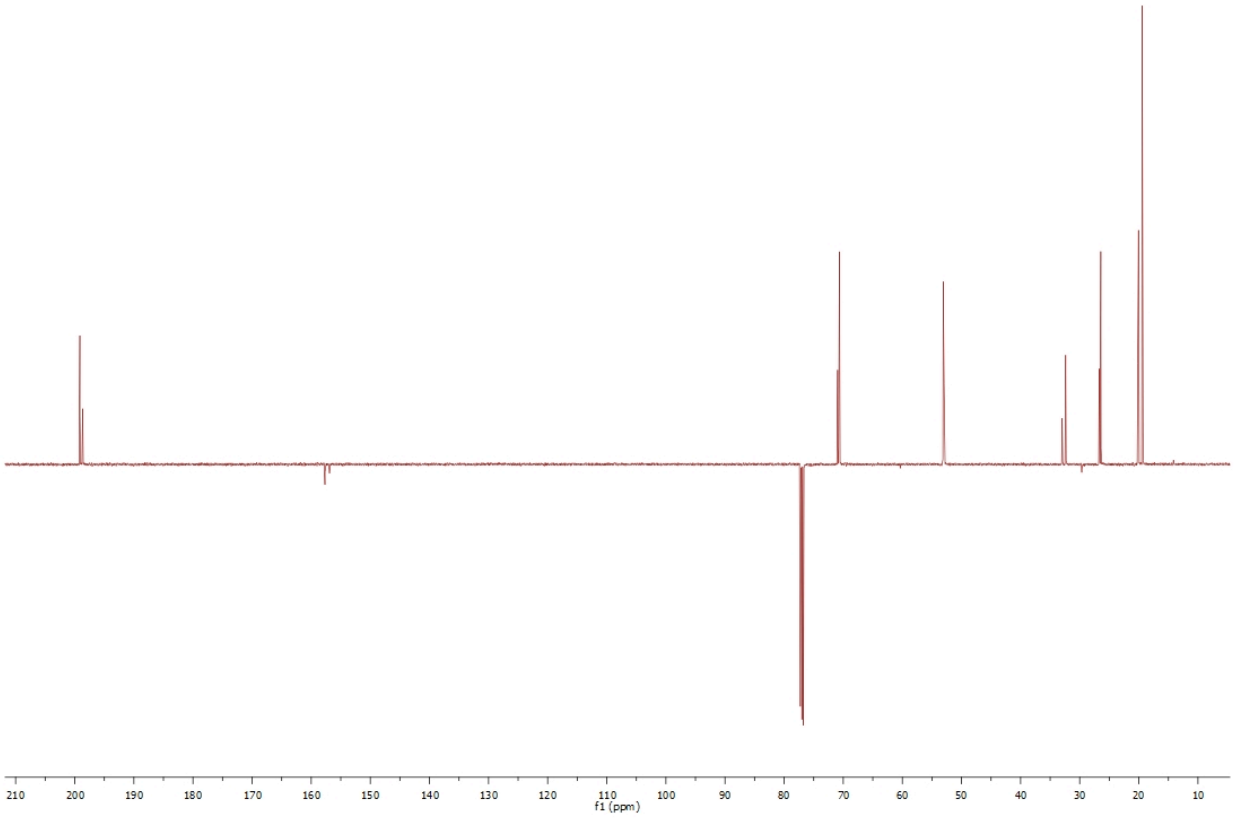

O
Me
N
H
CO2Me
OMe
1.00
2.03
2.02
0.95
3.13
2.93
0.97
1.16
3.01
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
f1 (ppm)
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
f1 (ppm)

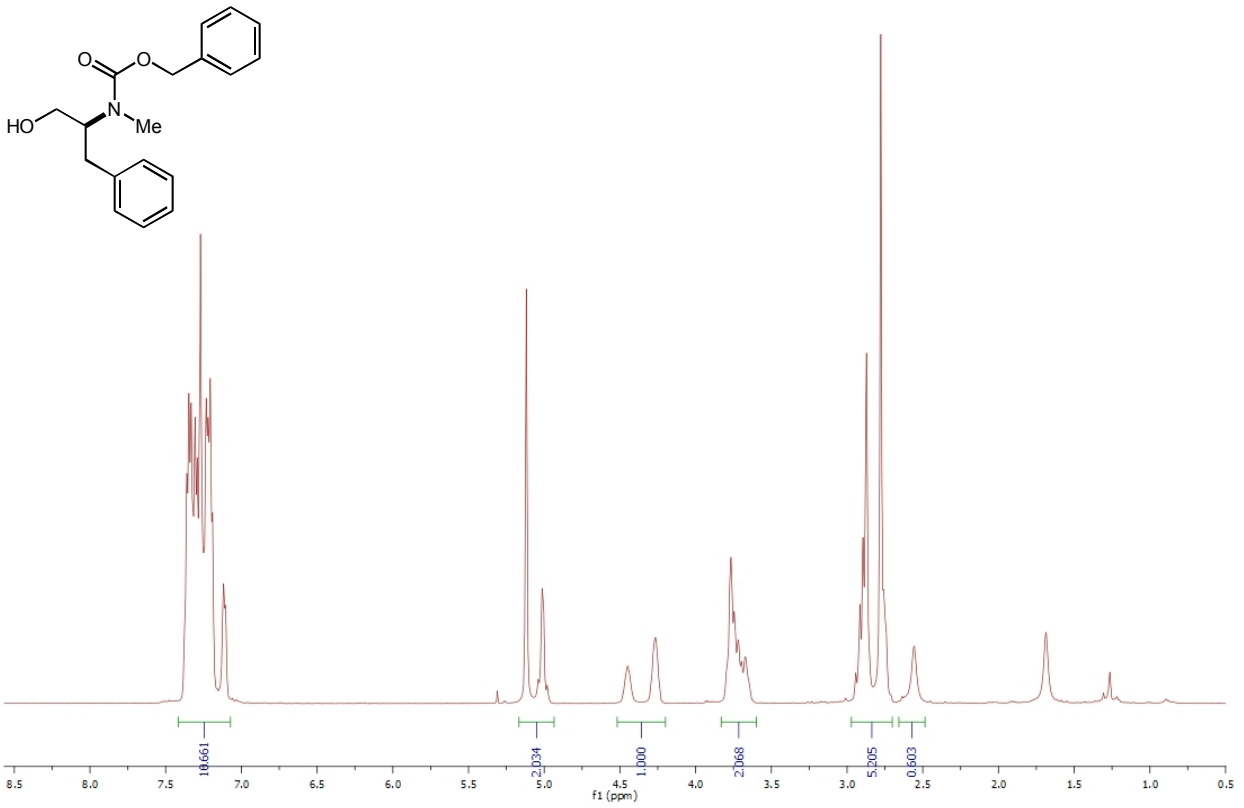

O
Me
H
N
CO2Me
0.984
0.590
0.372
3.000
3.020
6.165
1.066
4.235
1.026
1.085
10.5 10.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)

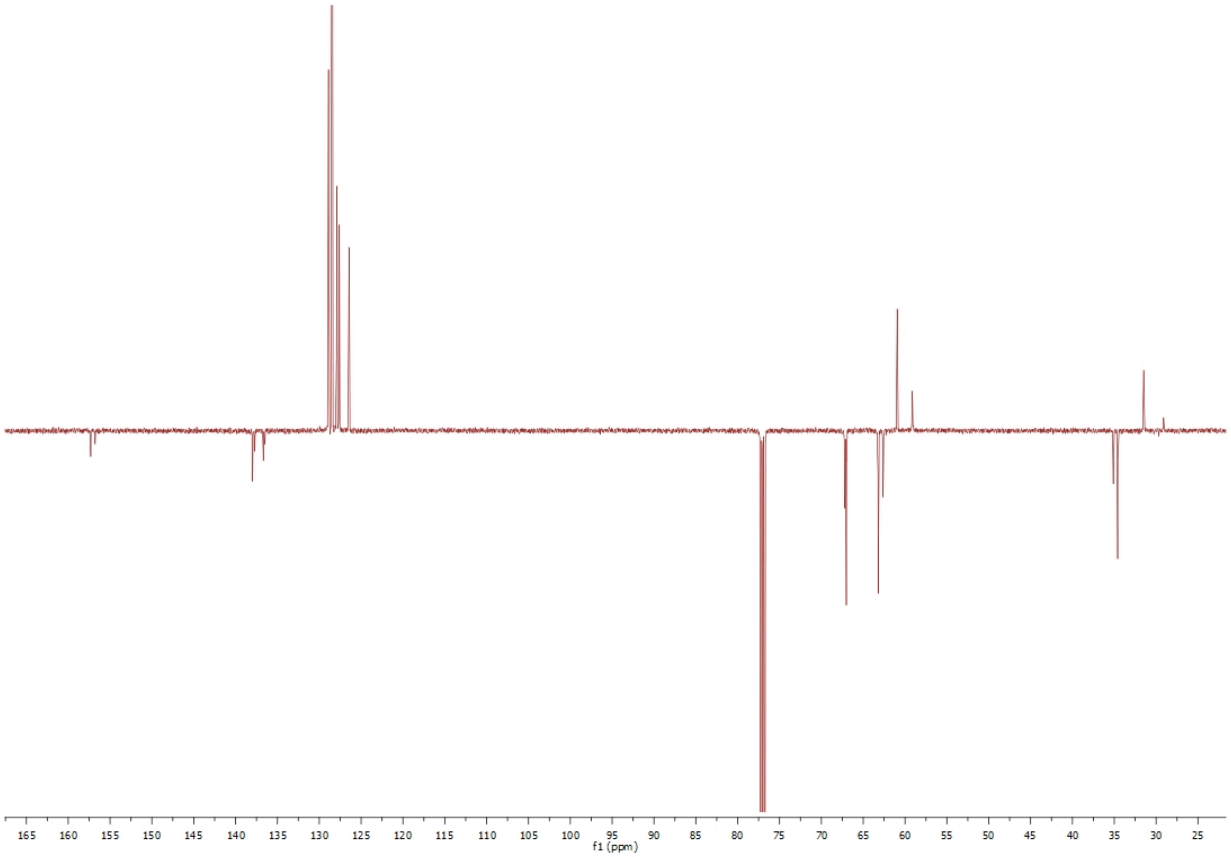

210 200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20
f1 (ppm)

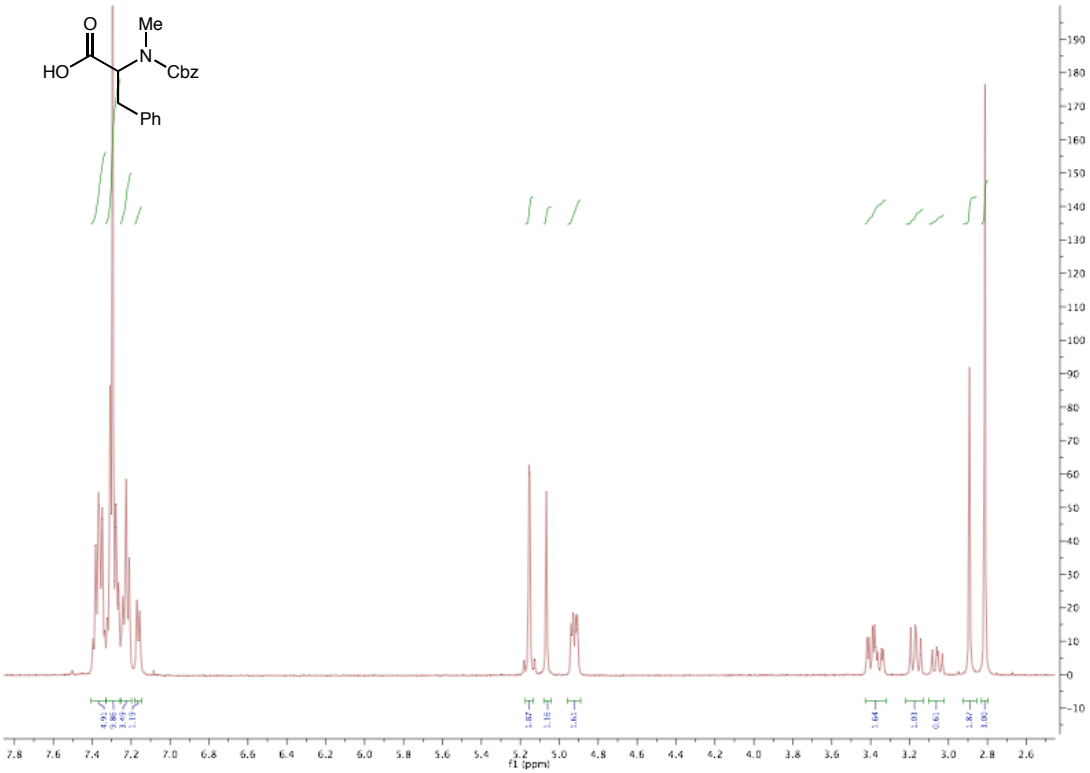

O
H
Me
N
O
O
f1 (ppm)
f1 (ppm)

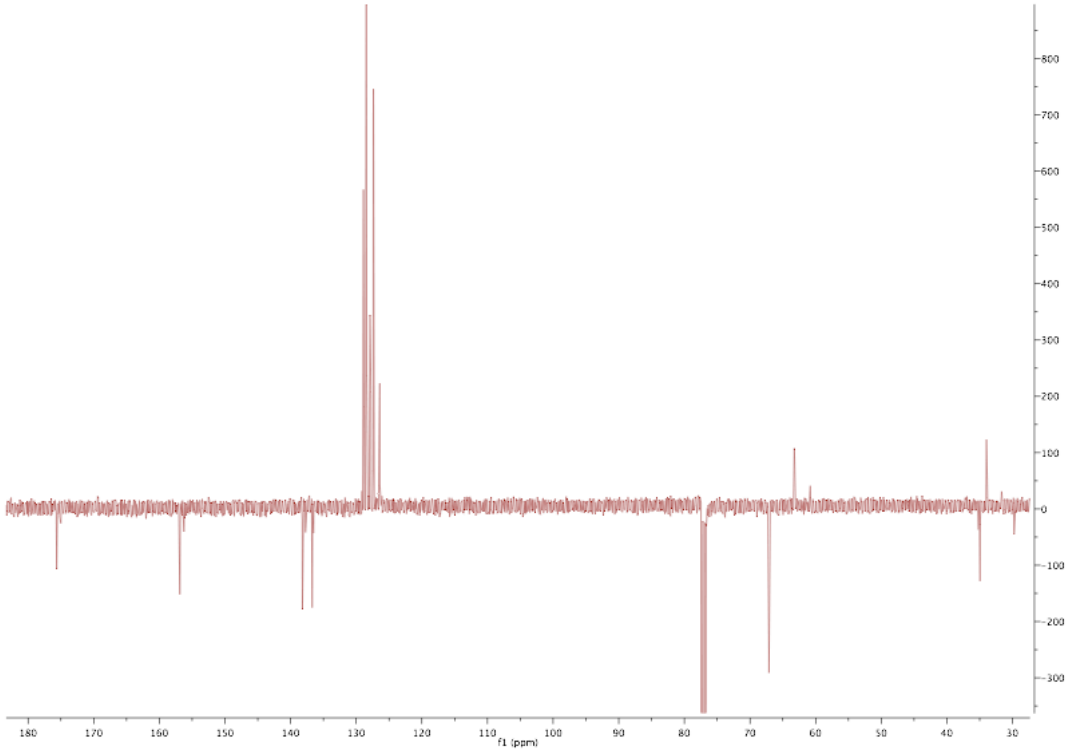

O
Me
N
H
CO2Me
H3C
CH3
0.957
0.575
0.333
3.000
2.998
1.030
3.058
3.099
f1 (ppm)

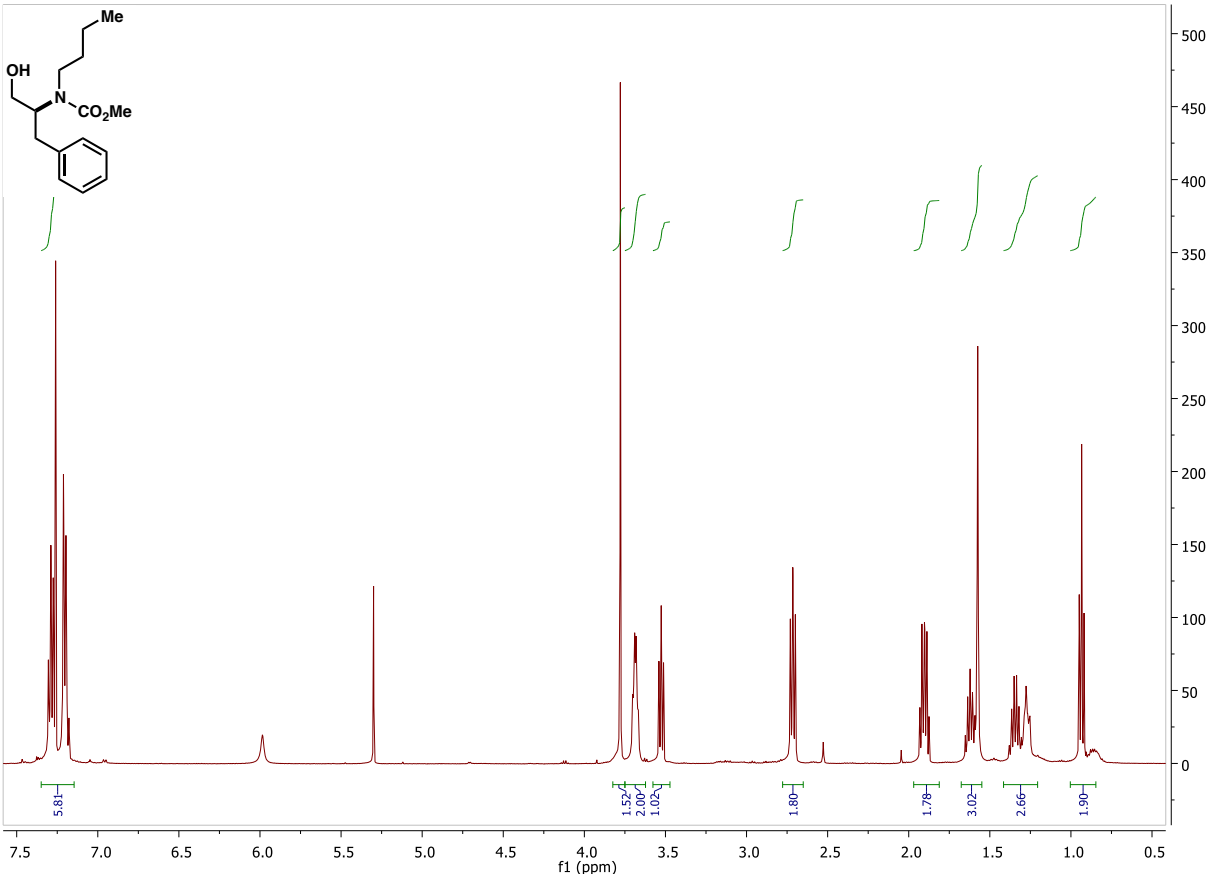

f1 (ppm)

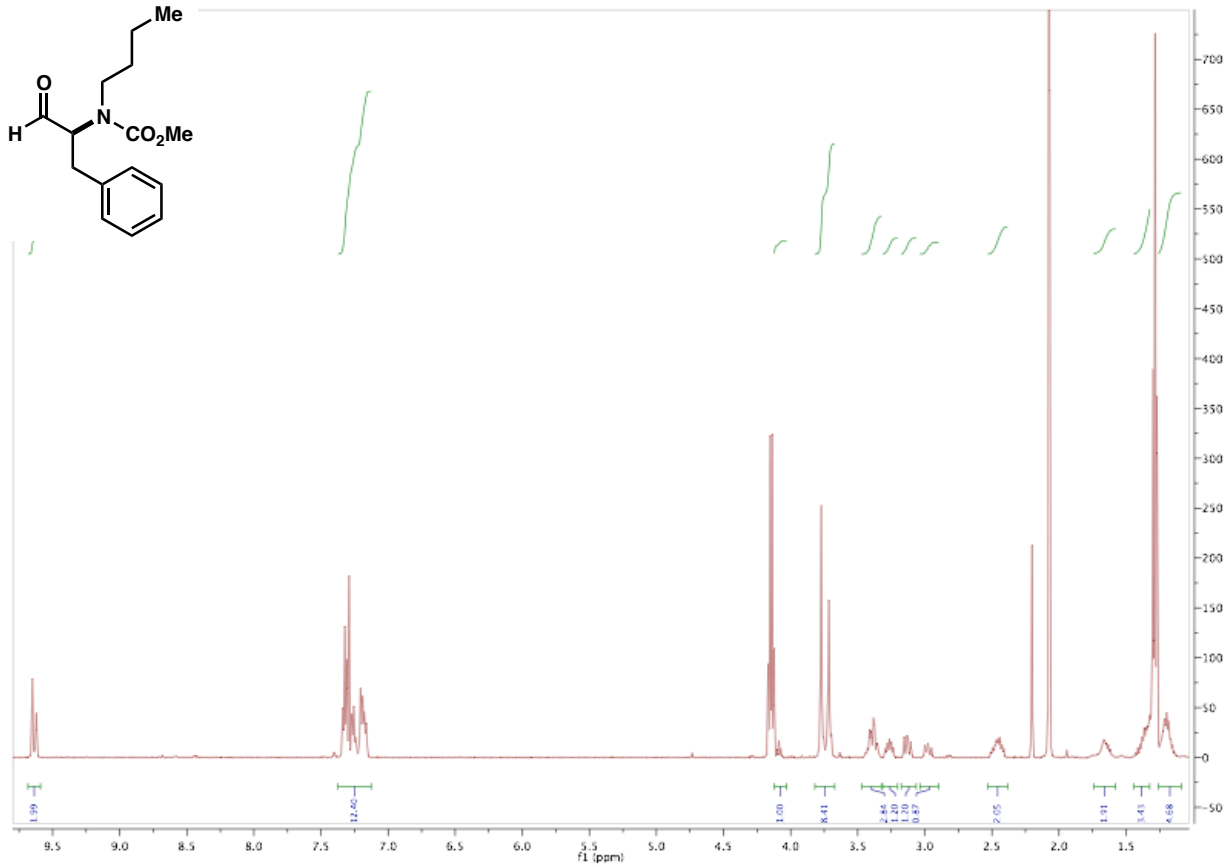

O
O
N
Me
HO
18.661
2.034
1.000
2.068
5.205
0.603
f1 (ppm)

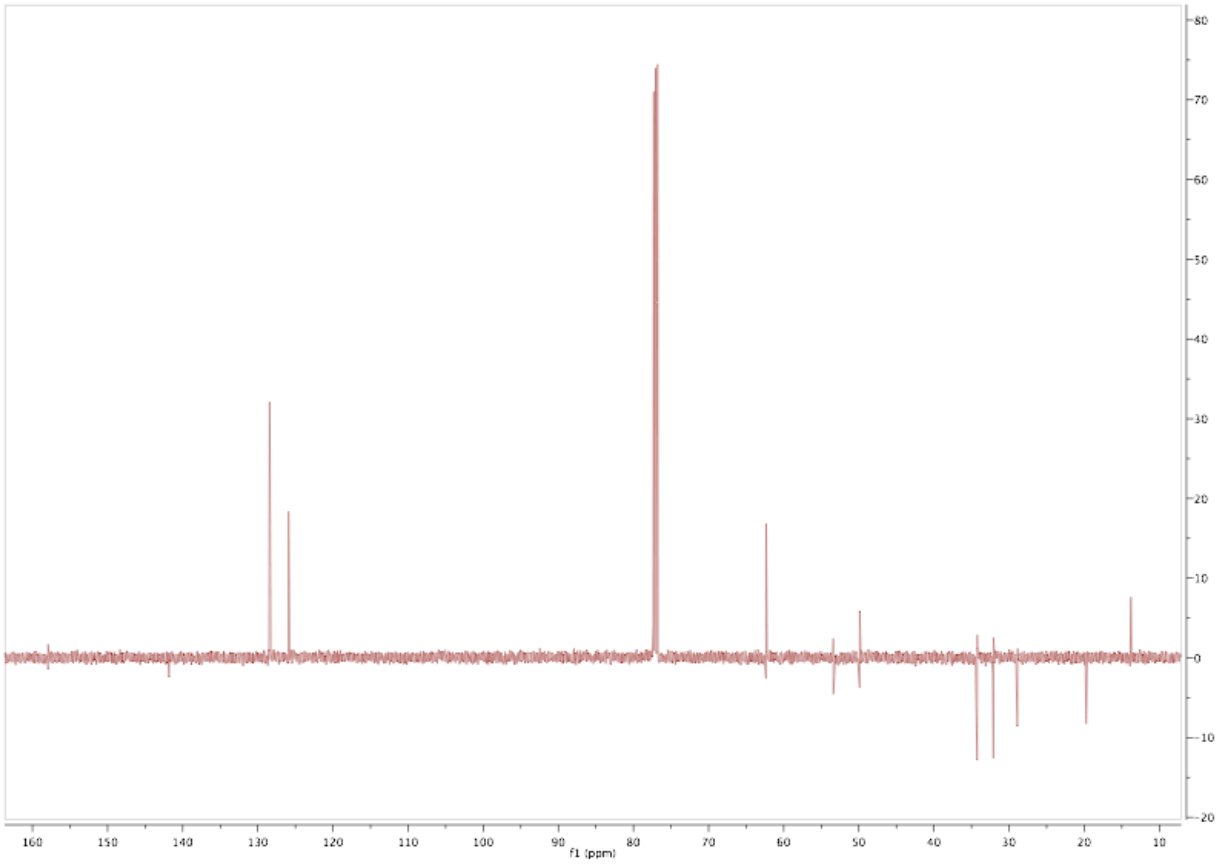

f1 (ppm)


O
Me
HO
N
Cbz
Ph
f1 (ppm)


f1 (ppm)


Me
OH
N
CO2Me
f1 (ppm)


Me
O
H
N
CO2Me
f1 (ppm)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40
30
20
10
0
-10
-20
160
150
140
130
120
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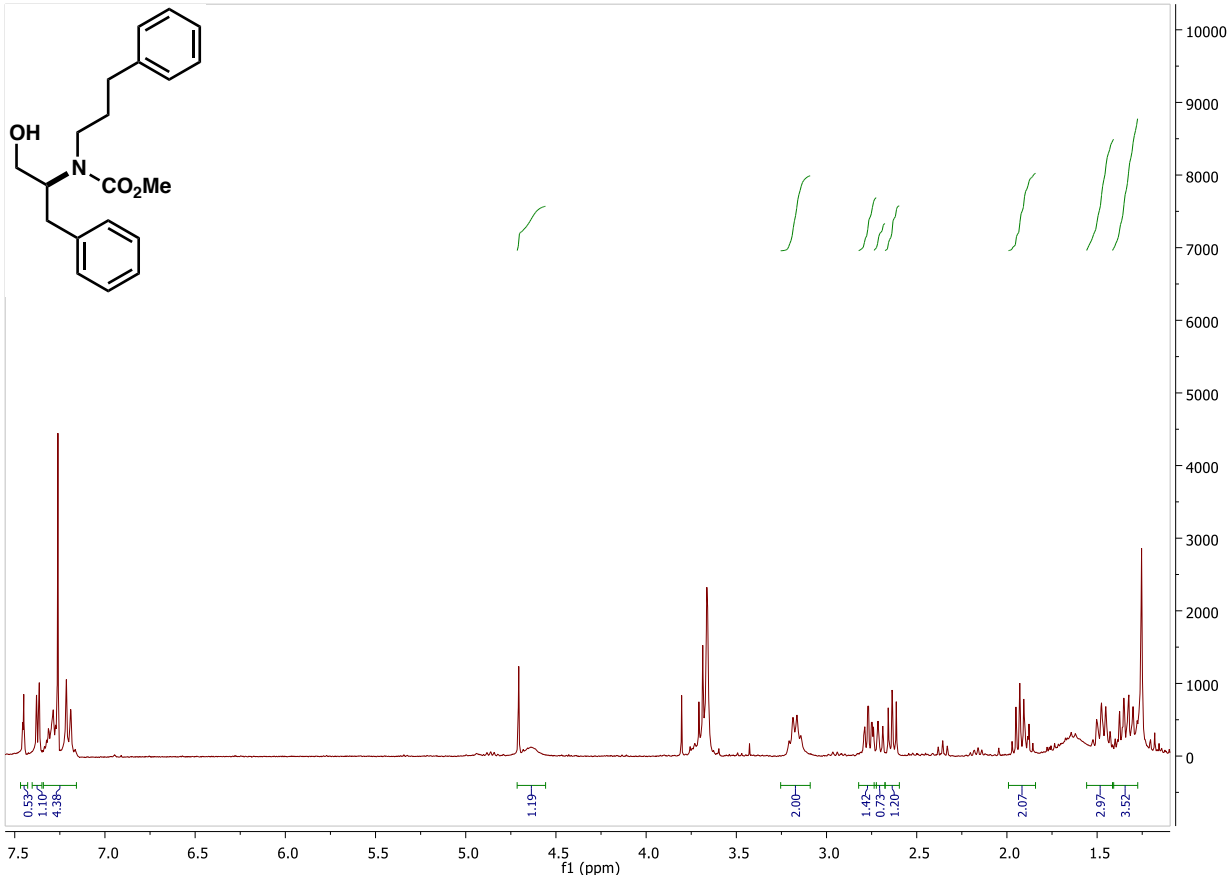
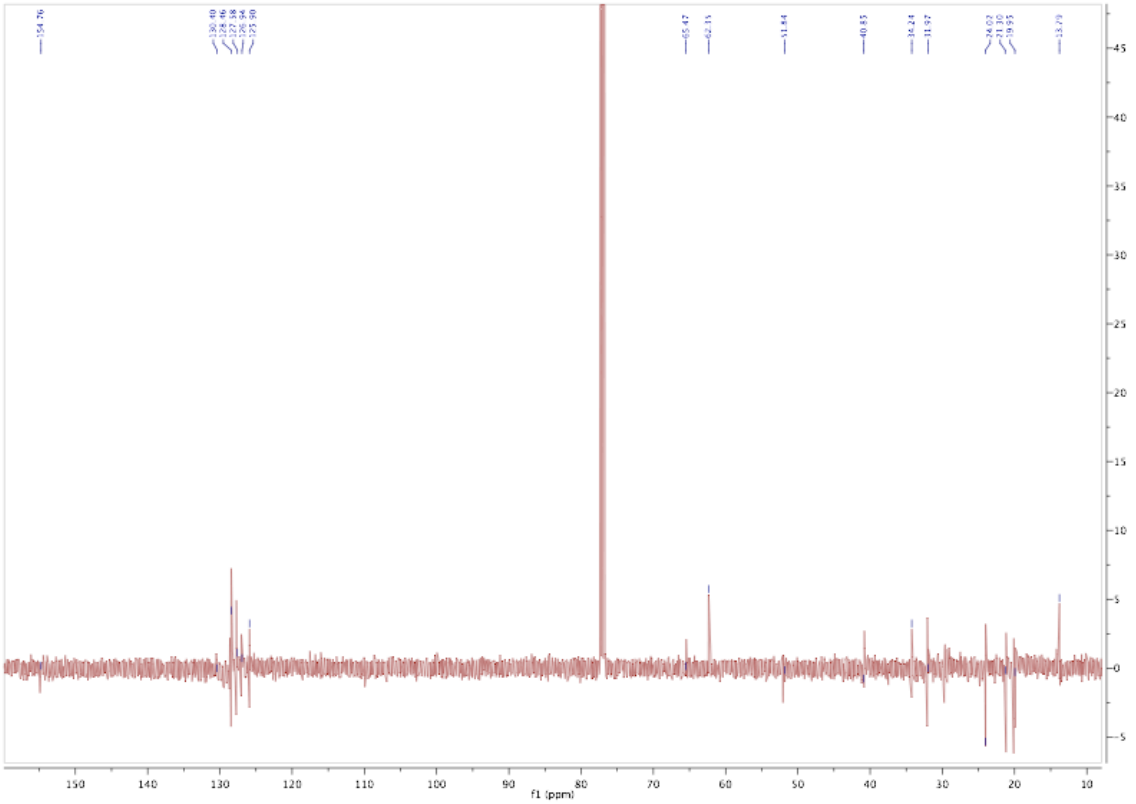
100
90
80
70
60
50
40
30
20
10
f1 (ppm)


OH
N
CO2Me
f1 (ppm)


f1 (ppm)