**Supporting Information**

# Kinetic Resolution of 2-Aryl-4-methylenepiperidines towards Enantioenriched Functionalisable Piperidine Fragments

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## Contents

## 1. General procedures

Reagents were obtained from commercial suppliers and were used without further purification or after distillation; *n*-BuLi was titrated before use. Solvents were obtained from a Grubbs dry solvent system. *tert*-Butyl 4-oxopyridine-1(4*H*)-carboxylate and compound **1a** were synthesised using the methods reported by Dieter and co-workers.[1] LiBH($^s$Bu)$_3$ was obtained as a solution of L-Selectride® (1 M in THF) from Sigma Aldrich. Thin layer chromatography was performed on Merck silica gel 60F254 plates and visualised by UV irradiation at 254 nm or by staining with an alkaline KMnO4 dip. Flash column chromatography was performed using DAVISIL or Geduran silica gel (40-63 micron mesh). Melting points were recorded on a Gallenkamp hot stage and were uncorrected. InfraRed spectra were recorded on a Perkin Elmer Spectrum RX Fourier Transform – IR System and only selected peaks are reported. $^1$H NMR spectra were recorded on a Bruker AC400 (400 MHz) instrument. Chemical shifts are reported in ppm with respect to the residual solvent peaks, with multiplicities given as s = singlet, d = doublet, t = triplet, q = quartet, m = multiplet, br = broad. Coupling constants (J values) are quoted to the nearest 0.5 Hz with values in Hertz (Hz). $^{13}$C{1H} NMR spectra (proton-decoupled) were recorded on the above instrument at 100 MHz. Low and high resolution (accurate mass) mass spectra were recorded on a Walters LCT instrument for Electro–Spray (ES).

Intensity data for X-ray crystal structures were collected at 100 K on a Bruker D8 Venture diffractometer using a Cu Kα microfocus X-ray source. Suitable crystals were mounted on a MiTiGen microloop using fomblin oil and transferred directly to the cold nitrogen stream at 100 K for data collection on a Bruker D8 VENTURE diffractometer equipped with an Oxford 700+ cryostream, a PHOTON 100 CMOS detector and using Cu-Kα micro-focus X-ray source. Intensity data was collected in shutterless mode with a final fast scan collected at lower incident beam intensity to enable correction for any detector saturation for low-angle data. Data

reduction was performed using the Bruker Apex3 software.[1] Intensity data were corrected for absorption using empirical methods (SADABS) based upon symmetry equivalent reflections combined with measurements at different azimuthal angles.[2] The crystal structure was solved using ShelXT[3] and refined against all $F^2$ values using the SHELXL[4] accessed via the Olex2 program.[5] Non-hydrogen atoms were refined anisotropically. Hydrogen atoms were placed in calculated positions with idealized geometries and then refined by employing a riding model and isotropic displacement parameters.

The selectivity factors (S) in the manuscript were calculated using the formula

$$S = \ln[(1–C)(1–ee)] / \ln[(1–C)(1+ee)]$$

where C is the conversion based on the amount of recovered starting material (e.g. for 46% recovered starting material, C = 0.54) and ee is the enantiomeric excess of the recovered starting material (e.g. enantiomer ratio, er 90:10 is 80% ee, so ee = 0.8).

All calculations were performed using density functional theory, employing the B3LYP[6] functional as implemented in the D.01 version of Gaussian 09.[7] Calculations included dispersion corrections using the GD3-BJ[8] method. Calculations used the def2TZVP[9] basis set. Solvent was included via the PCM method[10] as implemented in Gaussian with the default parameters for THF.

## 2. Experimental Procedures and Characterization Data

### 2.1 General Procedures

**General Procedure A: Synthesis of enones 1b–h**

Following methods reported by Dieter and co-workers.[11]

To a solution of aryl magnesium halide (1.2 equiv.) [PhMgCl (2 M in THF) or prepared from refluxing aryl bromide with magnesium turnings (1:1 molar ratio) in THF (2 M) for 30 min and cooling to rt] at –78 °C was added a mixture of *tert*-Butyl 4-oxopyridine-1(4*H*)-carboxylate (1 equiv.) and $Me_3SiCl$ (3 equiv.) in THF (0.33 M). The mixture was warmed to rt over 16 h and quenched with saturated aq $NH_4Cl$. The mixture was diluted with water followed by $Et_2O$ and the layers were separated. The organic layer was dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give the crude product. The crude product was purified by column chromatography on silica gel to give the enone product.

**General Procedure B: Synthesis of 2-aryl-4-piperidones 2a–h**

To a solution of enone **1a–h** (1 equiv.) in THF (0.2 M) under an argon atmosphere at –78 °C was added $LiBH(^sBu)_3$ (1.1 equiv., 1 M in THF). After 2 h, the mixture was warmed to rt and quenched with quenched with saturated aq $NaHCO_3$. The mixture was diluted with water followed by $Et_2O$ and the layers were separated. The organic layer was dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give the crude product. The crude product was purified by column chromatography on silica gel to give the 2-aryl-4-piperidone product.

**General Procedure C: Synthesis of 2-aryl-4-methylenepiperidines 3a–h**

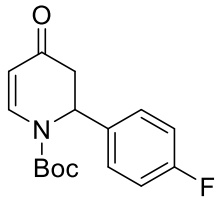
To a suspension of $MePPh_3Br$ (4 equiv.) in THF was added KO$^t$Bu (4 equiv.). The mixture was heated at 40 °C for 30 min and cooled to rt. 2-Aryl-4-piperidone **2a–h** (1 equiv.) in THF was added dropwise and the mixture was heated (stirrer hotplate and drysyn block) at 40 °C for 2–3 h. Upon cooling to rt, the mixture was diluted with water followed by $Et_2O$ and the layers were separated. The organic layer was dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give the crude product. The crude product was purified by column chromatography on silica gel to give the 2-aryl-4-methylenepiperidine product.

**General Procedure D: Lithiation-trapping of 2-aryl-4-substituted-piperidines**

To a solution of 2-aryl-4-substituted-piperidine (1 equiv.) in THF (0.25 M) under an argon atmosphere was added *n*-BuLi (1.2 equiv., 2.0–2.4 M in hexanes) at –40 °C or –78 °C. After 10 min the electrophile (2.0–3.5 equiv.) was added and the mixture was warmed to rt over 16 h. The reaction was quenched with MeOH (1 mL) and the solvent was evaporated to give the crude product.

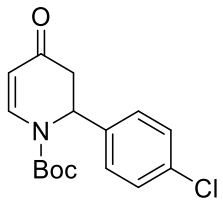
## 2.2 Preparation of enones 1b–h

*tert*-Butyl 2-(4-Fluorophenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1b**




Using general procedure A, magnesium (0.15 g, 6.1 mmol), 1-bromo-4-fluorobenzene (0.68 mL, 6.1 mmol), *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) gave enone **1b** (1.4 g, 94%) as a white amorphous solid; mp 98–100 °C [$CH_2Cl_2$–MeOH] (no lit. mp reported); $R_f$ 0.63 [$CH_2Cl_2$−MeOH (19:1)]; $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.96 (d, 1H, *J* = 8.0 Hz), 7.26–7.17 (m, 2H), 7.08–6.96 (m, 2H), 5.66 (d, 1H, *J* = 8.0 Hz), 5.38 (d, 1H, *J* = 8.0 Hz), 3.16 (dd, 1H, *J* = 16.5, 8.0 Hz), 2.76 (d, 1H, *J* = 16.5 Hz), 1.49 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 191.9, 162.3 (d, *J* = 247.0 Hz), 151.3, 142.8, 134.8, 127.63 (d, *J* = 8.0 Hz), 115.7 (d, *J* = 21.5 Hz), 107.0, 83.9, 55.1, 41.9, 28.0; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −114.31; Data as reported.[12]

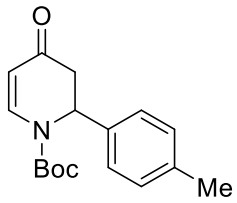
*tert*-Butyl 2-(4-Chlorophenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1c**




Using general procedure A, magnesium (0.15 g, 6.1 mmol), 1-bromo-4-chlorobenzene (1.2 g, 6.1 mmol), *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on

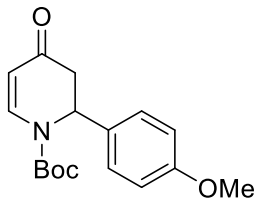
silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) gave enone **1c** (1.2 g, 76%) as a white amorphous solid; mp 106–108 °C [$CH_2Cl_2$–MeOH] (no lit. mp reported); $R_f$ 0.68 [$CH_2Cl_2$−MeOH (19:1)]; $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.97 (d, 1H, *J* = 7.5 Hz), 7.36–7.24 (m, 2H), 7.22–7.13 (m, 2H), 5.65 (d, 1H, *J* = 7.5 Hz), 5.38 (d, 1H, *J* = 7.5 Hz), 3.17 (dd, 1H, *J* = 16.5, 7.5 Hz), 2.75 (d, 1H, *J* = 16.5 Hz), 1.49 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 191.7, 151.3, 142.8, 137.4, 133.8, 129.0, 127.3, 107.0, 84.0, 55.1, 41.7, 28.0; Data as reported.[12]

*tert*-Butyl 2-(4-Methylphenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1d**



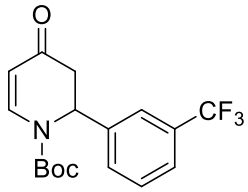

Using general procedure A, magnesium (0.15 g, 6.1 mmol), 1-bromo-4-methylbenzene (1 g, 6.1 mmol) dropwise, *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) to give enone **1d** (1.3 g, 89%) as a clear oil; $R_f$ 0.65 [$CH_2Cl_2$–MeOH (19:1)]; $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.96 (d, 1H, *J* = 7.5 Hz), 7.18–7.03 (m, 4H), 5.65 (d, 1H, *J* = 7.5 Hz), 5.36 (d, 1H, *J* = 7.5 Hz), 3.14 (dd, 1H, *J* = 16.5, 7.5 Hz), 2.79 (d, 1H, *J* = 16.5 Hz), 2.33 (s, 3H), 1.49 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 192.4, 151.5, 142.9, 137.6, 135.8, 129.4, 125.8, 107.0, 83.7, 55.4, 41.9, 28.0, 21.0; Data as reported.[13]

*tert*-Butyl 2-(4-Methoxyphenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1e**




Using general procedure A, magnesium (0.15 g, 6.1 mmol), 1-bromo-4-methoxybenzene (0.76 mL, 6.1 mmol), *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) gave enone **1e** (1.5 g, 97%) as a clear oil; $R_f$ 0.69 [$CH_2Cl_2$–MeOH (19:1)]; $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.94 (d, 1H, *J* = 7.5 Hz), 7.17 (d, 2H, *J* = 8.5 Hz), 6.84 (d, 2H, *J* = 8.5 Hz), 5.64 (d, 1H, *J* = 7.5 Hz), 5.37 (d, 1H, *J* = 7.5 Hz), 3.79 (s, 3H), 3.14 (dd, 1H, *J* = 16.5, 7.5 Hz), 2.77 (d, 1H, *J* = 16.5 Hz), 1.49 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 192.5, 159.2, 151.5, 142.9, 131.0, 127.2, 114.1, 106.9, 83.7, 55.3, 55.1, 41.9, 28.0. Data as reported.[13]

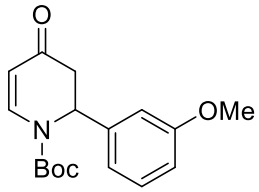
*tert*-Butyl 2-(4-Trifluoromethylphenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1f**




Using general procedure A, magnesium (0.15 g, 6.1 mmol), 1-bromo-4-trifluoromethylbenzene (0.85 mL, 6.1 mmol), *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) gave enone **1f** (1.7 g, 98%) as a pale yellow oil; $R_f$ 0.56 [$CH_2Cl_2$–MeOH (19:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1723 (C=O), 1668

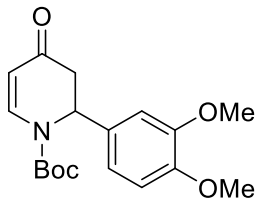
(C=O), 1605 (C=C); $^{1}$H NMR ($CDCl_3$, 400 MHz) δ = 8.01 (d, 1H, *J* = 8.5 Hz), 7.62–7.51 (m, 1H), 7.50–7.39 (m, 3H), 5.72 (d, 1H, *J* = 7.5 Hz), 5.41 (d, 1H, *J* = 8.5 Hz), 3.21 (dd, 1H, *J* = 16.5, 7.5 Hz), 2.81 (d, 1H, *J* = 16.5 Hz), 1.49 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, one quaternary carbon not observed) δ = 191.4, 151.2, 142.8, 140.0, 131.61–130.85 (m), 129.5, 129.0, 125.07–124.64 (m), 123.19–122.59 (m), 107.2, 84.3, 55.3, 41.5, 27.9; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −62.78; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{18}F_3NO_3Na$ 364.1131; Found 364.1134; LRMS *m/z* (ES) 286 (100%), 364 (20%, $MNa^+$).

*tert*-Butyl 2-(3-Methoxyphenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1g**




Using general procedure A, magnesium (0.15 g, 6.1 mmol), 1-bromo-3-methoxybenzene (0.77 mL, 6.1 mmol), *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) gave enone **1g** (1.3 g, 84%) as a clear oil; $R_f$ 0.69 [$CH_2Cl_2$–MeOH (19:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1753 (C=O), 1665 (C=O), 1602 (C=C); $^{1}$H NMR ($CDCl_3$, 400 MHz) δ = 7.98 (d, 1H, *J* = 8.5 Hz), 7.32–7.18 (m, 1H), 6.84–6.78 (m, 2H), 6.78–6.74 (m, 1H), 5.64 (d, 1H, *J* = 7.5 Hz), 5.37 (d, 1H, *J* = 8.5 Hz), 3.78 (s, 3H), 3.15 (dd, 1H, *J* = 16.5, 7.5 Hz), 2.80 (d, 1H, *J* = 16.5 Hz), 1.49 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 192.1, 159.9, 151.4, 143.0, 140.5, 129.9, 118.0, 112.9, 111.9, 107.0, 83.7, 55.6, 55.2, 41.9, 28.0; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{21}NO_4Na$ 326.1363; Found 326.1379; LRMS *m/z* (ES) 248 (100%), 304 (15%), 326 (50%, $MNa^+$).

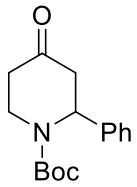
*tert*-Butyl 2-(3,4-Dimethoxyphenyl)-4-oxo-3,4-dihydropyridine-1(2*H*)-carboxylate **1h**




Using general procedure A, magnesium (0.15 g, 6.1 mmol), 4-bromo-1,2-dimethoxybenzene (0.88 mL, 6.1 mmol), *tert*-butyl 4-oxopyridine-1(4*H*)-carboxylate (1 g, 5.1 mmol) and $Me_3SiCl$ (2.0 mL, 15 mmol) in THF (15 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (49:1) gave enone **1h** (0.68 g, 40%) as a clear oil; $R_f$ 0.56 [$CH_2Cl_2$–MeOH (19:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1720 (C=O), 1665 (C=O), 1602 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) $\delta$ = 7.92 (d, 1H, *J* = 7.5 Hz), 6.86–6.72 (m, 3H), 5.65 (d, 1H, *J* = 7.5 Hz), 5.37 (d, 1H, *J* = 7.5 Hz), 3.87 (s, 3H), 3.85 (s, 3H), 3.14 (dd, 1H, *J* = 16.5, 7.5 Hz), 2.81 (d, 1H, *J* = 16.5 Hz), 1.51 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) $\delta$ = 192.5, 151.5, 149.1, 148.7, 142.7, 131.5, 118.3, 111.0, 109.5, 106.8, 83.7, 55.9, 55.8, 55.2, 41.7, 28.0; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{23}NO_5Na$ 356.1468; Found 356.1462; LRMS *m/z* (ES) 278 (100%), 334 (30%), 356 (40%, $MNa^+$).

## 2.3 Preparation of 2-aryl-4-piperidones 2a–h

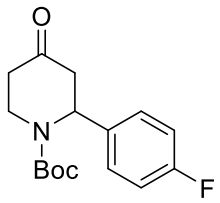
*tert*-Butyl 4-Oxo-2-phenylpiperidine-1-carboxylate **2a**




Using general procedure B, enone **1a** (2 g, 7.3 mmol) and LiBH($^s$Bu)$_3$ (8 mL, 8 mmol, 1 M in THF) in THF (37 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave piperidone **2a** (1.7 g, 85%) as a clear oil; $R_f$ 0.63 [petrol–EtOAc (1:1)]; $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.41–7.18 (m, 5H), 5.74 (br s, 1H), 4.25 (br, 1H), 3.17 (br t, 1H, *J* = 11.0 Hz), 2.99 (dd, 1H, *J* = 15.5, 2.5 Hz), 2.87 (dd, 1H, *J* = 15.5, 7.0 Hz), 2.62–2.46 (m, 1H), 2.44–2.30 (m, 1H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 207.9, 154.8, 140.5, 128.8, 127.6, 126.6, 80.8, 54.4, 44.4, 40.7, 38.7, 28.4. Data as reported.[14]

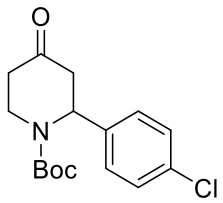
Resolution between the enantiomers of piperidone **2a** was achieved using a Beckman system fitted with a Phenomenex Cellulose-1 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (97:3 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 12.1 min and 14.1 min.

*tert*-Butyl 2-(4-Fluorophenyl)-4-oxopiperidine-1-carboxylate **2b**




Using general procedure B, enone **1b** (1.3 g, 4.5 mmol) and LiBH($^s$Bu)$_3$ (5 mL, 5 mmol, 1 M in THF) in THF (23 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (4:1), gave piperidone **2b** (0.94 g, 71%) as a clear oil; $R_f$ 0.30 [petrol–EtOAc (7:3)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1717 (C=O), 1691 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) $\delta$ = 7.25–7.17 (m, 2H), 7.07–6.94 (m, 2H), 5.73 (br, 1H), 4.24 (br, 1H), 3.14 (br t, 1H, *J* = 11.0 Hz), 2.99–2.79 (m, 2H), 2.63–2.47 (m, 1H), 2.47–2.30 (m, 1H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) $\delta$ =207.7, 162.1 (d, *J* = 246.5 Hz), 154.7, 136.2, 128.3 (d, *J* = 8.0 Hz), 115.6 (d, *J* = 21.5 Hz), 80.9, 53.9, 44.5, 40.7, 38.7, 28.4; $^{19}$F NMR ($CDCl_3$, 377 MHz) $\delta$ = −114.77; HRMS (ESI-TOF) *m/z*: [M+Na]$^+$ Calcd for $C_{16}H_{20}FNO_3Na$ 316.1319; Found 316.1325; LRMS *m/z* (ES) 142 (30%), 194 (25%), 238 (100%), 316 (45%, MNa$^+$).

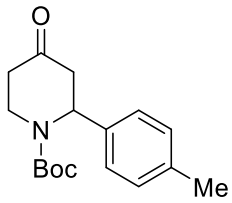
*tert*-Butyl 2-(4-Chlorophenyl)-4-oxopiperidine-1-carboxylate **2c**




Using general procedure B, enone **1c** (0.85 g, 2.8 mmol) and LiBH($^s$Bu)$_3$ (3.1 mL, 3.0 mmol, 1 M in THF) in THF (14 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (4:1), gave piperidone **2c** (0.69 g, 81%) as a clear oil; $R_f$ 0.28 [petrol–EtOAc (7:3)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1727 (C=O), 1691 (C=O); $^1$H NMR

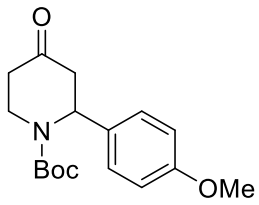
($CDCl_3$, 400 MHz) δ = 7.38–7.25 (m, 2H), 7.25–7.11 (m, 2H), 5.70 (br, 1H), 4.38–4.11 (m, 1H), 3.16 (t, 1H, *J* = 11.5 Hz), 2.99–2.81 (m, 2H), 2.61–2.47 (m, 1H), 2.47–2.30 (m, 1H), 1.49 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) δ = 207.5, 154.7, 139.1, 133.5, 128.9, 128.0, 81.0, 54.0, 44.4, 40.6, 38.8, 28.4; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{16}H_{20}{}^{35}ClNO_3Na$ 332.1024; Found 332.1033; LRMS *m/z* (ES) 332 (100%, $MNa^+$ for $^{35}Cl$), 333 (15%), 334 (35%, $MNa^+$ for $^{37}Cl$), 335 (5%).

*tert*-Butyl 2-(4-Methylphenyl)-4-oxopiperidine-1-carboxylate **2d**



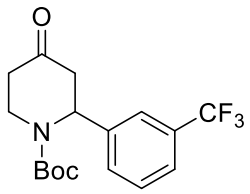

Using general procedure B, enone **1d** (1.3 g, 4.5 mmol) and $LiBH(^sBu)_3$ (5 mL, 5 mmol, 1 M in THF) in THF (23 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (4:1), gave piperidone **2d** (1.1 g, 84%) as a clear oil; $R_f$ 0.23 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1720 (C=O), 1688 (C=O); $^1H$ NMR ($CDCl_3$, 400 MHz) δ = 7.21–7.08 (m, 4H), 5.74 (br, 1H), 4.23 (br, 1H), 3.20–3.06 (m, 1H), 2.97 (dd, 1H, *J* = 15.5, 2.0 Hz), 2.85 (dd, 1H, *J* = 15.5, 7.0 Hz), 2.61–2.46 (m, 1H), 2.43–2.27 (m, 4H), 1.51 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz, one quaternary carbon not observed) δ = 208.1, 154.8, 137.3, 129.4, 126.6, 80.7, 54.1, 44.4, 40.7, 38.6, 28.4, 21.0; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{23}NO_3Na$ 312.1570; Found 312.1581; LRMS *m/z* (ES) 142 (65%), 190 (15%), 234 (75%), 312 (100%, $MNa^+$).

*tert*-Butyl 2-(4-Methoxyphenyl)-4-oxopiperidine-1-carboxylate **2e**




Using general procedure B, enone **1e** (1.5 g, 4.9 mmol) and LiBH($^s$Bu)$_3$ (5.4 mL, 5.4 mmol, 1 M in THF) in THF (25 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (17:3), gave piperidone **2e** (1.2 g, 80%) as a clear oil; $R_f$ 0.30 [petrol–EtOAc (7:3)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1718 (C=O), 1687 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) $\delta$ = 7.18 (d, 2H, *J* = 8.5 Hz), 6.87 (d, 2H, *J* = 8.5 Hz), 5.74 (br, 1H), 4.21 (br, 1H), 3.80 (s, 3H), 3.18–3.03 (m, 1H), 2.95 (dd, 1H, *J* = 15.5, 1.5 Hz), 2.84 (dd, 1H, *J* = 15.5, 6.5 Hz), 2.63–2.45 (m, 1H), 2.42–2.29 (m, 1H), 1.51 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) $\delta$ = 208.1, 158.9, 154.8, 132.3, 127.9, 114.1, 80.7, 55.3, 53.8, 44.4, 40.8, 38.5, 28.4; HRMS (ESI-TOF) *m/z*: [M+Na]$^+$ Calcd for $C_{17}H_{23}NO_4Na$ 328.1519; Found 328.1534; LRMS *m/z* (ES) 328 (100%, MNa$^+$).

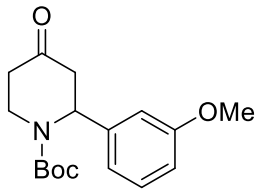
*tert*-Butyl 2-(3-Trifluoromethylphenyl)-4-oxopiperidine-1-carboxylate **2f**




Using general procedure B, enone **1f** (1.7 g, 5.0 mmol) and LiBH($^s$Bu)$_3$ (5.5 mL, 5.5 mmol, 1 M in THF) in THF (25 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (3:1), gave piperidone **2f** (1.2 g, 70%) as a clear oil; $R_f$ 0.29 [petrol–EtOAc (1:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1686 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz)

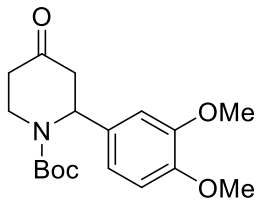
δ = 7.61–7.42 (m, 4H), 5.71 (br, 1H), 4.29 (br d, 1H, *J* = 12.0 Hz), 3.33–3.18 (m, 1H), 3.01–2.86 (m, 2H), 2.66–2.52 (m, 1H), 2.42 (dt, 1H, *J* = 16.5, 3.5 Hz), 1.47 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 207.2, 154.7, 131.7–130.9 (m), 129.6, 129.3, 125.3, 124.8–124.2 (m), 123.7–123.0 (m), 122.6, 81.2, 54.4, 44.4, 40.5, 39.0, 28.3; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −62.72; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{20}F_3NO_3Na$ 366.1287; Found 366.1302; LRMS *m/z* (ES) 244 (20%), 288 (100%), 366 (30%, $MNa^+$).

*tert*-Butyl 2-(3-Methoxyphenyl)-4-oxopiperidine-1-carboxylate **2g**




Using general procedure B, enone **1g** (1.3 g, 4.3 mmol) and $LiBH(^sBu)_3$ (4.7 mL, 4.7 mmol, 1 M in THF) in THF (22 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (3:1), gave piperidone **2g** (1 g, 76%) as a clear oil; $R_f$ 0.26 [petrol–EtOAc (7:3)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1723 (C=O), 1686 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.32–7.19 (m, 1H), 6.90–6.77 (m, 3H), 5.71 (br, 1H), 4.23 (br, 1H), 3.80 (s, 3H), 3.26–3.08 (m, 1H), 2.97 (dd, 1H, *J* = 15.5, 3.5 Hz), 2.85 (dd, 1H, *J* = 15.5, 7.0 Hz), 2.60–2.46 (m, 1H), 2.42–2.33 (m, 1H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 207.8, 160.0, 154.8, 142.1, 129.8, 118.8, 112.9, 112.4, 80.7, 55.2, 54.3, 44.4, 40.6, 38.8, 28.4; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{23}NO_4Na$ 328.1519; Found 328.1530; LRMS *m/z* (ES) 188 (75%), 232 (100%), 328 (90%, $MNa^+$).

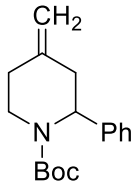
*tert*-Butyl 2-(3,4-Dimethoxyphenyl)-4-oxopiperidine-1-carboxylate **2h**




Using general procedure B, enone **1h** (0.67 g, 2.0 mmol) and $LiBH(^{s}Bu)_3$ (2.2 mL, 2.2 mmol, 1 M in THF) in THF (20 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol−EtOAc (1:1), gave piperidone **2h** (0.39 g, 58%) as a clear oil; $R_f$ 0.14 [petrol−EtOAc (7:3)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1713 (C=O), 1687 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 6.92–6.68 (m, 3H), 5.77 (br, 1H), 4.21 (br, 1H), 3.88 (s, 3H), 3.87 (s, 3H), 3.07 (t, 1H, *J* = 11.5 Hz), 2.97 (d, 1H, *J* = 15.5 Hz), 2.85 (dd, 1H, *J* = 15.5, 7.0 Hz), 2.61–2.47 (m, 1H), 2.36 (d, 1H, *J* = 15.5 Hz), 1.53 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 208.1, 154.8, 149.2, 148.5, 132.8, 118.9, 110.9, 110.0, 80.7, 55.9, 55.8, 54.0, 44.2, 40.8, 38.6, 28.4; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{25}NO_5Na$ 358.1625; Found 358.1635; LRMS *m/z* (ES) 98 (20%), 236 (15%), 358 (100%, $MNa^+$).

## 2.4 Preparation of 2-aryl-4-methylenepiperidines 3a–h

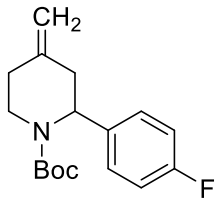
*tert*-Butyl 4-Methylidene-2-phenylpiperidine-1-carboxylate **3a**




Using general procedure C, $MePPh_3Br$ (26 g, 73 mmol), $KO^tBu$ (8 g, 73 mmol) and piperidone **2a** (5 g, 18 mmol) in THF (130 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave alkene **3a** (3.5 g, 71%) as a clear oil; $R_f$ 0.52 [petrol–EtOAc (4:1)]; $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.38–7.20 (m, 5H), 5.51 (br, 1H), 4.98–4.77 (m, 2H), 4.17–3.99 (m, 1H), 2.95–2.74 (m, 2H), 2.72–2.61 (m, 1H), 2.42–2.13 (m, 2H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.3, 142.4, 140.8, 128.3, 127.2, 126.7, 111.4, 79.9, 53.9, 40.1, 36.6, 33.8, 28.5. Data as reported.[15]

Resolution between the enantiomers of alkene **3a** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 5.6 min and 12.3 min.

*tert*-Butyl 2-(4-Fluorophenyl)-4-methylidenepiperidine-1-carboxylate **3b**



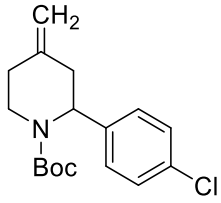

Using general procedure C, $MePPh_3Br$ (4.3 g, 12 mmol), $KO^tBu$ (1.3 g, 12 mmol) and piperidone **2b** (0.92 g, 3.1 mmol) in THF (22 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol−EtOAc (9:1), gave alkene **3b** (0.73 g, 81 %) as a clear oil; $R_f$ 0.58 [petrol−EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1687 (C=O), 1652 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.35–7.26 (m, 2H), 7.05–6.95 (m, 2H), 5.48 (br d, 1H, *J* = 6.0 Hz), 4.88 (br s, 2H), 4.07 (dd, 1H, *J* = 13.0, 4.0 Hz), 2.87–2.71 (m, 2H), 2.67 (dd, 1H, *J* = 14.5, 6.0 Hz), 2.38–2.18 (m, 2H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 161.7 (d, *J* = 245.0 Hz), 155.1, 142.2, 136.6, 128.8 (d, *J* = 8.0 Hz), 115.1 (d, *J* = 21.0 Hz), 111.6, 80.0, 53.2, 39.9, 36.7, 33.7, 28.5; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −116.28; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{22}FNO_2Na$ 314.1527; Found 314.1535; LRMS *m/z* (ES) 140 (15%), 236 (100%), 314 (25%, $MNa^+$).

Resolution between the enantiomers of alkene **3b** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·$min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·$L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 5.2 min and 11.2 min.

Alternatively, resolution between the enantiomers of alkene **3b** was achieved using a Agilent system fitted with a Chiralcel OX-H column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of

1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 5 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 5.4 min and 6.0 min.

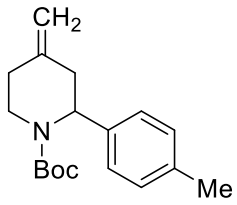
*tert*-Butyl 2-(4-Chlorophenyl)-4-methylidenepiperidine-1-carboxylate **3c**




Using general procedure C, MePPh$_3$Br (3.1 g, 8.7 mmol), KO$^t$Bu (1.0 g, 8.7 mmol) and piperidone **2c** (0.68 g, 2.2 mmol) in THF (16 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave alkene **3c** (0.58 g, 86%) as a clear oil; $R_f$ 0.48 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1685 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.40–7.22 (m, 4H), 5.46 (br d, 1H, *J* = 4.5 Hz), 4.87 (br s, 2H), 4.08 (dd, 1H, *J* = 13.0, 4.0 Hz), 2.86–2.72 (m, 2H), 2.72–2.60 (m, 1H), 2.39–2.15 (m, 2H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.1, 142.0, 139.4, 132.5, 128.6, 128.4, 111.6, 80.1, 53.4, 40.1, 36.6, 33.7, 28.4; HRMS (ESI-TOF) *m/z*: [M+Na]$^+$ Calcd for $C_{17}H_{22}{}^{35}ClNO_2Na$ 330.1123; Found 330.1238; LRMS *m/z* (ES) 330 (100%, MNa$^+$ for $^{35}$Cl), 331 (15%), 332 (35%, MNa$^+$ for $^{37}$Cl), 333 (10%).

Resolution between the enantiomers of alkene **3c** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 4.9 min and 6.4 min.

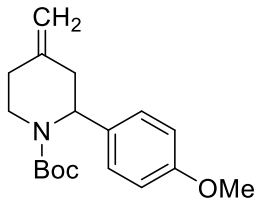
*tert*-Butyl 2-(4-Methylphenyl)-4-methylidenepiperidine-1-carboxylate **3d**




Using general procedure C, $MePPh_3Br$ (5.4 g, 15 mmol), $KO^tBu$ (1.7 g, 15 mmol) and piperidone **2d** (1.1 g, 3.7 mmol) in THF (27 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave alkene **3d** (0.81 g, 76%) as a clear oil; $R_f$ 0.54 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1689 (C=O), 1652 (C=C); $^1H$ NMR ($CDCl_3$, 400 MHz) $\delta$ = 7.23 (d, 2H, *J* = 8.0 Hz), 7.14 (d, 2H, *J* = 8.0 Hz), 5.49 (br, 1H), 4.94–4.78 (m, 2H), 4.08 (d, 1H, *J* = 9.0 Hz), 2.92–2.73 (m, 2H), 2.65 (dd, 1H, *J* = 14.0, 5.5 Hz), 2.40–2.13 (m, 5H), 1.51 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) $\delta$ = 155.3, 142.5, 137.6, 136.3, 129.0, 127.1, 111.3, 79.8, 53.6, 40.0, 36.6, 33.9, 28.5, 21.0; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{25}NO_2Na$ 310.1778; Found 310.1792; LRMS *m/z* (ES) 140 (40%), 232 (100%), 310 (50%, $MNa^+$).

Resolution between the enantiomers of alkene **3d** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 5.3 min and 9.3 min.

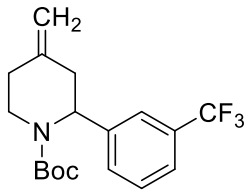
*tert*-Butyl 2-(4-Methoxyphenyl)-4-methylidenepiperidine-1-carboxylate **3e**




Using general procedure C, $MePPh_3Br$ (5.7 g, 16 mmol), $KO^tBu$ (1.8 g, 16 mmol) and piperidone **2e** (1.2 g, 3.9 mmol) in THF (28 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol−EtOAc (9:1), gave alkene **3e** (0.89 g, 73%) as a clear oil; $R_f$ 0.57 [petrol−EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1685 (C=O), 1654 (C=C); $^1H$ NMR ($CDCl_3$, 400 MHz) δ = 7.27 (d, 2H, *J* = 9.0 Hz), 6.86 (d, 2H, *J* = 9.0 Hz), 5.47 (br d, 1H, *J* = 5.5 Hz), 4.93-4.81 (m, 2H), 4.06 (dd, 1H, *J* = 13.0, 4.5 Hz), 3.81 (s, 3H), 2.89–2.72 (m, 2H), 2.70–2.60 (m, 1H), 2.37–2.18 (m, 2H), 1.51 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) δ =158.3, 155.2, 142.6, 132.9, 128.4, 113.6, 111.3, 79.8, 55.2, 53.2, 39.8, 36.6, 33.9, 28.5; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{25}NO_3Na$ 326.1727; Found 326.1718; LRMS *m/z* (ES) 140 (100%), 248 (100%), 326 (90%, $MNa^+$).

Resolution between the enantiomers of alkene **3e** was achieved using a Beckman system fitted with a Daicel Chiralpak-IA column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 10.7 min and 13.1 min.

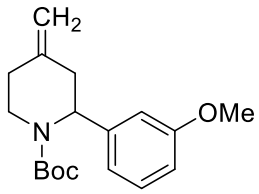
*tert*-Butyl 2-(3-Trifluoromethylphenyl)-4-methylidenepiperidine-1-carboxylate **3f**




Using general procedure C, $MePPh_3Br$ (5.0 g, 14 mmol), $KO^tBu$ (1.6 g, 14 mmol) and piperidone **2f** (1.2 g, 3.5 mmol) in THF (25 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol−EtOAc (9:1), gave alkene **3f** (0.91 g, 76%) as a clear oil; $R_f$ 0.48 [petrol−EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1695 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.63–7.40 (m, 4H), 5.51 (br, 1H), 4.89 (br s, 2H), 4.10 (d, 1H, *J* = 13.5 Hz), 2.93–2.63 (m, 3H), 2.40–2.20 (m, 2H), 1.50 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.2, 142.0, 141.8, 130.5, 128.8, 126.9 (q, *J* = 267.0 Hz), 124.23–123.85 (m), 123.85–123.44 (m), 111.8, 80.3, 53.7, 40.2, 36.6, 33.6, 28.4; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −62.67; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{22}F_3NO_2Na$ 364.1495; Found 364.1512; LRMS *m/z* (ES) 242 (10%), 286 (100%), 364 (15%, $MNa^+$).

Resolution between the enantiomers of alkene **3f** was achieved using a Beckman system fitted with a Phenomenex Amylose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 6.0 min and 6.5 min.

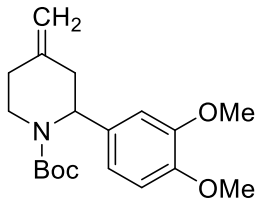
*tert*-Butyl 2-(3-Methoxyphenyl)-4-methylidenepiperidine-1-carboxylate **3g**




Using general procedure C, $MePPh_3Br$ (4.6 g, 13 mmol), $KO^tBu$ (1.5 g, 13 mmol) and piperidone **2g** (0.95 g, 3.1 mmol) in THF (22 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave alkene **3g** (0.79 g, 84%) as a clear oil; $R_f$ 0.50 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1689 (C=O); $^1H$ NMR ($CDCl_3$, 400 MHz) $\delta$ = 7.32–7.20 (m, 1H), 6.97–6.88 (m, 2H), 6.82–6.76 (m, 1H), 5.48 (br, 1H), 4.94–4.82 (m, 2H), 4.09 (br d, 1H, *J* = 10.0 Hz), 3.80 (s, 3H), 2.94–2.75 (m, 2H), 2.66 (dd, 1H, *J* = 14.0, 6.0 Hz), 2.40–2.17 (m, 2H), 1.51 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) $\delta$ = 159.6, 155.2, 142.54, 142.47, 129.3, 119.6, 113.2, 111.9, 111.4, 79.9, 55.1, 53.8, 40.1, 36.6, 33.8, 28.5; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{25}NO_3Na$ 326.1727; Found 326.1720; LRMS *m/z* (ES) 161 (35%), 204 (15%), 248 (100%), 326 (45%, $MNa^+$).

Resolution between the enantiomers of alkene **3g** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 9.6 min and 18.6 min.

*tert*-Butyl 2-(3,4-Dimethoxyphenyl)-4-methylidenepiperidine-1-carboxylate **3h**

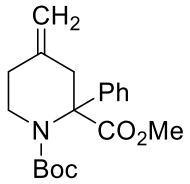



Using general procedure C, $MePPh_3Br$ (1.7 g, 4.6 mmol), $KO^tBu$ (0.52 g, 4.6 mmol) and piperidone **2h** (0.39 g, 1.2 mmol) in THF (8.4 mL) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (7:3), gave alkene **3h** (0.33 g, 85%) as a clear oil; $R_f$ 0.29 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1690 (C=O), 1650 (C=C); $^1H$ NMR ($CDCl_3$, 400 MHz) δ = 6.98–6.89 (m, 2H), 6.82 (d, 1H, *J* = 8.0 Hz), 5.48 (d, 1H, *J* = 5.0 Hz), 4.90 (br s, 2H), 4.06 (d, 1H, *J* = 10.0 Hz), 3.88 (s, 3H), 3.86 (s, 3H), 2.92–2.59 (m, 3H), 2.39–2.16 (m, 2H), 1.52 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) δ = 155.2, 148.8, 147.8, 143.0, 133.5, 119.6, 111.2, 110.8, 110.7, 79.8, 55.84, 55.78, 53.2, 39.9, 36.6, 33.9, 28.5; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{19}H_{27}NO_4Na$ 356.1832; Found 356.1841; LRMS *m/z* (ES) 96 (5%), 140 (35%), 191 (20%), 278 (25%), 356 (100%, $MNa^+$).

Resolution between the enantiomers of alkene **3h** was achieved using a Beckman system fitted with a Phenomenex Cellulose-1 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (97:3 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 8.1 min and 9.3 min.

## 2.5 Preparation of racemic 2,2-disubstituted products

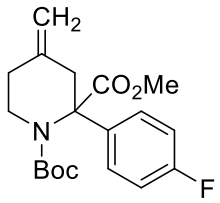
1-*tert*-Butyl 2-Methyl 4-Methylidene-2-phenylpiperidine-1,2-dicarboxylate **4a**




Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3a** (100 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (9:1), gave carbamate **4a** (106 mg, 87%) as a clear oil; $R_f$ 0.41 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1744 (C=O), 1696 (C=O), 1654 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.46 (d, 2H, *J* = 7.5 Hz), 7.34 (t, 2H, *J* = 7.5 Hz), 7.30–7.23 (m, 1H), 4.82–4.70 (m, 2H), 4.01–3.87 (m, 1H), 3.72 (s, 3H), 3.54 (br, 1H), 3.13–2.88 (m, 2H), 2.57–2.21 (m, 2H), 1.34 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, two quaternary carbon signals and one $CH_2$ signal not observed) δ = 172.7, 140.0, 127.7, 127.3, 127.0, 112.1, 80.8, 52.2, 41.8, 31.0, 28.1; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{19}H_{25}NO_4Na$ 354.1676; Found 354.1691; LRMS *m/z* (ES) 232 (100%), 354 (55%, $MNa^+$).

Resolution between the enantiomers of carbamate **4a** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 10.9 min and 12.6 min.

1-*tert*-Butyl 2-Methyl 2-(4-Fluorophenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4b**



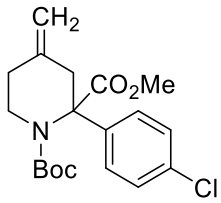

Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3b** (108 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7) gave carbamate **4b** (116 mg, 90%) as a clear oil; $R_f$ 0.23 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1744 (C=O), 1696 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.50–7.37 (m, 2H), 7.07–6.95 (m, 2H), 4.75 (br s, 2H), 3.97–3.86 (m, 1H), 3.73 (s, 3H), 3.54 (br, 1H), 3.04 (d, 1H, *J* = 14.5 Hz), 2.98–2.79 (m, 1H), 2.59–2.21 (m, 2H), 1.34 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, three quaternary carbon signals & three $CH_2$ signals not observed) δ = 172.7, 161.8 (d, *J* = 246.0 Hz), 139.6, 129.0, 114.5 (d, *J* = 21.0 Hz), 112.3, 81.0, 52.3, 28.1; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −116.13; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{19}H_{24}FNO_4Na$ 372.1582; Found 372.1596; LRMS *m/z* (ES) 187 (10%), 250 (100%), 372 (90%, $MNa^+$).

Resolution between the enantiomers of carbamate **4b** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 11.4 min and 12.6 min.

Alternatively, resolution between the enantiomers of carbamate **4b** was achieved using a Agilent system fitted with a Chiral Art Cellulose-C column (250 mm × 4.60 mm i.d.) as the

stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 5 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 7.7 min and 8.4 min.

1-*tert*-Butyl 2-Methyl 2-(4-Chlorophenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4c**

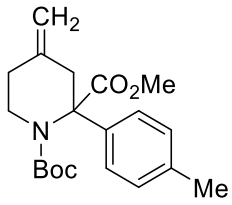



Using general procedure D, *n*-BuLi (0.20 mL, 0.44 mmol, 2.2 M in hexanes) and alkene **3c** (114 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7), gave carbamate **4c** (106 mg, 78%) as a clear oil; $R_f$ 0.32 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1744 (C=O), 1698 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.45–7.37 (m, 2H), 7.34–7.27 (m, 2H), 4.75 (br s, 2H), 3.95–3.84 (m, 1H), 3.73 (s, 3H), 3.54 (br, 1H), 3.04 (d, 1H, *J* = 14.5 Hz), 2.96–2.79 (m, 1H), 2.59–2.18 (m, 2H), 1.34 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, two quaternary carbon signals & three $CH_2$ signals not observed) δ = 172.5, 139.3, 132.9, 128.8, 127.8, 112.4, 81.1, 67.6, 52.4, 28.1; HRMS (ESI-TOF) *m/z*: [M+Na]$^+$ Calcd for $C_{19}H_{24}{}^{35}ClNO_4Na$ 388.1287; Found 388.1300; LRMS *m/z* (ES) 388 (100%, $MNa^+$ for $^{35}$Cl), 389 (20%), 390 (35%, $MNa^+$ for $^{37}$Cl), 391 (5%).

Resolution between the enantiomers of carbamate **4c** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume

was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 8.5 min and 10.0 min.

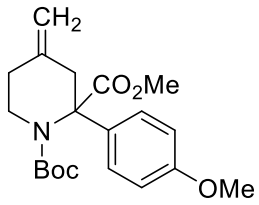
1-*tert*-Butyl 2-Methyl 2-(4-Methylphenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4d**




Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3d** (106 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7), gave carbamate **4d** (117 mg, 92%) as a clear oil; $R_f$ 0.47 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1741 (C=O), 1693 (C=O), 1655 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.32 (d, 2H, *J* = 8.0 Hz), 7.14 (d, 2H, *J* = 8.0 Hz), 4.84–4.67 (m, 2H), 3.99–3.88 (m, 1H), 3.71 (s, 3H), 3.44 (br, 1H), 3.07–2.91 (m, 2H), 2.52–2.18 (m, 5H), 1.37 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, one quaternary carbon signal & one $CH_2$ signal not observed) δ = 172.8, 155.8, 140.2, 136.7, 128.5, 127.3, 112.0, 80.8, 67.7, 52.2, 42.0, 31.1, 28.1, 21.0; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{20}H_{27}NO_4Na$ 368.1832; Found 368.1839; LRMS *m/z* (ES) 185 (10%), 246 (100%), 368 (90%, $MNa^+$).

Resolution between the enantiomers of carbamate **4d** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 10.3 min and 12.2 min.

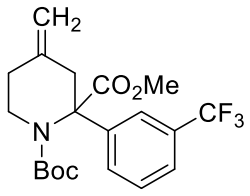
1-*tert*-Butyl 2-Methyl 2-(4-Methoxyphenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4e**




Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3e** (112 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7), gave carbamate **4e** (80 mg, 60%) as a clear oil; $R_f$ 0.29 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1744 (C=O), 1698 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.36 (d, 2H, *J* = 9.0 Hz), 6.86 (d, 2H, *J* = 9.0 Hz), 4.85–4.68 (m, 2H), 3.98–3.87 (m, 1H), 3.82 (s, 3H), 3.71 (s, 3H), 3.42 (br, 1H), 3.10–2.86 (m, 2H), 2.51–2.18 (m, 2H), 1.37 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, $CDCl_3$, three quaternary carbon signals & one $CH_2$ signal not observed) δ = 172.9, 158.5, 140.2, 128.7, 113.1, 112.1, 80.8, 55.2, 52.2, 41.9, 31.2, 28.1; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{20}H_{27}NO_5Na$ 384.1781; Found 384.1799; LRMS *m/z* (ES) 384 (100%, $MNa^+$).

Resolution between the enantiomers of carbamate **4e** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 18.2 min and 23.7 min.

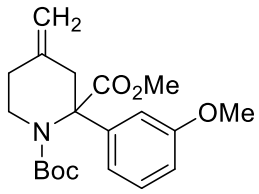
1-*tert*-Butyl 2-Methyl 2-(3-Trifluoromethylphenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4f**




Using general procedure D, *n*-BuLi (0.19 mL, 0.44 mmol, 2.3 M in hexanes) and alkene **3f** (126 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7), gave carbamate **4f** (139 mg, 94%) as a clear oil; $R_f$ 0.30 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1747 (C=O), 1698 (C=O), 1656 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.78–7.64 (m, 2H), 7.59–7.41 (m, 2H), 4.75 (br s, 2H), 4.00–3.85 (m, 1H), 3.82–3.40 (m, 4H), 3.08 (d, 1H, *J* = 14.5 Hz), 2.94–2.80 (m, 1H), 2.61–2.22 (m, 2H), 1.31 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, four quaternary carbon signals, three $CH_2$ signals & one CH signal not observed) δ = 172.4, 139.0, 131.0–130.6 (m), 128.1, 124.22–123.61 (m), 112.5, 81.2, 52.5, 28.0; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −62.50; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{20}H_{24}F_3NO_4Na$ 422.1550; Found 422.1571; LRMS *m/z* (ES) 300 (100%), 422 (50%, $MNa^+$).

Resolution between the enantiomers of carbamate **4f** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 6.9 min and 7.5 min.

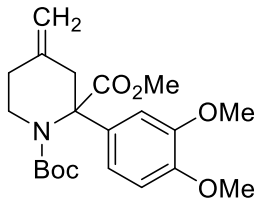
1-*tert*-Butyl 2-Methyl 2-(3-Methoxyphenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4g**




Using general procedure D, *n*-BuLi (0.19 mL, 0.44 mmol, 2.3 M in hexanes) and alkene **3g** (112 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7), gave carbamate **4g** (93 mg, 70%) as a clear oil; $R_f$ 0.24 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1747 (C=O), 1698 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = $^1$H NMR (400 MHz, $CDCl_3$) δ 7.28–7.20 (m, 1H), 7.10–7.01 (m, 2H), 6.83–6.77 (m, 1H), 4.82–4.72 (m, 2H), 4.00–3.86 (m, 1H), 3.82 (s, 3H), 3.72 (s, 3H), 3.50 (br, 1H), 3.09–2.84 (m, 2H), 2.57–2.16 (m, 2H), 1.35 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, three quaternary carbon signals & one $CH_2$ signal not observed) δ = 172.5, 159.2, 140.0, 128.6, 119.8, 113.6, 112.2, 112.1, 80.8, 55.2, 52.2, 41.9, 30.8, 28.1; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{20}H_{27}NO_5Na$ 384.1781; Found 384.1792; LRMS *m/z* (ES) 384 (100%, $MNa^+$).

Resolution between the enantiomers of carbamate **4g** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 18.6 min and 22.5 min.

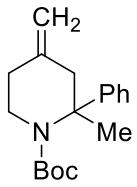
1-*tert*-Butyl 2-Methyl 2-(3,4-Dimethoxyphenyl)-4-methylidenepiperidine-1,2-dicarboxylate **4h**




Using general procedure D, *n*-BuLi (0.19 mL, 0.44 mmol, 2.3 M in hexanes) and alkene **3h** (123 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (3:1), gave carbamate **4h** (96 mg, 66%) as a clear oil; $R_f$ 0.54 [petrol–EtOAc (1:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1735 (C=O), 1699 (C=O), 1656 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.06 (d, 1H, *J* = 2.0 Hz), 6.99 (dd, 1H, *J* = 8.5, 2.0 Hz), 6.82 (d, 1H, *J* = 8.5 Hz), 4.78 (br s, 2H), 4.00–3.81 (m, 7H), 3.71 (s, 3H), 3.41 (br, 1H), 3.08–2.92 (m, 2H), 2.58–2.14 (m, 2H), 1.38 (br s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, one quaternary carbon signal & one $CH_2$ signal not observed) δ = 172.8, 155.8, 148.2, 148.0, 140.3, 120.0, 112.1, 111.2, 110.3, 80.8, 67.4, 55.9, 55.8, 52.2, 42.1, 31.2, 28.2; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{21}H_{29}NO_6Na$ 414.1887; Found 414.1902; LRMS *m/z* (ES) 208 (5%), 292 (50%), 414 (100%, $MNa^+$).

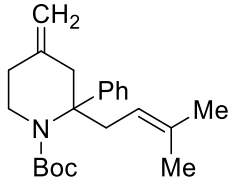
Resolution between the enantiomers of carbamate **4h** was achieved using a Beckman system fitted with a Phenomenex Cellulose-1 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (97:3 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 14.1 min and 17.5 min.

*tert*-Butyl 2-Methyl-4-methylidene-2-phenylpiperidine-1-carboxylate **5a**




Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3a** (100 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeI (0.08 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (9:1), gave carbamate **5a** (96 mg, 90%) as a clear oil; $R_f$ 0.28 [petrol–EtOAc (9:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1683 (C=O), 1651 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.34–7.27 (m, 4H), 7.24–7.18 (m, 1H), 4.86 (s, 1H), 4.80 (s, 1H), 4.07–3.93 (m, 1H), 3.81–3.69 (m, 1H), 2.70 (d, 1H, *J* = 14.5 Hz), 2.64–2.55 (m, 2H), 2.30 (d, 1H, *J* = 14.5 Hz), 1.76 (s, 3H), 1.10 (s, 9H); $^{13}$C{1H} NMR (100 MHz, $CDCl_3$) δ = 155.4, 149.4, 141.4, 127.9, 125.9, 124.4, 111.3, 79.6, 60.3, 49.7, 40.9, 30.4, 28.0, 25.0; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{25}NO_2Na$ 310.1778; Found 310.1789; LRMS *m/z* (ES) 145 (20%), 232 (100%), 310 (30%, $MNa^+$).

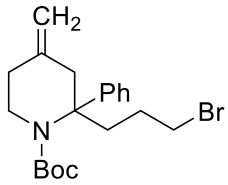
*tert*-Butyl 2-(3-Methylbut-2-en-1-yl)-4-methylidene-2-phenylpiperidine-1-carboxylate **6a**




Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3a** (100 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and prenyl bromide (0.15 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane−EtOAc (19:1) gave carbamate **6a** (112 mg, 89%) as a clear oil; $R_f$ 0.52 [petrol−EtOAc

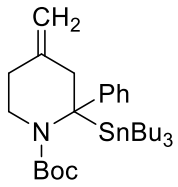
(4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1687 (C=O), 1654 (C=C); $^{1}$H NMR ($CDCl_3$, 400 MHz) δ = 7.37–7.14 (m, 5H), 5.33–5.23 (m, 1H), 4.72 (s, 1H), 4.54 (s, 1H), 4.27–4.13 (m, 1H), 3.43–3.31 (m, 1H), 3.14 (dd, 1H, *J* = 14.0, 6.0 Hz), 2.96 (d, 1H, *J* = 14.5 Hz), 2.83 (dd, 1H, *J* = 14.0, 9.0 Hz), 2.71–2.45 (m, 2H), 2.12 (d, 1H, *J* = 14.5 Hz), 1.79 (s, 3H), 1.72 (s, 3H), 1.14 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.4, 148.1, 141.0, 134.8, 127.5, 125.7, 125.0, 119.6, 111.6, 79.6, 63.6, 45.6, 41.0, 37.4, 30.1, 28.1, 26.2, 18.3; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{22}H_{31}NO_2Na$ 364.2247; Found 364.2263; LRMS *m/z* (ES) 286 (100%), 364 (35%, $MNa^+$).

*tert*-Butyl 2-(3-Bromopropyl)-4-methylidene-2-phenylpiperidine-1-carboxylate **7a**



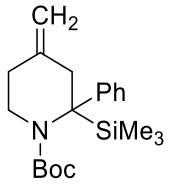

Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3a** (100 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and 1,3-dibromopropane (0.13 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (93:7), gave carbamate **7a** (102 mg, 70%) as a clear oil; $R_f$ 0.61 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1681 (C=O); $^{1}$H NMR ($CDCl_3$, 400 MHz) δ = 7.37–7.13 (m, 5H), 4.75 (s, 1H), 4.63 (s, 1H), 4.20–4.06 (m, 1H), 3.58–3.44 (m, 3H), 2.87 (d, 1H, *J* = 14.5 Hz), 2.74–2.45 (m, 3H), 2.31 (d, 1H, *J* = 14.5 Hz), 2.20 (td, 1H, *J* = 12.5, 4.0 Hz), 2.16–1.88 (m, 2H), 1.17 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.4, 148.1, 140.6, 127.7, 126.0, 124.8, 112.0, 79.9, 62.8, 46.6, 41.1, 39.1, 34.3, 30.2, 28.1, 27.8; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{20}H_{28}{}^{79}BrNO_2Na$ 416.1196; Found 416.1204; LRMS *m/z* (ES) 416 (100%, $MNa^+$ for $^{79}$Br), 417 (20%), 418 (100%, $MNa^+$ for $^{81}$Br), 419 (20%).

*tert*-Butyl 2-(Tributylstannyl)-4-methylidene-2-phenylpiperidine-1-carboxylate **8a**




Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3a** (100 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and $Bu_3SnCl$ (0.20 mL, 0.73 mmol) gave the crude product. Purification by column chromatography on a mixture of silica gel and $K_2CO_3$ (10% w/w), eluting with pentane–EtOAc (99:1), gave carbamate **8a** (181 mg, 87%) as a clear oil; $R_f$ 0.59 [petrol–EtOAc (19:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1667 (C=O); $^1H$ NMR ($CDCl_3$, 400 MHz) δ = 7.32–7.21 (m, 2H), 7.08–6.92 (m, 3H), 4.84–4.72 (m, 2H), 4.07–3.90 (m, 1H), 3.23–3.09 (m, 1H), 2.89–2.63 (m, 2H), 2.25 (dt, 1H, *J* = 13.0, 6.5 Hz), 2.04 (d, 1H, *J* = 13.0 Hz), 1.53 (s, 9H), 1.41–1.16 (m, 12H), 0.85 (t, 9H, *J* = 7.5 Hz), 0.80–0.58 (m, 6H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) δ = 157.3, 144.8, 143.0, 128.1, 125.0, 123.7, 110.6, 80.1, 58.8, 42.1, 40.6, 34.3, 29.0, 28.4, 27.7, 13.7, 13.2; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{29}H_{49}NO_2SnNa$ 586.2677; Found 586.2682; LRMS *m/z* (ES) 360 (100%), 381 (30%), 586 (30%, $MNa^+$).

*tert*-Butyl 2-(Trimethylsilyl)-4-methylidene-2-phenylpiperidine-1-carboxylate **9a**

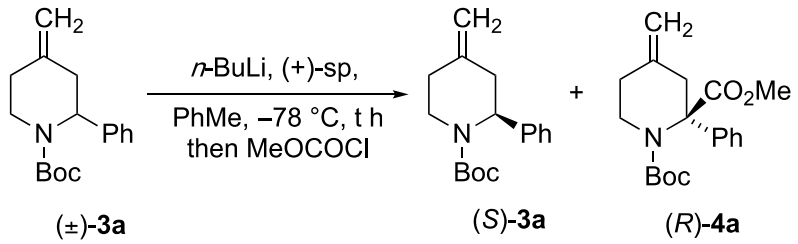



Using general procedure D, *n*-BuLi (0.18 mL, 0.44 mmol, 2.4 M in hexanes) and alkene **3a** (100 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and $Me_3SiCl$ (0.16 mL, 1.28 mmol) gave

the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (19:1), gave carbamate **9a** (89 mg, 70%) as a clear oil; $R_f$ 0.69 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1687 (C=O), 1652 (C=C); $^1$H NMR ($CDCl_3$, 400 MHz) $\delta$ = 7.33–7.25 (m, 2H), 7.17–7.04 (m, 3H), 4.87–4.75 (m, 2H), 4.01–3.87 (m, 1H), 3.02 (d, 1H, *J* = 14.0 Hz), 2.73–2.54 (m, 2H), 2.29–2.16 (m, 1H), 2.03 (d, 1H, *J* = 14.0 Hz), 1.54 (s, 9H), −0.02 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) $\delta$ = 156.1, 142.9, 142.0, 127.7, 127.5, 125.0, 111.3, 79.7, 57.8, 42.5, 38.5, 34.1, 28.4, 0.9; HRMS (ESI-TOF) *m/z*: $[M+H]^+$ Calcd for $C_{20}H_{32}NO_2Si$ 346.2197; Found 346.2212; LRMS *m/z* (ES) 274 (80%), 346 (100%, $MH^+$).

## 2.6 Kinetic resolution of racemic substrates 3a–h

Optimization of the kinetic resolution was carried out with substrate **3a** and (+)-sparteine:




*n*-BuLi (2.1 to 2.4 M in hexanes) was added to the alkene **3a** (1 eq) and (+)-sparteine (freshly distilled) in dry PhMe (0.25 M) at −78 °C (Table S1). After time t (h), MeOCOCl (2 eq) was added and the mixture was warmed to rt over 16 h. MeOH (1 mL) was added and the solvent was evaporated under reduced pressure. The crude product was purified by column chromatography on silica gel, eluting with petrol−EtOAc (93:7), to give recovered alkene (*S*)-**3a** and carbamate (*R*)-**4a**. The enantiomeric ratio of both compounds was determined by CSP-HPLC as described above.

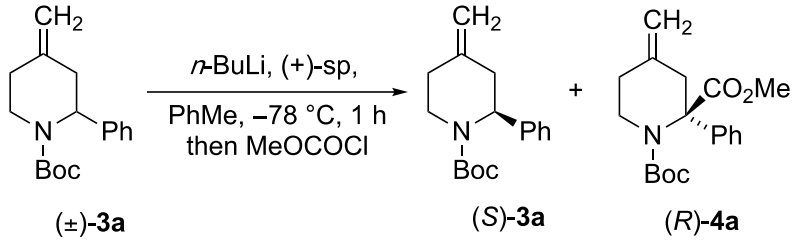
**Table S1** Optimization of the kinetic resolution

| Entry | (+)-sp eq | *n*-BuLi eq | t h | (*S*)-**3a** % Yield | (*S*)-**3a** er | (*R*)-**4a** % Yield | (*R*)-**4a** er | S |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.7 | 0.7 | 2 h | 61% | 88:12 | 35% | 91:9 | - |
| 2 | 0.85 | 0.85 | 2 h | 43% | 94:6 | 43% | 82:18 | 14 |
| 3 | 1 | 1 | 2 h | 43% | 90:10 | 24% | 80:20 | 10 |
| 4 | 0.9 | 0.8 | 2 h | 42% | 96:4 | 54% | 70:30 | 16 |
| 5 | 0.9 | 0.8 | 1 h | 45% | 92:8 | 35% | 90:10 | 14 |
| 6[a] | 0.9 | 0.8 | 1 h | 41% | 97:3 | 58% | 73:27 | 16 |

[a]Entries 1–5 on 100 mg **3a**; entry 6 on 300 mg **3a** as detailed on page S-38

Resolution of alkene **3a** with (+)-sparteine

*tert*-Butyl (2*S*)-4-Methylidene-2-phenylpiperidine-1-carboxylate (*S*)-**3a** and 1-*tert*-Butyl 2-Methyl (2*R*)-4-Methylidene-2-phenylpiperidine-1,2-dicarboxylate (*R*)-**4a**




(±)-**3a** (*S*)-**3a** (*R*)-**4a**

Reaction with 300 mg of alkene **3a**:

*n*-BuLi (0.40 mL, 0.88 mmol, 2.2 M in hexanes) was added to a mixture of (+)-sparteine (231 mg, 0.988 mmol) and the racemic alkene **3a** (300 mg, 1.10 mmol) in dry PhMe (4.4 mL) at –78 °C. After 1 h, MeOCOCl (0.17 mL, 2.2 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (3 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (93:7), to give recovered alkene (*S*)-**3a** (122 mg, 41%) as a clear oil; data as above; the enantiomeric ratio was determined to be 97:3 by CSP-HPLC as described above (major component eluted at 12.6 min); $[\alpha]_D^{23}$ –70 (*c* 1.0, $CHCl_3$). In addition, the carbamate (*R*)-**4a** (210 mg, 58%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 73:27 by CSP-HPLC (major component eluted at 10.6 min); $[\alpha]_D^{23}$ +9 (*c* 1.0, $CHCl_3$).

Reaction with 2 g of alkene **3a**:

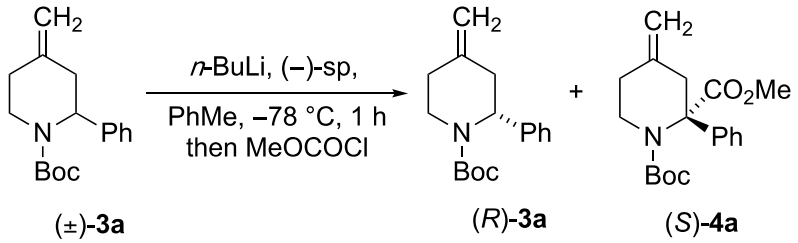
*n*-BuLi (2.4 mL, 5.8 mmol, 2.4 M in hexanes) was added to a mixture of (+)-sparteine (1.6 g, 6.6 mmol) and the racemic alkene **3a** (2.0 g, 7.3 mmol) in dry PhMe (29 mL) at –78 °C. After 1 h, MeOCOCl (1.1 mL, 15 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (15 mL) was added. The solvent was evaporated, and the residue was diluted with $Et_2O$ (150 mL) and water (60 mL). The aqueous layer was adjusted to pH 1 using aq HCl

(2 M) and the organic layer was separated, dried over anhydrous $MgSO_4$, filtered and concentrated to give the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (23:2), to give recovered alkene (*S*)-**3a** (0.6 g, 30%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC as described above (major component eluted at 12.6 min); $[\alpha]_D^{23}$ –84 (*c* 1.0, $CHCl_3$). In addition, the carbamate (*R*)-**4a** (1.6 g, 66%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 72:28 by CSP-HPLC (major component eluted at 10.9 min); $[\alpha]_D^{23}$ +7 (*c* 1.0, $CHCl_3$).

NB - The aqueous layer from the extraction was adjusted to pH 14 using NaOH pellets and $Et_2O$ (150 mL) was added. The organic layer was separated, dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give crude recovered (+)-sparteine (1.5 g) as a yellow oil.

Resolution of alkene **3a** with (–)-sparteine

*tert*-Butyl (2*R*)-4-Methylidene-2-phenylpiperidine-1-carboxylate (*R*)-**3a** and 1-*tert*-Butyl 2-Methyl (2*S*)-4-Methylidene-2-phenylpiperidine-1,2-dicarboxylate (*S*)-**4a**

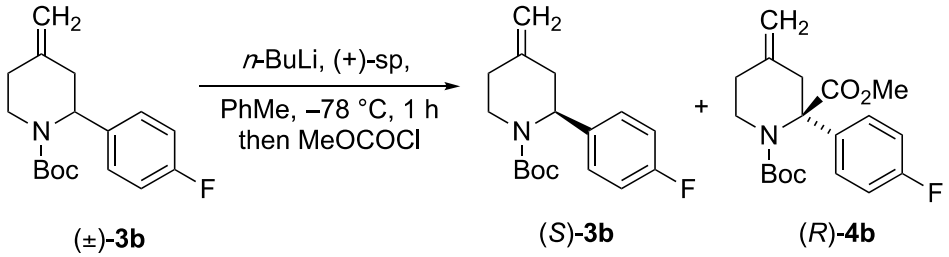



*n*-BuLi (0.13 mL, 0.29 mmol, 2.3 M in hexanes) was added to a mixture of (–)-sparteine (77 mg, 0.33 mmol) and the racemic alkene **3a** (100 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 1 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the

residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (93:7), to give recovered alkene (*R*)-**3a** (39 mg, 39%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC as described above (major component eluted at 5.6 min); $[\alpha]_D^{25}$ +81 (*c* 1.2, $CHCl_3$). In addition, the carbamate (*S*)-**4a** (70 mg, 57%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 81:19 by CSP-HPLC (major component eluted at 12.2 min); $[\alpha]_D^{25}$ –11 (*c* 1.1, $CHCl_3$).

Resolution of alkene **3b** with (+)-sparteine

*tert*-Butyl (2*S*)-2-(4-Fluorophenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3b** and 1-*tert*-Butyl 2-Methyl (2*R*)-2-(4-Fluorophenyl)-4-methylidenepiperidine-1,2-dicarboxylate (*R*)-**4b**




Reaction with 108 mg of alkene **3b**:

*n*-BuLi (0.13 mL, 0.29 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (77 mg, 0.33 mmol) and the racemic alkene **3b** (108 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 1 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (47:3), to give recovered alkene (*S*)-**3b** (51 mg, 47%) as a clear oil; data as above; the enantiomeric ratio was determined to be 94:6 by CSP-HPLC as described above (major component eluted at 11.2 min); $[\alpha]_D^{23}$ –60 (*c* 1.0, $CHCl_3$). In addition, the carbamate (*R*)-**4b**

(45 mg, 35%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 88:12 by CSP-HPLC (major component eluted at 11.4 min); $[\alpha]_D^{23}$ +8 (*c* 1.0, $CHCl_3$).

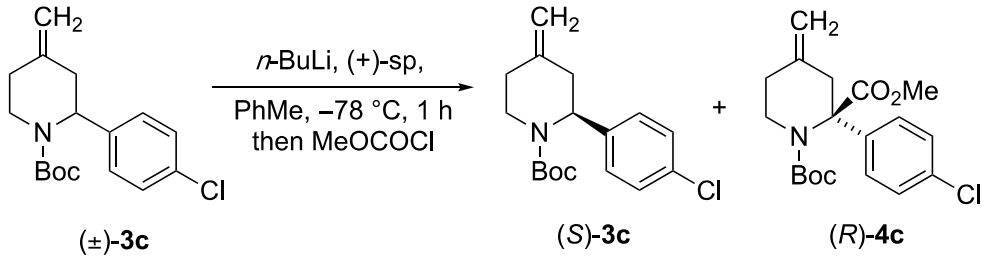
Reaction with 4 g of alkene **3b**:

*n*-BuLi (4.8 mL, 11 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (2.9 g, 12 mmol) and the racemic alkene **3b** (4.0 g, 14 mmol) in dry PhMe (62 mL) at –78 °C. After 1 h, MeOCOCl (2.7 mL, 34 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (20 mL) was added. The solvent was evaporated, and the residue was diluted with $Et_2O$ (150 mL) and water (75 mL). The aqueous layer was adjusted to pH 1 using aq HCl (2 M) and the organic layer was separated, dried over anhydrous $MgSO_4$, filtered and concentrated to give the crude product. Purification by column chromatography on silica gel, eluting with *n*-hexane–EtOAc (93:7), to give recovered alkene (*S*)-**3b** (1.4 g, 35%) as a clear oil; data as above; the enantiomeric ratio was determined to be 94:6 by CSP-HPLC as described above (major component eluted at 6.1 min on Agilent system fitted with a Chiralcel OX-H column). In addition, the carbamate (*R*)-**4b** (2.7 g, 56%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 75:25 by CSP-HPLC (major component eluted at 8.6 min on Agilent system fitted with a Chiral Art Cellulose-C column.

NB - The aqueous layer from the extraction was adjusted to pH 14 using NaOH pellets and $Et_2O$ (150 mL) was added. The organic layer was separated, dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give crude recovered (+)-sparteine (2.9 g) as a yellow oil.

Resolution of alkene **3c** with (+)-sparteine

*tert*-Butyl (2*S*)-2-(4-Chlorophenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3c** and 1-*tert*-Butyl 2-Methyl (2*R*)-2-(4-Chlorophenyl)-4-methylidenepiperidine-1,2-dicarboxylate (*R*)-**4c**

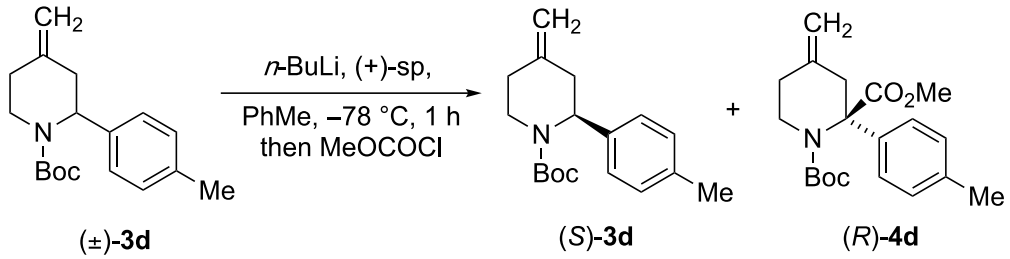



(±)-**3c** (*S*)-**3c** (*R*)-**4c**

*n*-BuLi (0.13 mL, 0.29 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (77 mg, 0.33 mmol) and the racemic alkene **3c** (114 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 1 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (47:3), to give recovered alkene (*S*)-**3c** (40 mg, 35%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC as described above (major component eluted at 6.6 min); $[\alpha]_D^{25}$ –78 (*c* 1.2, $CHCl_3$). In addition, the carbamate (*R*)-**4c** (77 mg, 57%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 76:24 by CSP-HPLC (major component eluted at 8.6 min); $[\alpha]_D^{27}$ +4 (*c* 1.0, $CHCl_3$).

Resolution of alkene **3d** with (+)-sparteine

*tert*-Butyl (2*S*)-2-(4-Methylphenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3d** and 1-*tert*-Butyl 2-Methyl (2*R*)-2-(4-Methylphenyl)-4-methylidenepiperidine-1,2-dicarboxylate (*R*)-**4d**

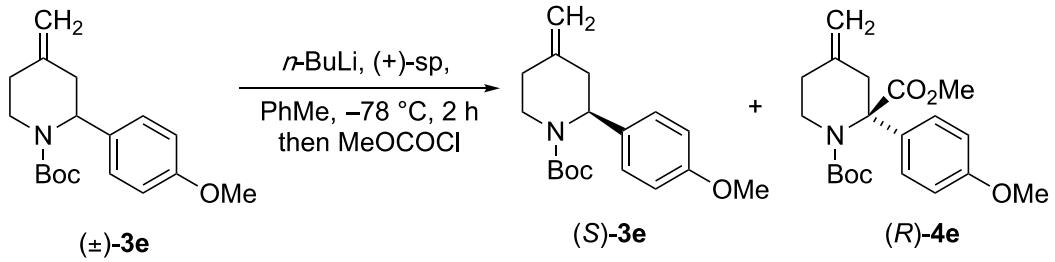



(±)-**3d** (*S*)-**3d** (*R*)-**4d**

*n*-BuLi (0.13 mL, 0.29 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (77 mg, 0.33 mmol) and the racemic alkene **3d** (106 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 1 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (47:3), to give recovered alkene (*S*)-**3d** (40 mg, 38%) as a clear oil; data as above; the enantiomeric ratio was determined to be 95:5 by CSP-HPLC as described above (major component eluted at 9.3 min); $[\alpha]_D^{23}$ –76 (*c* 1.0, $CHCl_3$). In addition, the carbamate (*R*)-**4d** (71 mg, 56%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 82:18 by CSP-HPLC (major component eluted at 10.2 min); $[\alpha]_D^{27}$ +12 (*c* 1.0, $CHCl_3$).

Resolution of alkene **3e** with (+)-sparteine

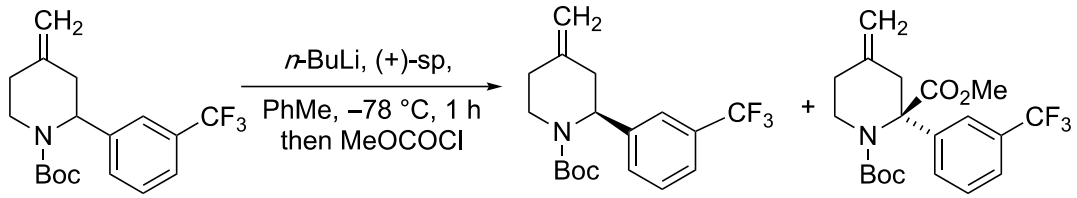
*tert*-Butyl (2*S*)-2-(4-Methoxyphenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3e** and 1-*tert*-Butyl 2-Methyl (2*R*)-2-(4-Methoxyphenyl)-4-methylidenepiperidine-1,2-dicarboxylate (*R*)-**4e**




*n*-BuLi (0.17 mL, 0.37 mmol, 2.2 M in hexanes) was added to a mixture of (+)-sparteine (95 mg, 0.41 mmol) and the racemic alkene **3e** (112 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 2 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (22:3), to give recovered alkene (*S*)-**3e** (35 mg, 31%) as a clear oil; data as above; the enantiomeric ratio was determined to be 96:4 by CSP-HPLC as described above (major component eluted at 12.6 min); $[\alpha]_D^{26}$ –71 (*c* 1.1, $CHCl_3$). In addition, the carbamate (*R*)-**4e** (88 mg, 66%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 70:30 by CSP-HPLC (major component eluted at 18.4 min); $[\alpha]_D^{26}$ +7 (*c* 1.1, $CHCl_3$).

Resolution of alkene **3f** with (+)-sparteine

*tert*-Butyl (2*S*)-4-Methylidene-2-[3-(trifluoromethyl)phenyl]piperidine-1-carboxylate (*S*)-**3f** and 1-*tert*-Butyl 2-Methyl (2*R*)-4-Methylidene-2-[3-(trifluoromethyl)phenyl]piperidine-1,2-dicarboxylate (*R*)-**4f**

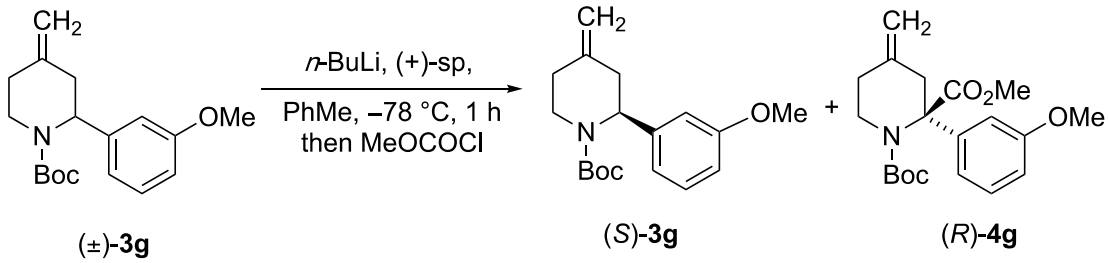



(±)-**3f** (*S*)-**3f** (*R*)-**4f**

*n*-BuLi (0.13 mL, 0.29 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (77 mg, 0.33 mmol) and the racemic alkene **3f** (126 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 1 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), to give recovered alkene (*S*)-**3f** (45 mg, 36%) as a clear oil; data as above; the enantiomeric ratio was determined to be 97:3 by CSP-HPLC as described above (major component eluted at 5.8 min); $[\alpha]_D^{23}$ –65 (*c* 1.1, $CHCl_3$). In addition, the carbamate (*R*)-**4f** (87 mg, 59%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 76:24 by CSP-HPLC (major component eluted at 7.0 min); $[\alpha]_D^{26}$ +5 (*c* 1.0, $CHCl_3$).

Resolution of alkene **3g** with (+)-sparteine

*tert*-Butyl (2*S*)-2-(3-Methoxyphenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3g** and 1-*tert*-Butyl 2-Methyl (2*R*)-2-(3-Methoxyphenyl)-4-methylidenepiperidine-1,2-dicarboxylate (*R*)-**4g**

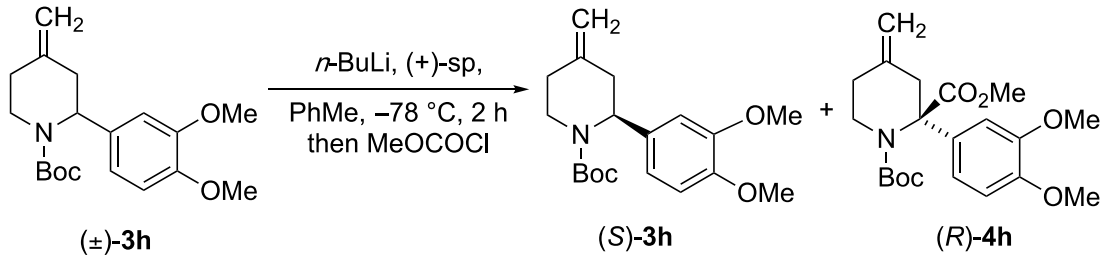



(±)-**3g** (*S*)-**3g** (*R*)-**4g**

*n*-BuLi (0.16 mL, 0.37 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (95 mg, 0.41 mmol) and the racemic alkene **3g** (112 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 1 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), to give recovered alkene (*S*)-**3g** (42 mg, 38%) as a clear oil; data as above; the enantiomeric ratio was determined to be 97:3 by CSP-HPLC as described above (major component eluted at 19.4 min); $[\alpha]_D^{23}$ –72 (*c* 1.0, $CHCl_3$). In addition, the carbamate (*R*)-**4g** (70 mg, 52%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 82:18 by CSP-HPLC (major component eluted at 18.7 min); $[\alpha]_D^{26}$ +16 (*c* 1.0, $CHCl_3$).

Resolution of alkene **3h** with (+)-sparteine

*tert*-Butyl (2*S*)-2-(3,4-Dimethoxyphenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3h** and 1-*tert*-Butyl 2-Methyl (2*R*)-2-(3,4-dimethoxyphenyl)-4-methylidenepiperidine-1,2-dicarboxylate (*R*)-**4h**

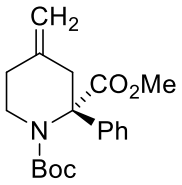



(±)-**3h** (*S*)-**3h** (*R*)-**4h**

*n*-BuLi (0.16 mL, 0.37 mmol, 2.3 M in hexanes) was added to a mixture of (+)-sparteine (95 mg, 0.41 mmol) and the racemic alkene **3h** (123 mg, 0.366 mmol) in dry PhMe (1.5 mL) at –78 °C. After 2 h, MeOCOCl (0.06 mL, 0.7 mmol) was added and the mixture was allowed to warm to rt over 16 h then MeOH (1 mL) was added. The solvent was evaporated, and the residue was purified by column chromatography on silica gel, eluting with petrol–EtOAc (22:3), to give recovered alkene (*S*)-**3h** (35 mg, 28%) as a clear oil; data as above; the enantiomeric ratio was determined to be 85:15 by CSP-HPLC as described above (major component eluted at 8.4 min); $[\alpha]_D^{25}$ –54 (*c* 1.2, $CHCl_3$). In addition, the carbamate (*R*)-**4h** (97 mg, 66%) was isolated as a clear oil, data as above; the enantiomeric ratio was determined to be 66:33 by CSP-HPLC (major component eluted at 10.5 min); $[\alpha]_D^{25}$ +18 (*c* 1.0, $CHCl_3$).

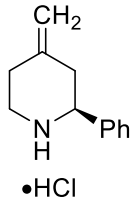
## 2.7 Further functionalization of 3a and (*S*)-3a and (*S*)-3b

1-*tert*-Butyl 2-Methyl (2*S*)-4-Methylidene-2-phenylpiperidine-1,2-dicarboxylate (*S*)-**4a**




Using general procedure D, *n*-BuLi (0.09 mL, 0.22 mmol, 2.4 M in hexanes) and alkene (*S*)-**3a** (50 mg, 0.18 mmol, er 99:1) in THF (0.75 mL) at –78 °C and MeOCOCl (0.05 mL, 0.6 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave carbamate (*S*)-**4a** (47 mg, 77%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC (major component eluted at 12.5 min); $[\alpha]_D^{23}$ –18 (*c* 1.0, $CHCl_3$).

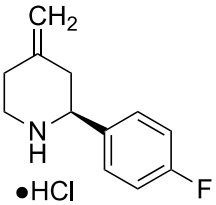
(2*S*)-4-Methylidene-2-phenylpiperidine hydrochloride (*S*)-**10**




HCl (1.3 mL, 5.1 mmol, 4 M in dioxane) was added to alkene (*S*)-**3a** (139 mg, 0.508 mmol, er 99:1) in $CH_2Cl_2$ (5 mL) at 0 °C then the mixture was warmed to rt. After 16 h, the solvent was evaporated and the oily residue and was suspended in $Et_2O$. The solvent was evaporated to give hydrochloride salt (*S*)-**10** (98 mg, 92%) as an amorphous off-white solid; mp 174–176 °C [$Et_2O$] (no lit. mp reported); $R_f$ 0.01 [petrol−EtOAc (1:1)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1654 (C=C): $^1$H NMR (DMSO-$d^6$, 400 MHz) δ = 10.14 (br s, 1H), 9.50 (br s, 1H), 7.77–7.59 (m, 2H), 7.50–

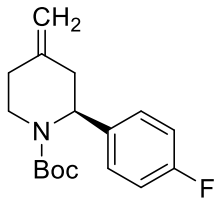
7.36 (m, 3H), 5.02–4.88 (m, 2H), 4.30–4.14 (m, 1H), 3.44–3.28 (m, 1H), 3.07–2.91 (m, 1H), 2.83–2.67 (m, 2H), 2.66–2.37 (m, 2H); $^{13}$C{1H} NMR (DMSO-d$^6$, 100 MHz) δ = 141.5, 137.6, 129.4, 129.2, 128.1, 112.3, 60.6, 45.4, 38.9, 30.0; HRMS (ESI-TOF) *m/z*: [M+H]$^+$ Calcd for $C_{12}H_{16}N$ 174.1284; Found 174.1284; LRMS *m/z* (ES) 174 (100%, MH$^+$); $[\alpha]_D^{23}$ +68 (*c* 1.0, MeOH).

(2*S*)-4-Methylidene-2-(4-fluorophenyl)piperidine hydrochloride (*S*)-**11**




HCl (12 mL, 47 mmol, 4 M in dioxane) was added to alkene (*S*)-**3b** (1.3 mg, 4.5 mmol, er 94:6) in $CH_2Cl_2$ (45 mL) at 0 °C then the mixture was warmed to rt. After 16 h, the solvent was evaporated and the oily residue and was suspended in $Et_2O$. The solvent was evaporated to give the crude product. The crude product was recrystallized from EtOH–$Et_2O$ to give hydrochloride salt (*S*)-**11** (0.67 g, 67%) as an amorphous white solid; mp 206–208 °C [EtOH–$Et_2O$]; $R_f$ 0.01 [petrol−EtOAc (1:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1655 (C=C): $^1$H NMR (DMSO-d$^6$, 400 MHz) δ = 10.15 (br s, 1H), 9.49 (br s, 1H), 7.81–7.69 (m, 2H), 7.36–7.20 (m, 2H), 5.00–4.88 (m, 2H), 4.34–4.14 (m, 1H), 3.46–3.29 (m, 1H), 3.08–2.84 (m, 1H), 2.81–2.65 (m, 2H), 2.61–2.39 (m, 2H); $^{13}$C{1H} NMR (DMSO-d$^6$, 100 MHz) δ = 162.7 (d, *J* = 245.5 Hz), 141.4, 133.9 (d, *J* = 3.0 Hz), 130.6 (d, *J* = 8.5 Hz), 116.0 (d, *J* = 21.5 Hz), 112.3, 59.8, 45.3, 38.7, 29.9; $^{19}$F NMR (377 MHz, DMSO-d$^6$) δ = −112.86; HRMS (ESI-TOF) *m/z*: [M+H]$^+$ Calcd for $C_{12}H_{14}FN$ 192.1183; Found 192.1174; LRMS *m/z* (ES) 192 (100%, MH$^+$).

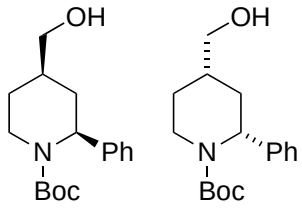
*tert*-Butyl (2*S*)-2-(4-fluorophenyl)-4-methylidenepiperidine-1-carboxylate (*S*)-**3b**




To a solution of hydrochloride salt (*S*)-**11** (72 mg, 0.32 mmol) in $CH_2Cl_2$ (2 mL) at 0 °C was added $Et_3N$ (0.13 mL, 0.95 mmol) followed by $Boc_2O$ (0.10 g, 0.47 mmol). After 30 min, the mixture was warmed to rt and was stirred for 16 h. The solvent was evaporated to give the crude product. Purification by column chromatography on silica gel, eluting with *n*-hexane−EtOAc (9:1), gave carbamate (*S*)-**3b** (82 mg, 89%) as an oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC (major component eluted at 6.9 min* on an Agilent system fitted with a Chiralcel OX-H column); $[\alpha]_D^{25}$ −65 (0.6, $CHCl_3$).

*HPLC retention times for enantiomers were different when compared to original racemic compound (see above). A new HPLC for the racemic compound was run at the same time which gave the retention times 6.1 min and 6.9 min.

(±)-*cis*-*tert*-Butyl 4-(Hydroxymethyl)-2-phenylpiperidine-1-carboxylate **12**

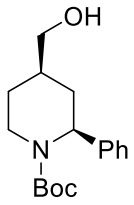



$BH_3$•THF complex solution (2.2 mL, 2.2 mmol, 1 M in THF) was added to alkene **3a** (100 mg, 0.366 mmol) at 0 °C. The mixture was warmed (stirrer hotplate and drysyn block) to 35 °C and stirred for 2 h. After cooling to 0 °C, aq NaOH (0.74 mL, 1.5 mmol, 2 M) was added followed

by $H_2O_2$ (0.41 mL, 3.5 mmol, 30% w/w). The mixture was warmed to 35 °C and stirred for 1 h. After cooling to rt, the mixture was diluted with water (60 mL) and EtOAc (60 mL). The aqueous layer was adjusted to pH 7 using aq HCl (2 M) and the organic layer was separated, dried over anhydrous $MgSO_4$, filtered and concentrated under reduced pressure to give the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$–MeOH (47:3), gave alcohol **12** (70 mg, 65%) as a clear oil; $R_f$ 0.29 [$CH_2Cl_2$–MeOH (47:3)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 3400 (O-H), 1691 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.39–7.30 (m, 2H), 7.26–7.20 (m, 3H), 4.98–4.85 (m, 1H), 4.13–4.02 (m, 1H), 3.57–3.35 (m, 1H), 3.33–3.23 (m, 1H), 2.18–2.10 (m, 1H), 2.05–1.91 (m, 2H), 1.78–1.65 (m, 1H), 1.53–1.38 (m, 2H), 1.32 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.8, 144.4, 128.4, 126.5, 125.1, 79.6, 66.4, 56.3, 38.0, 34.2, 32.9, 28.3, 25.4; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{17}H_{25}NO_3Na$ 314.1727; Found 314.1742; LRMS *m/z* (ES) 236 (75%), 314 (100%, $MNa^+$). Data as reported.[5]

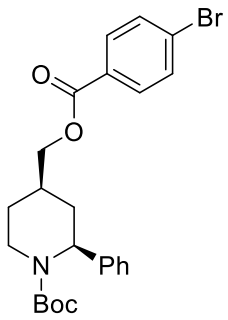
Resolution between the enantiomers of alcohol **12** was achieved using a Beckman system fitted with a Phenomenex Cellulose-1 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (9:1 v/v) as the mobile phase at a flow rate of 1 $mL \cdot min^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 $g \cdot L^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 16.9 min and 26.6 min.

*tert*-Butyl (2*S*,4*R*)-4-(Hydroxymethyl)-2-phenylpiperidine-1-carboxylate (2*S*,4*R*)-**12**



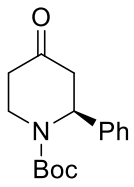

$BH_3$•THF complex solution (2.2 mL, 2.2 mmol, 1 M in THF) was added to alkene (*S*)-**3a** (100 mg, 0.366 mmol, er 99:1) at 0 °C. The mixture was warmed (stirrer hotplate and drysyn block) to 35 °C and stirred for 1 h. After cooling to 0 °C, aq NaOH (0.74 mL, 1.5 mmol, 2 M) was added followed by $H_2O_2$ (0.41 mL, 4.4 mmol, 30% w/w). The mixture was warmed to 35 °C and stirred for 1 h. After cooling to rt, the mixture was diluted with water (30 mL) and EtOAc (60 mL). The aqueous layer was adjusted to pH 7 using aq HCl (2M) and the organic layer was separated, dried over anhydrous $MgSO_4$, filtered and concentrated under reduced pressure to give the crude product. Purification by column chromatography on silica gel, eluting with $CH_2Cl_2$−MeOH (19:1), gave alcohol (2*S*,4*R*)-**12** (71 mg, 67%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC (major component eluted at 17.0 min); $[\alpha]_D^{23}$ −62 (*c* 1.0, $CHCl_3$).

*tert*-Butyl (2*S*,4*R*)-4-{[(4-Bromobenzoyl)oxy]methyl}-2-phenylpiperidine-1-carboxylate (2*S*,4*R*)-**13**



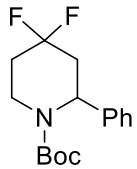

$Et_3N$ (0.15 mL, 1.1. mmol) was added to alcohol (2*S*,4*R*)-**12** (70 mg, 0.24 mmol, er 99:1) and DMAP (2 mg, 0.01 mmol) in $CH_2Cl_2$ (0.5 mL) at 0 °C, followed by 4-bromobenzoyl chloride (116 mg, 0.528 mmol) in $CH_2Cl_2$ (0.23 mL). The mixture was warmed to rt over 16 h and the solvent was evaporated to give the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave ester (2*S*,4*R*)-**13** (83 mg, 73%) as a white amorphous solid; mp 94–96 °C [petrol–EtOAc]; $R_f$ 0.38 [petrol–EtOAc (7:3)]; FT-IR $\nu_{max}$ (film)/$cm^{-1}$ 1720 (C=O), 1687 (C=O); $^1H$ NMR ($CDCl_3$, 400 MHz) δ = 7.88 (d, 2H, *J* = 8.5 Hz), 7.60 (d, 2H, *J* = 8.5 Hz), 7.36–7.30 (m, 2H), 7.26–7.20 (m, 3H), 5.01–4.90 (m, 1H), 4.23–4.06 (m, 3H), 3.42–3.27 (m, 1H), 2.34–2.01 (m, 3H), 1.90–1.75 (m, 1H), 1.56–1.45 (m, 1H), 1.33 (s, 9H); $^{13}C\{1H\}$ NMR ($CDCl_3$, 100 MHz) δ = 165.7, 155.7, 143.9, 131.8, 131.1, 129.0, 128.5, 128.2, 126.7, 125.2, 79.8, 68.1, 56.1, 37.8, 33.0, 31.2, 28.3, 25.7; HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{24}H_{28}{}^{79}BrNO_4Na$ 496.1094; Found 496.1115; LRMS *m/z* (ES) 496 (100%, $MNa^+$ for $^{79}Br$), 497 (20%), 498 (100%, $MNa^+$ for $^{81}Br$), 499 (20%); $[\alpha]_D^{23}$ −16 (*c* 1.0, $CHCl_3$).

*tert*-Butyl (2*S*)-4-Oxo-2-phenylpiperidine-1-carboxylate (*S*)-**2a**




Ozone was bubbled through a solution of alkene (*S*)-**3a** (300 mg, 1.10 mmol, er 99:1) in $CH_2Cl_2$ (99 mL) and MeOH (11 mL) at –78 °C for 1 h. $Me_2S$ (1.6 mL, 22 mmol) was added dropwise and the mixture was warmed to rt over 16 h. The solvent was evaporated to give the crude product. Purification by column chromatography on silica gel, eluting with petrol−EtOAc (15:5), gave piperidone (*S*)-**2a** (275 mg, 91%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC (major component eluted at 12.0 min); $[\alpha]_D^{23}$ –71 (*c* 1.0, $CHCl_3$), lit.[14] $[\alpha]_D^{20}$ –68.2 (*c* 1.95, $CHCl_3$).

*tert*-Butyl 4,4-Difluoro-2-phenylpiperidine-1-carboxylate **14**

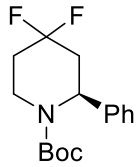



$Et_2NSF_3$ (1.5 ml, 11 mmol) was added to piperidone **2a** (1.0 g, 3.6 mmol) in $CH_2Cl_2$ (6 mL) at 0 °C. After 4 h, the mixture was warmed to rt and stirred for 16 h. The mixture was cooled to 0 °C and carefully quenched with saturated aq $NaHCO_3$. The mixture was diluted with water (50 mL) and $CH_2Cl_2$ (100 mL). The organic layer was separated, dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give the crude product. Purification by column

chromatography on silica gel, eluting with petrol–EtOAc (19:1), gave difluoride **14** (0.69 g, 64%) as a clear oil; $R_f$ 0.43 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1693 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.43–7.33 (m, 2H), 7.32–7.22 (m, 3H), 5.63 (br d, 1H, *J* = 6.0 Hz), 4.34–4.19 (m, 1H), 3.20–3.01 (m, 1H), 2.90–2.73 (m, 1H), 2.42–2.21 (m, 1H), 2.09–1.85 (m, 2H), 1.48 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz) δ = 155.0, 139.0, 128.5, 126.9, 125.8, 121.8 (t, *J* = 242.5 Hz), 80.7, 52.4 (d, *J* = 9.5 Hz), 37.1 (d, *J* = 9.5 Hz), 35.8 (t, *J* = 23.0 Hz), 34.0 (t, *J* = 23.5 Hz), 28.3; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −87.60 (d, *J* = 238.5 Hz), −96.15 (d, *J* = 238.5 Hz); HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{16}H_{21}F_2NO_2Na$ 320.1433; Found 320.1442; LRMS *m/z* (ES) 198 (20%), 222 (20%), 242 (100%), 320 (20%, $MNa^+$).

Resolution between the enantiomers of difluoride **14** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 6.0 min and 6.9 min.

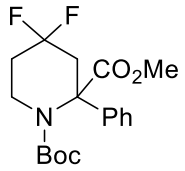
*tert*-Butyl (2*S*)-4,4-Difluoro-2-phenylpiperidine-1-carboxylate (*S*)-**14**




$Et_2NSF_3$ (1.5 ml, 11 mmol) was added to piperidone (*S*)-**2a** (275 mg, 0.998 mmol, er 99:1) in $CH_2Cl_2$ (1.7 mL) at 0 °C. After 2 h, the mixture was warmed to rt and stirred for 16 h. The mixture was cooled to 0 °C and carefully quenched with saturated aq $NaHCO_3$. The mixture

was diluted with water (40 mL) and $CH_2Cl_2$ (60 mL). The organic layer was separated, dried over anhydrous $MgSO_4$, filtered and the solvent was evaporated to give the crude product. Purification by column chromatography on silica gel, eluting with petrol–EtOAc (9:1), gave difluoride (*S*)-**14** (256 mg, 86%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC (major component eluted at 6.8 min); $[\alpha]_D^{22}$ –71 (*c* 1.0, $CHCl_3$).

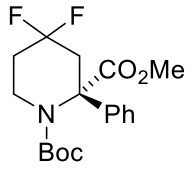
1-*tert*-Butyl 2-Methyl 4,4-Difluoro-2-phenylpiperidine-1,2-dicarboxylate **15**




Using general procedure D, *n*-BuLi (0.22 mL, 0.44 mmol, 2.0 M in hexanes) and difluoride **14** (110 mg, 0.366 mmol) in THF (1.5 mL) at –40 °C and MeOCOCl (0.1 mL, 1.28 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (9:1). gave carbamate **15** (100 mg, 76%) as a clear oil; $R_f$ 0.52 [petrol–EtOAc (4:1)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 1747 (C=O), 1699 (C=O); $^1$H NMR ($CDCl_3$, 400 MHz) δ = 7.50–7.18 (m, 5H), 4.03–3.88 (m, 1H), 3.74 (s, 3H), 3.68–3.52 (m, 1H), 2.94–2.70 (m, 2H), 2.20–1.95 (m, 2H), 1.35 (s, 9H); $^{13}$C{1H} NMR ($CDCl_3$, 100 MHz, one quaternary carbon signal not observed) δ = 171.2, 155.9, 128.1, 127.5, 126.8, 121.13 (t, *J* = 243.0 Hz), 81.6, 66.9, 52.7, 41.9, 40.35 (t, *J* = 5.0 Hz), 33.5 (t, *J* = 24.0 Hz), 28.0; $^{19}$F NMR ($CDCl_3$, 377 MHz) δ = −90.81 (br), −92.86 (d, *J* = 236.5 Hz); HRMS (ESI-TOF) *m/z*: $[M+Na]^+$ Calcd for $C_{18}H_{23}F_2NO_4Na$ 378.1487; Found 378.1506; LRMS *m/z* (ES) 256 (100%), 378 (60%, $MNa^+$).

Resolution between the enantiomers of carbamate **15** was achieved using a Beckman system fitted with a Phenomenex Cellulose-2 column (250 mm × 4.60 mm i.d.) as the stationary phase with a mixture of *n*-hexane:isopropanol (99:1 v/v) as the mobile phase at a flow rate of 1 mL·min$^{-1}$; ambient temperature, detection by UV absorbance at 210 nm. Injection volume was 10 μL of the sample prepared in a 2 g·L$^{-1}$ solution of the eluent. Under these conditions, the components were eluted at 9.3 min and 12.2 min.

1-*tert*-Butyl 2-Methyl (2*S*)-4-Oxo-2-phenylpiperidine-1,2-dicarboxylate (*S*)-**15**




Using general procedure D, *n*-BuLi (0.10 mL, 0.24 mmol, 2.4 M in hexanes) and (*S*)-**14** (60 mg, 0.20 mmol, er 99:1) in THF (0.8 mL) at –78 °C and MeOCOCl (0.05 mL, 0.7 mmol) gave the crude product. Purification by column chromatography on silica gel, eluting with pentane–EtOAc (9:1), gave carbamate (*S*)-**15** (45 mg, 63%) as a clear oil; data as above; the enantiomeric ratio was determined to be 99:1 by CSP-HPLC (major component eluted at 12.1 min); $[\alpha]_D^{22}$ –12 (*c* 1.0, $CHCl_3$).

## 3. References

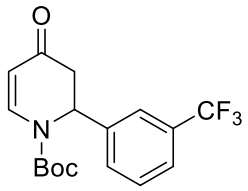

1. Bruker (2017) Apex3 v2017.3-0. Bruker AXS Inc., Madison, Wisconsin, USA.
2. L. Krause, R. Herbst-Irmer, G. M. Sheldrick, D. Stalke, J. Appl. Cryst., 2015, 48, 3.
3. G. M. Sheldrick, Acta Cryst., 2015, A71, 3.
4. G. M. Sheldrick, Acta Cryst., 2015, C71, 3.
5. O.V. Dolomanov, L. J. Bourhis, R. J. Gildea, J. A. K. Howard, H. Puschmann, J. Appl. Cryst., 2009, 42, 339.
6. A. D. Becke, J. Chem. Phys. 1993, 98, 5648.
7. M. J. Frisch, G. W. Trucks, H. B. Schlegel, G. E. Scuseria, M. A. Robb, J. R. Cheeseman, G. Scalmani, V. Barone, B. Mennucci, G. A. Petersson, H. Nakatsuji, M. Caricato, X. Li, H. P. Hratchian, A. F. Izmaylov, J. Bloino, G. Zheng, J. L. Sonnenberg, M. Hada, M. Ehara, K. Toyota, R. Fukuda, J. Hasegawa, M. Ishida, T. Nakajima, Y. Honda, O. Kitao, H. Nakai, T. Vreven, J. A. Montgomery Jr, J. E. Peralta, F. Ogliaro, M. Bearpark, J. J. Heyd, E. Brothers, K. N. Kudin, V. N. Staroverov, R. Kobayashi, J. Normand, K. Raghavachari, A. Rendell, J. C. Burant, S. S. Iyengar, J. Tomasi, M. Cossi, N. Rega, J. M. Millam, M. Klene, J. E. Knox, J. B. Cross, V. Bakken, C. Adamo, J. Jaramillo, R. Gomperts, R. E. Stratmann, O. Yazyev, A. J. Austin, R. Cammi, C. Pomelli, J. W. Ochterski, R. L. Martin, K. Morokuma, V. G. Zakrzewski, G. A. Voth, P. Salvador, J. J. Dannenberg, S. Dapprich, A. D. Daniels, Ö. Farkas, J. B. Foresman, J. V. Ortiz, J. Cioslowski, D. J. Fox, Gaussian 09, Revision D.01, Gaussian, Inc., Wallingford CT, 2009.
8. S. Grimme, S. Ehrlich, L. Goerigk, J. Comput. Chem. 2011, 32, 1456.
9. F. Weigend, R. Ahlrichs, Phys. Chem. Chem. Phys., 2005, 7, 3297.
10. a) G. Scalmani, M. J. Frisch, J. Chem. Phys. 2010, 132, 114110; b) M. Cossi, N. Rega, G. Scalmani, V. Barone, J. Comput. Chem. 2003, 24, 669 and references therein.
11. Guo, F.; Dhakal, R. C.; Dieter, R. K. *J. Org. Chem.* **2013**, *78*, 8451.
12. Li, H.; Wu, J. *Org. Lett.* **2015**, *17*, 5424.

13. Guo, F.; McGilvary, M.A.; Jeffries, M.C.; Graves, B.N.; Graham, S.A.; Wu, Y. *Molecules* **2017**, *22*, 723.

14. Xu, Q.; Zhang, R.; Zhang, T.; Shi, M. *J. Org. Chem.* **2010**, *75*, 3935.

15. Rice, K. Patent WO 2012071509 A2.

## 4. $^{1}H$, $^{19}F$ and $^{13}C\{1H\}$ NMR spectra

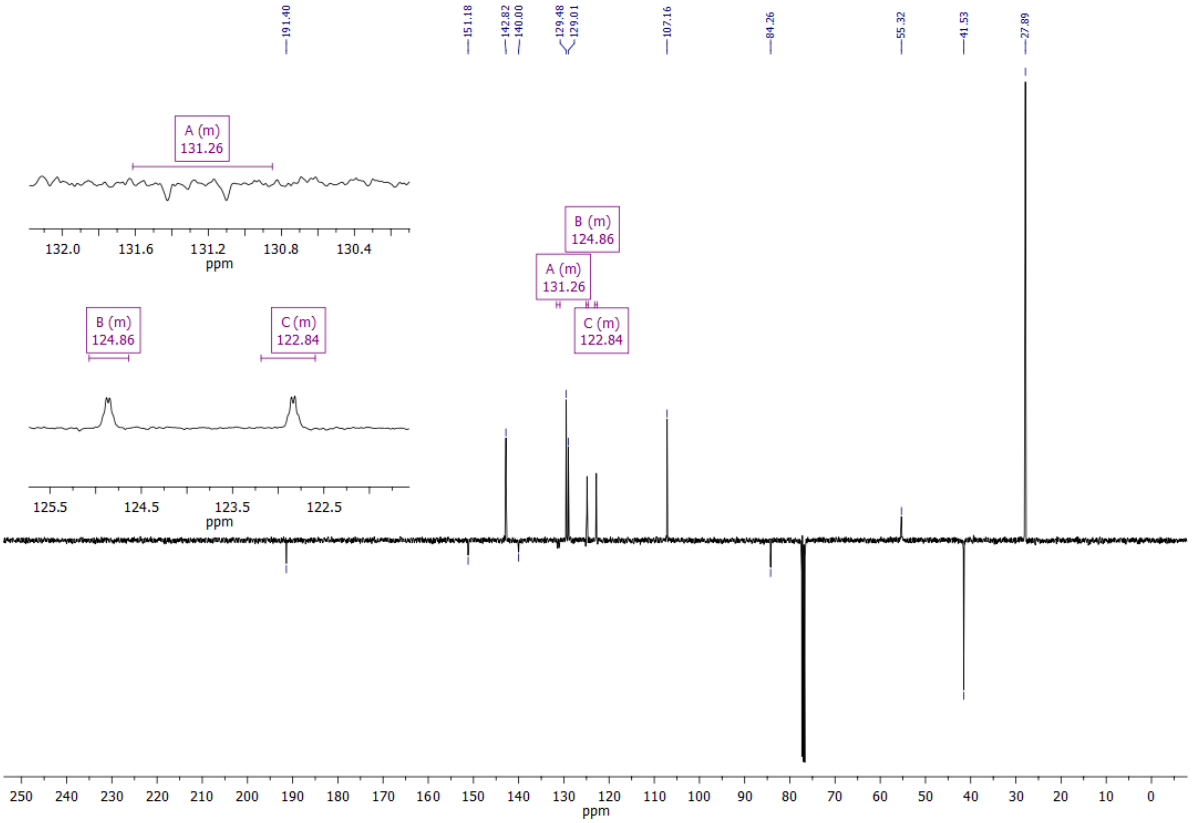



**1f**

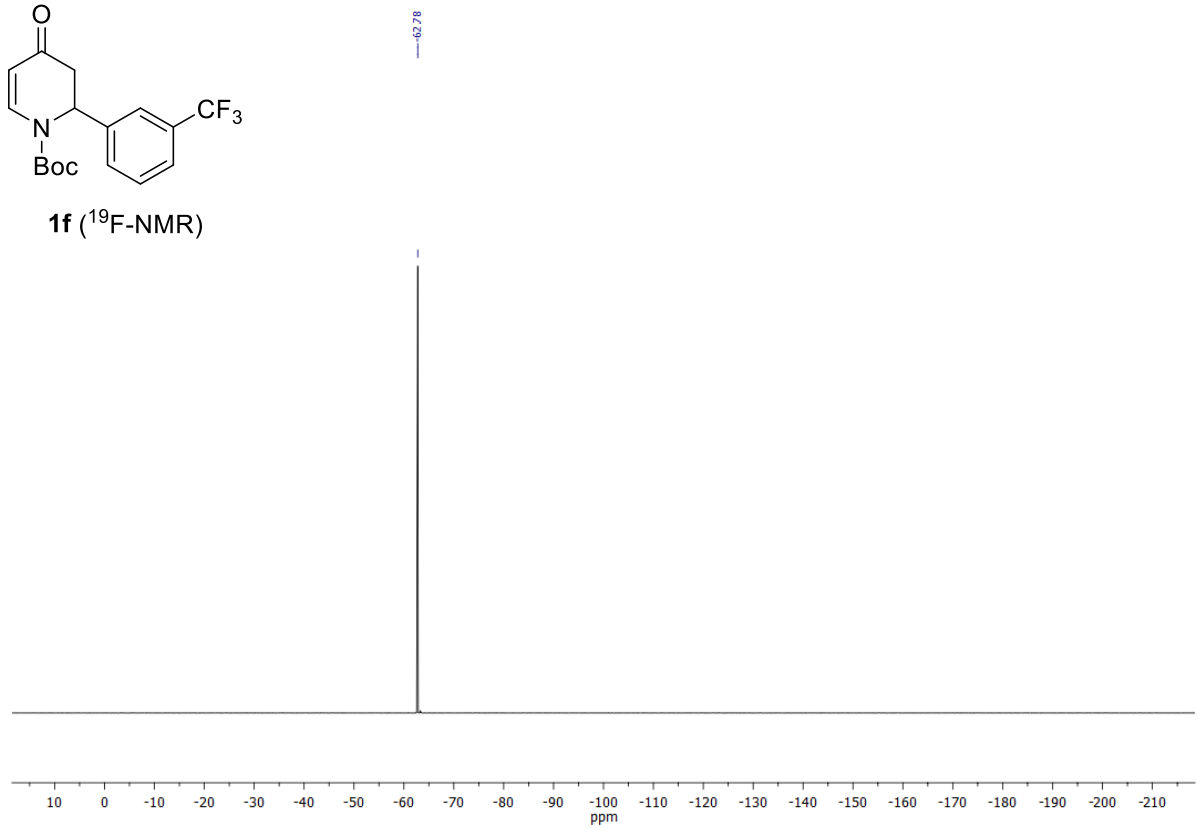
$^{1}H$ NMR spectrum ($CDCl_3$, 400 MHz):



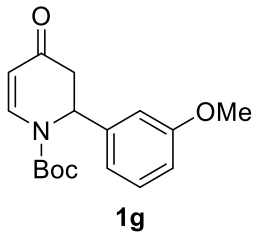

$^{13}C\{1H\}$ NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):




**1f** ($^{19}$F-NMR)

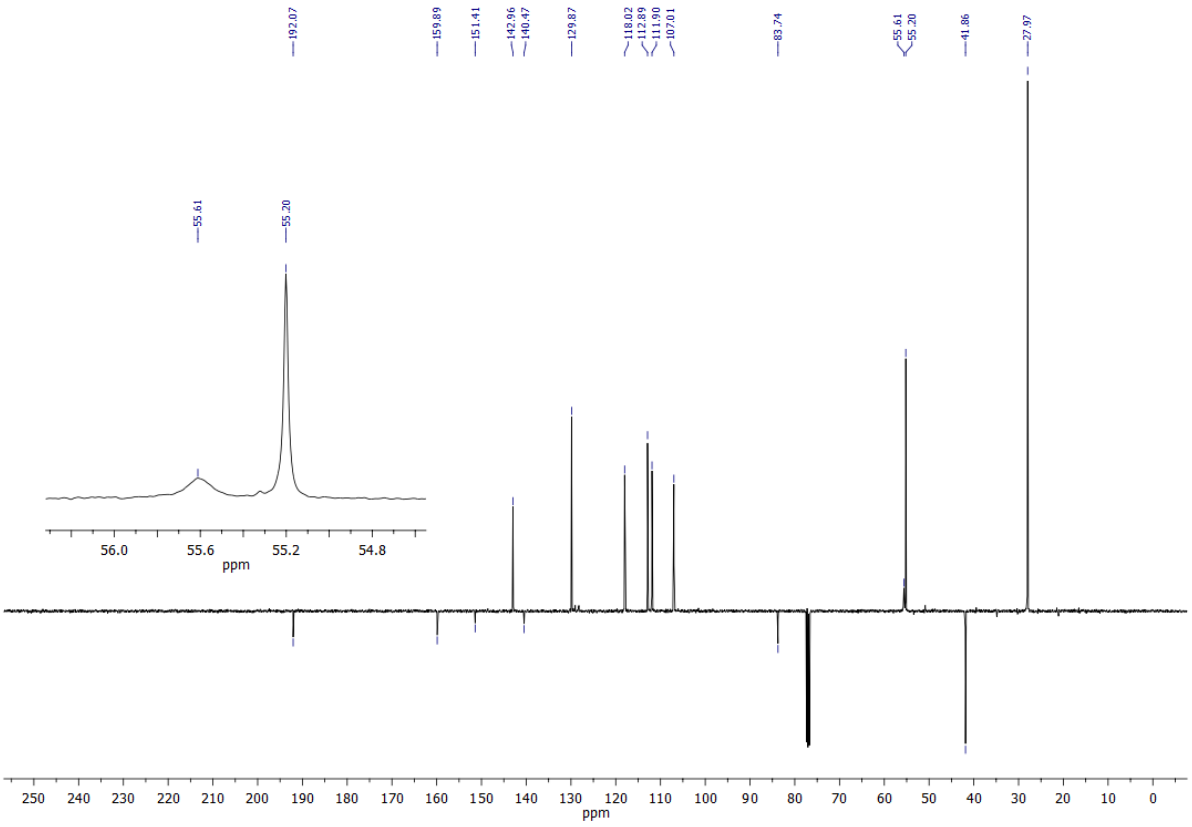


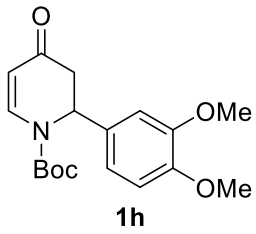

**1g**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



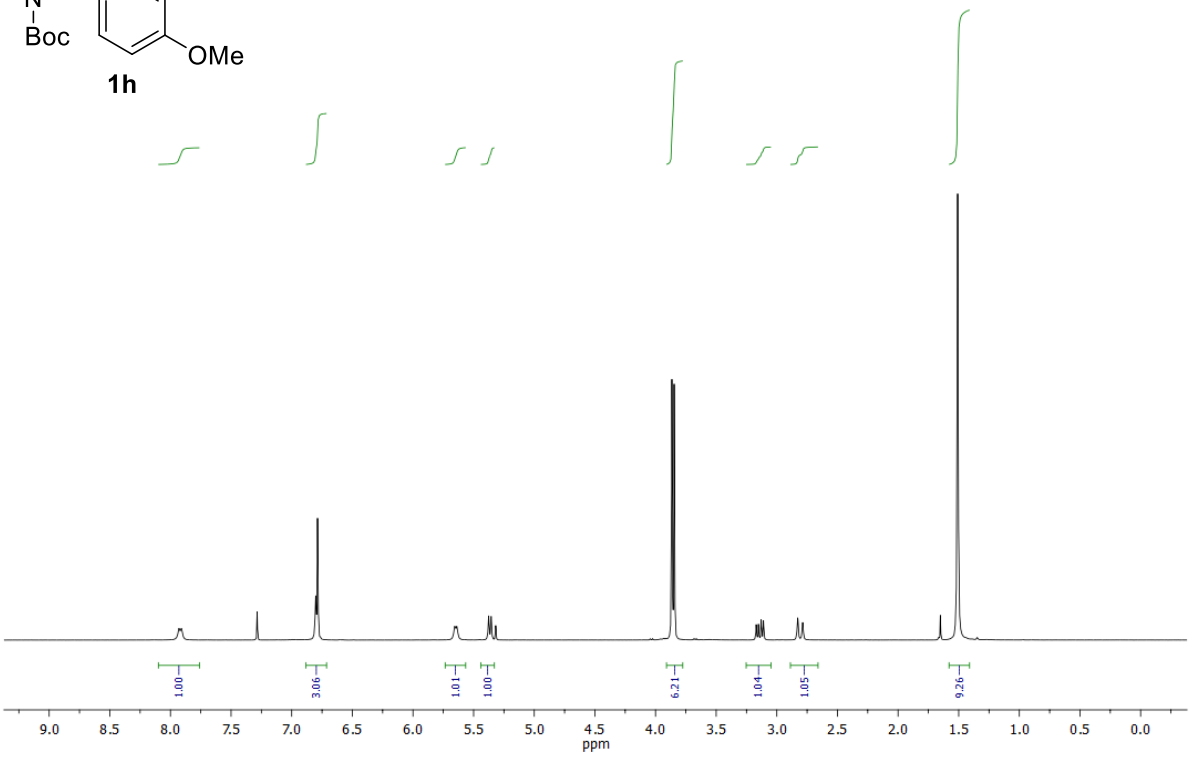

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



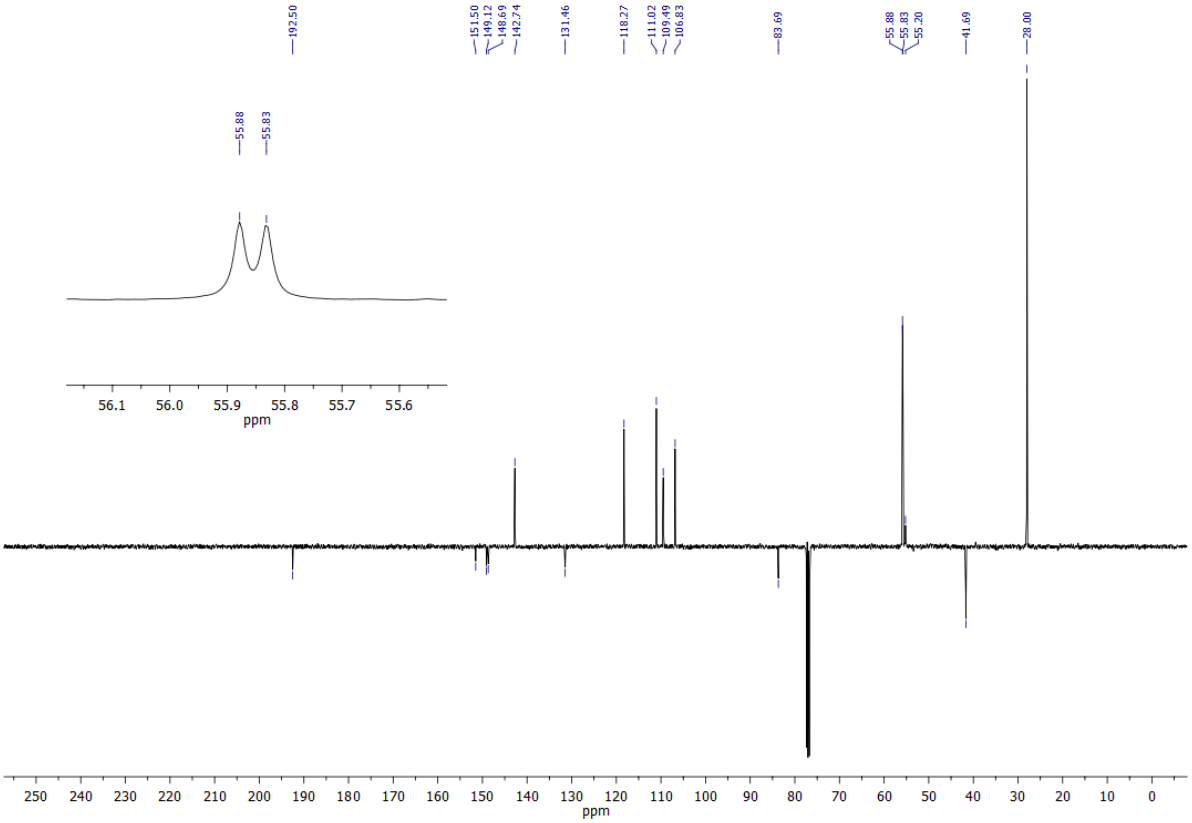


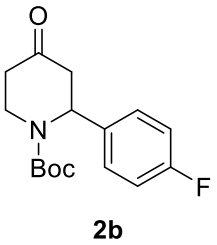

**1h**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



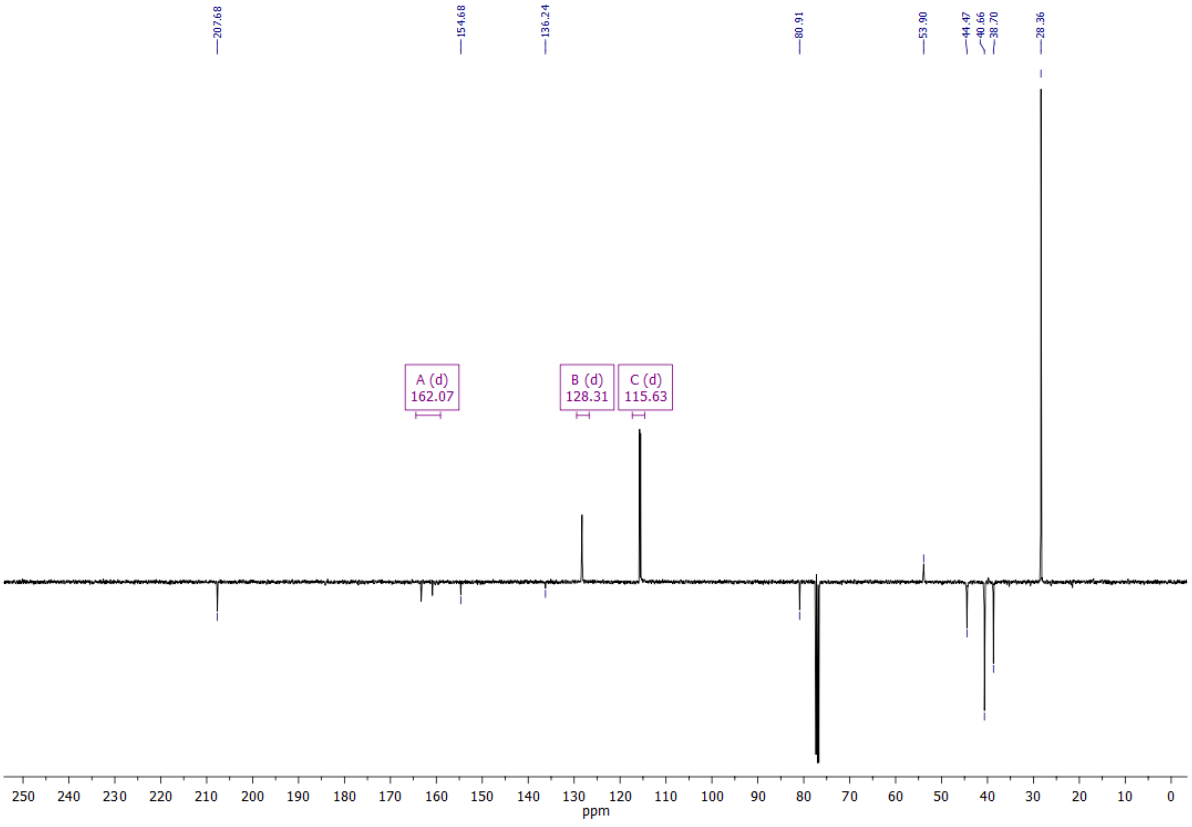



**2b**

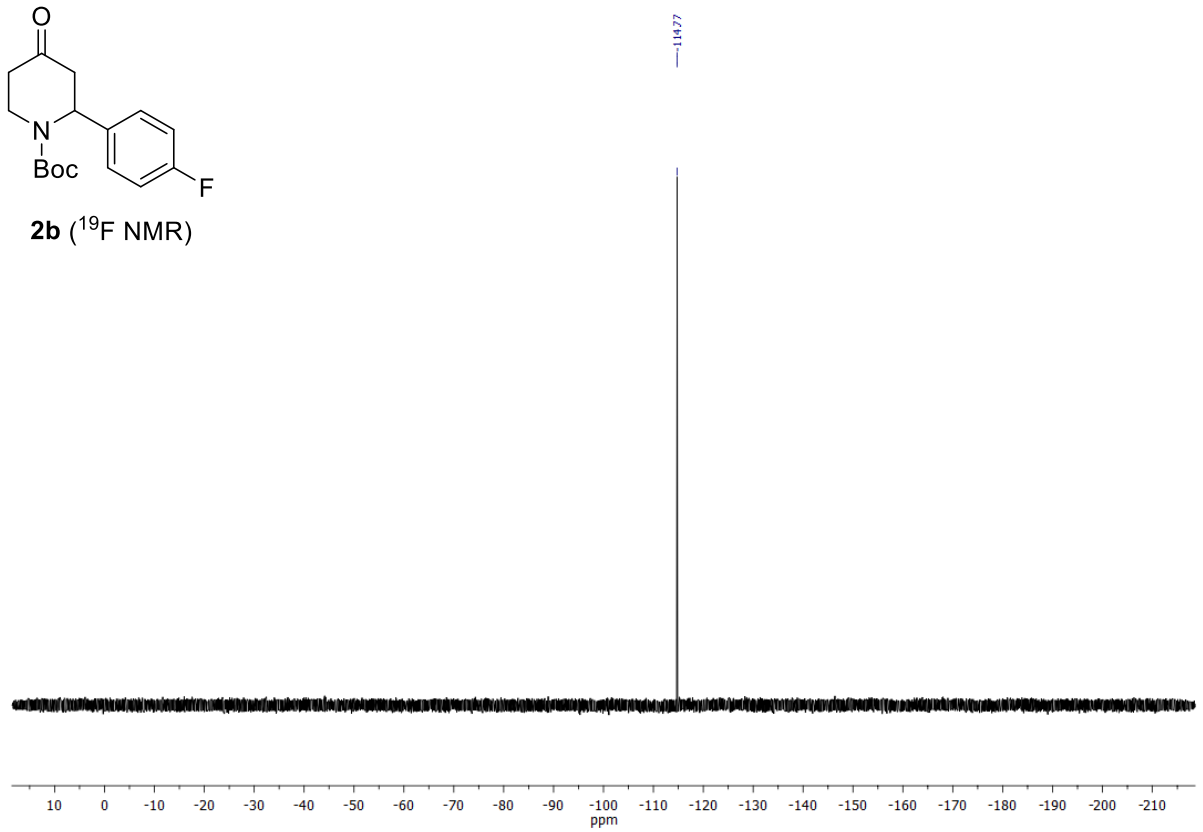
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



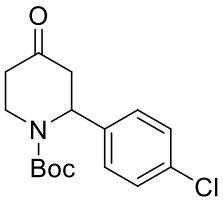

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}F$ NMR spectrum ($CDCl_3$, 377 MHz):




**2b** ($^{19}F$ NMR)

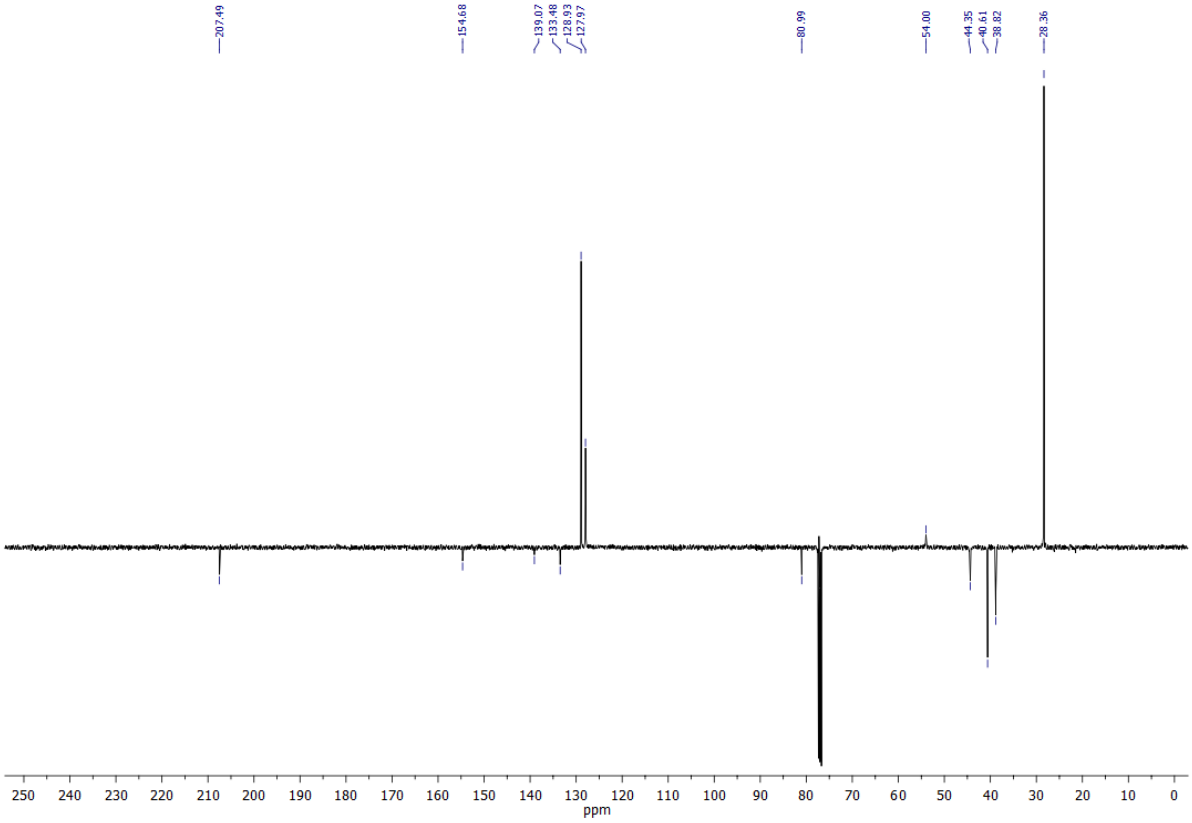


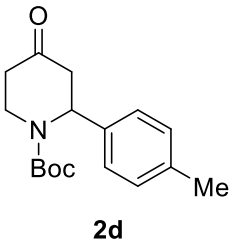

**2c**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



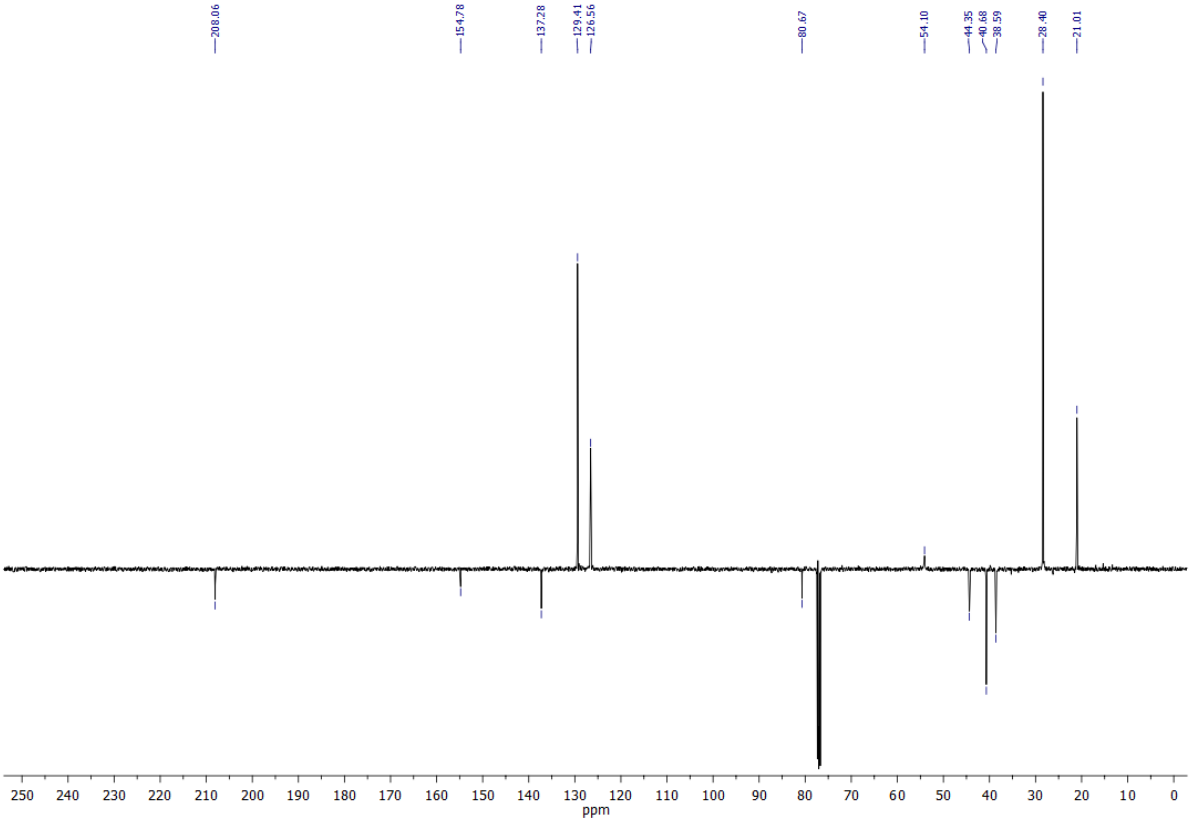


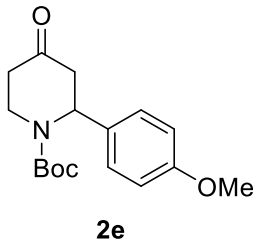

**2d**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



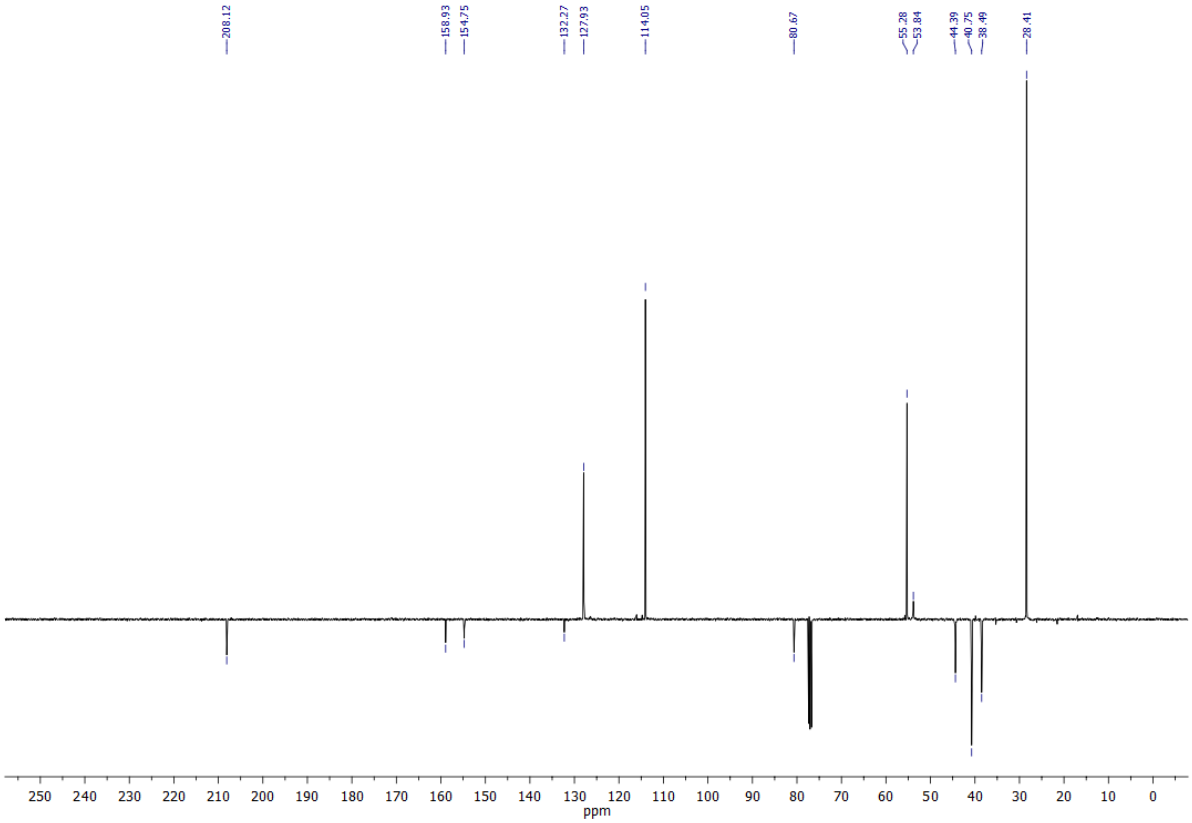


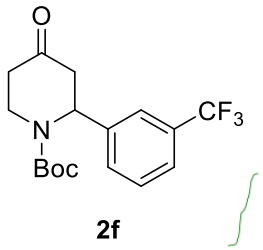

**2e**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



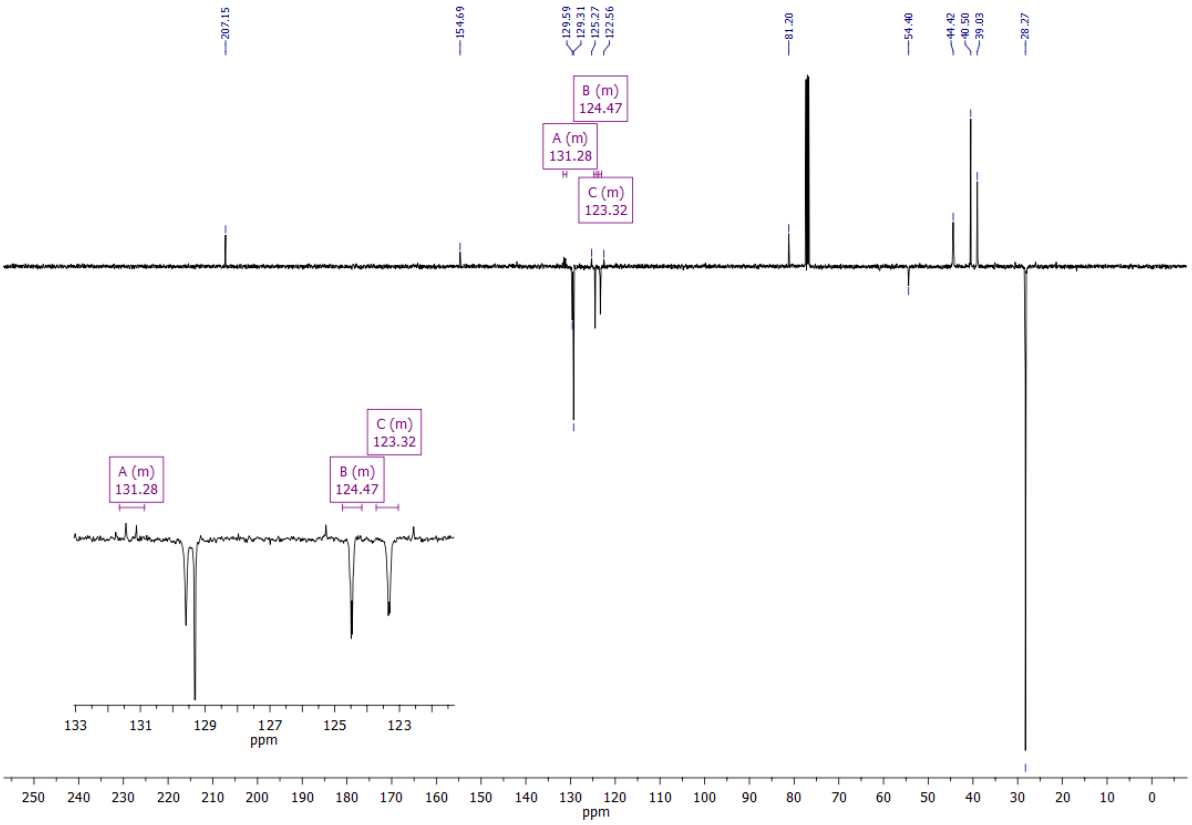



**2f**

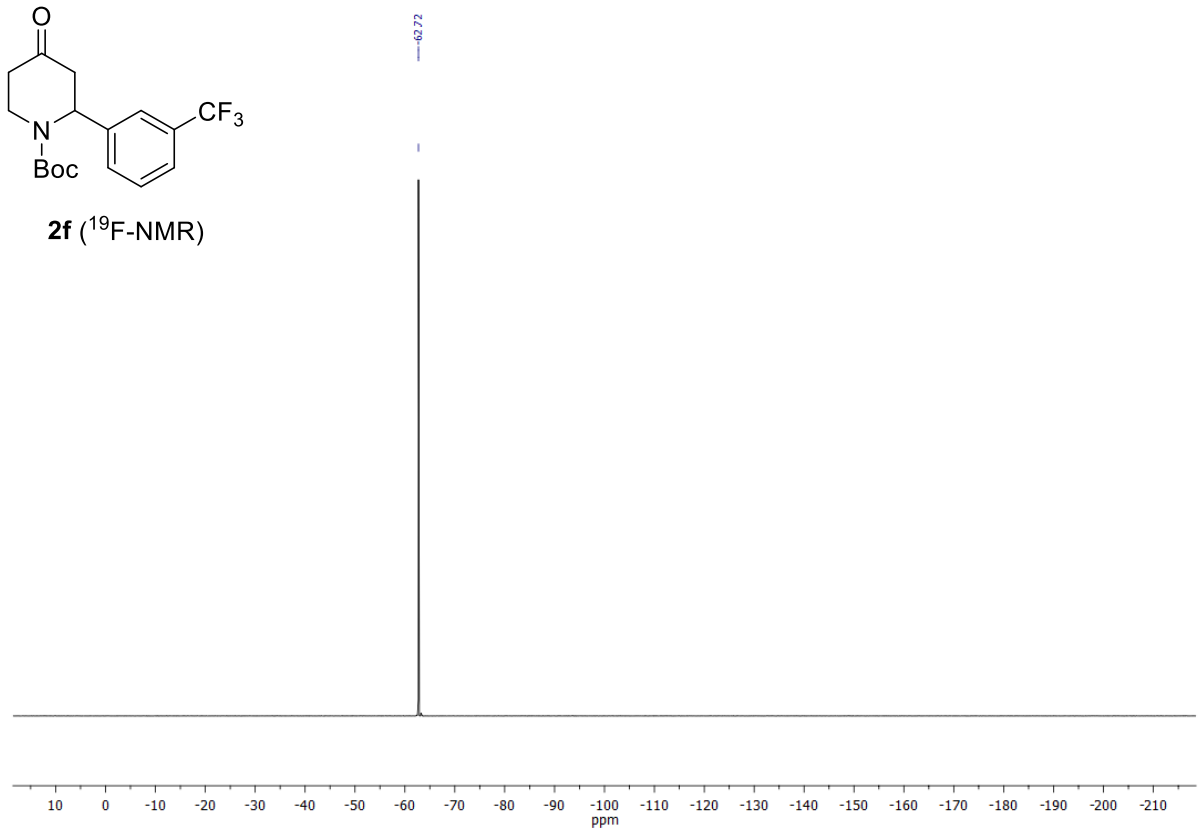
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



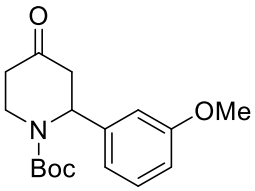

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):




**2f** ($^{19}$F-NMR)

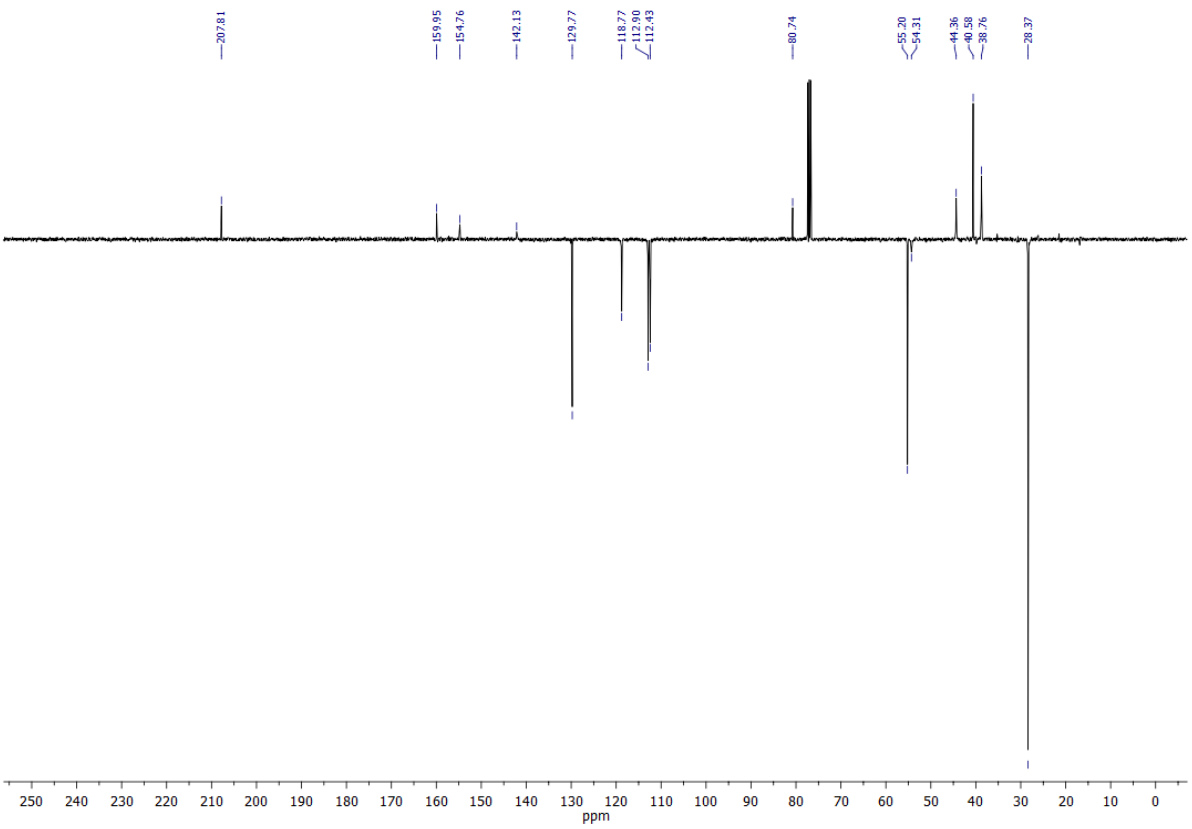


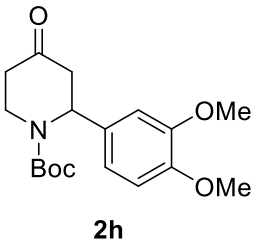

**2g**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



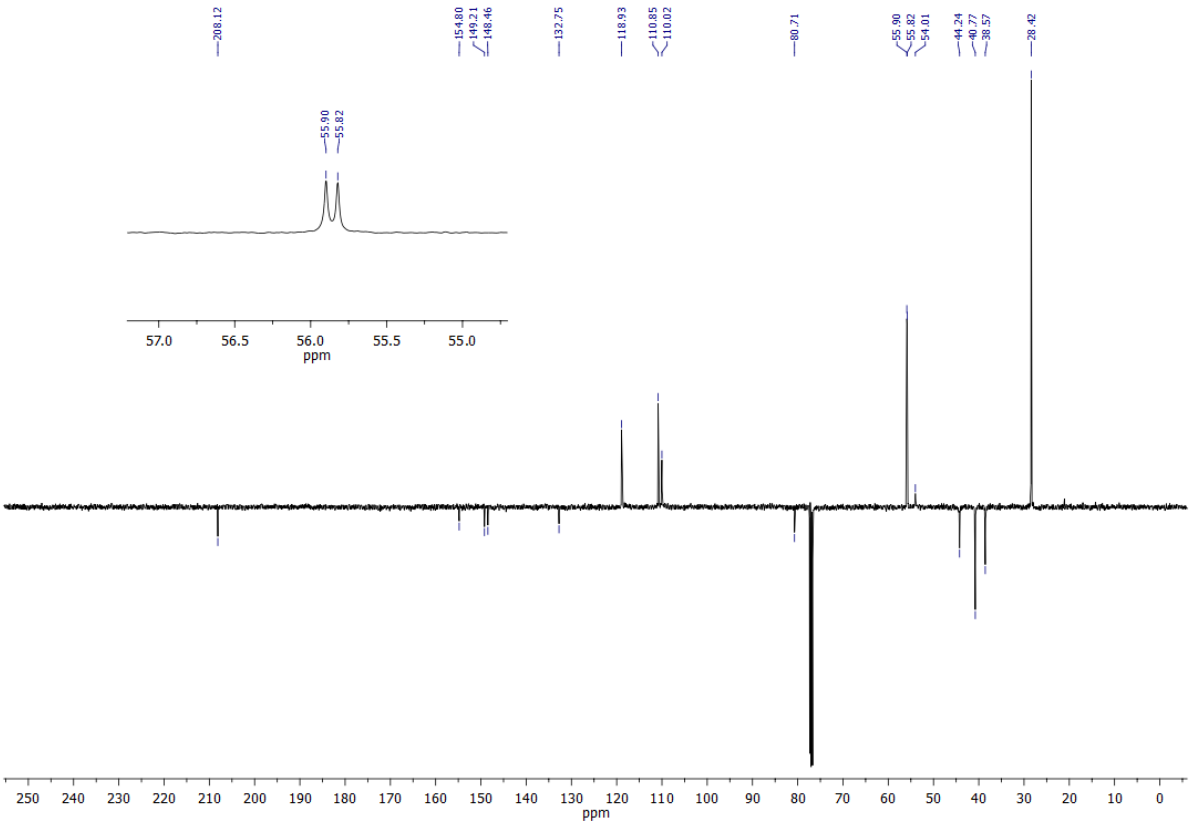


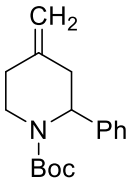

**2h**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



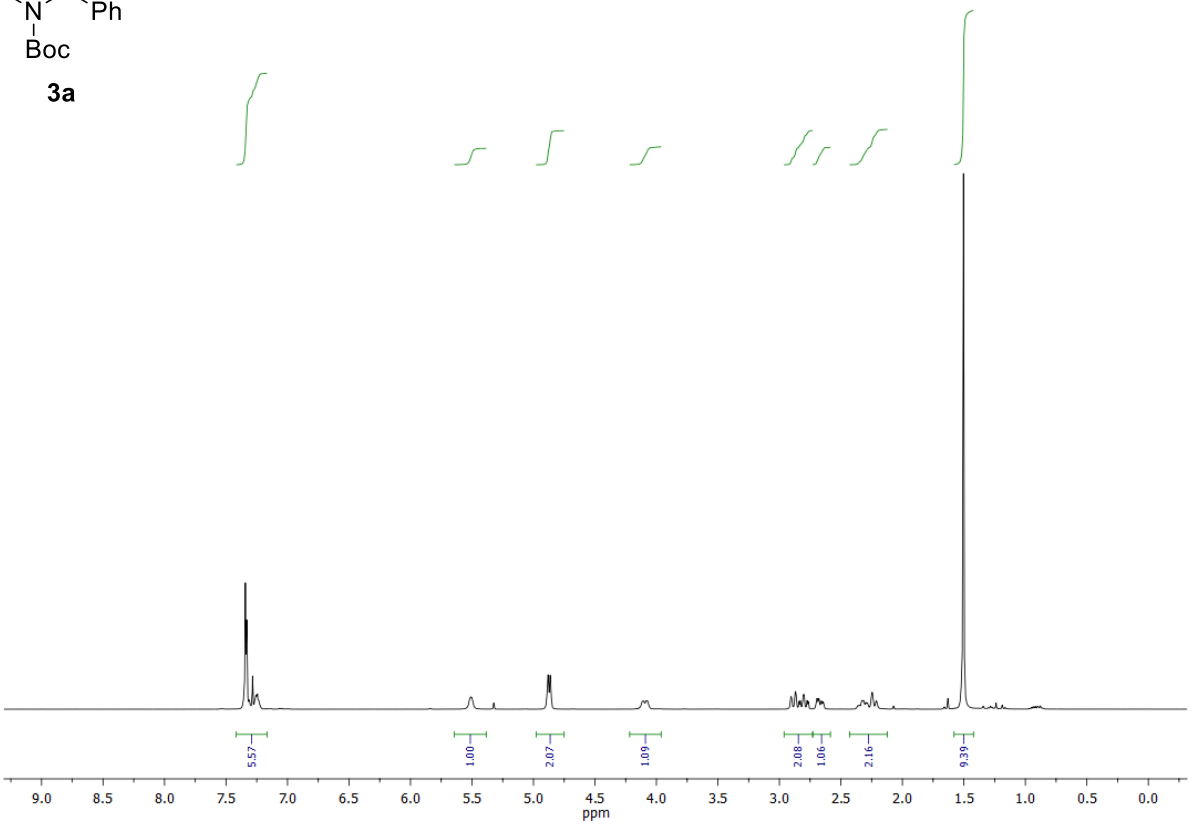

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



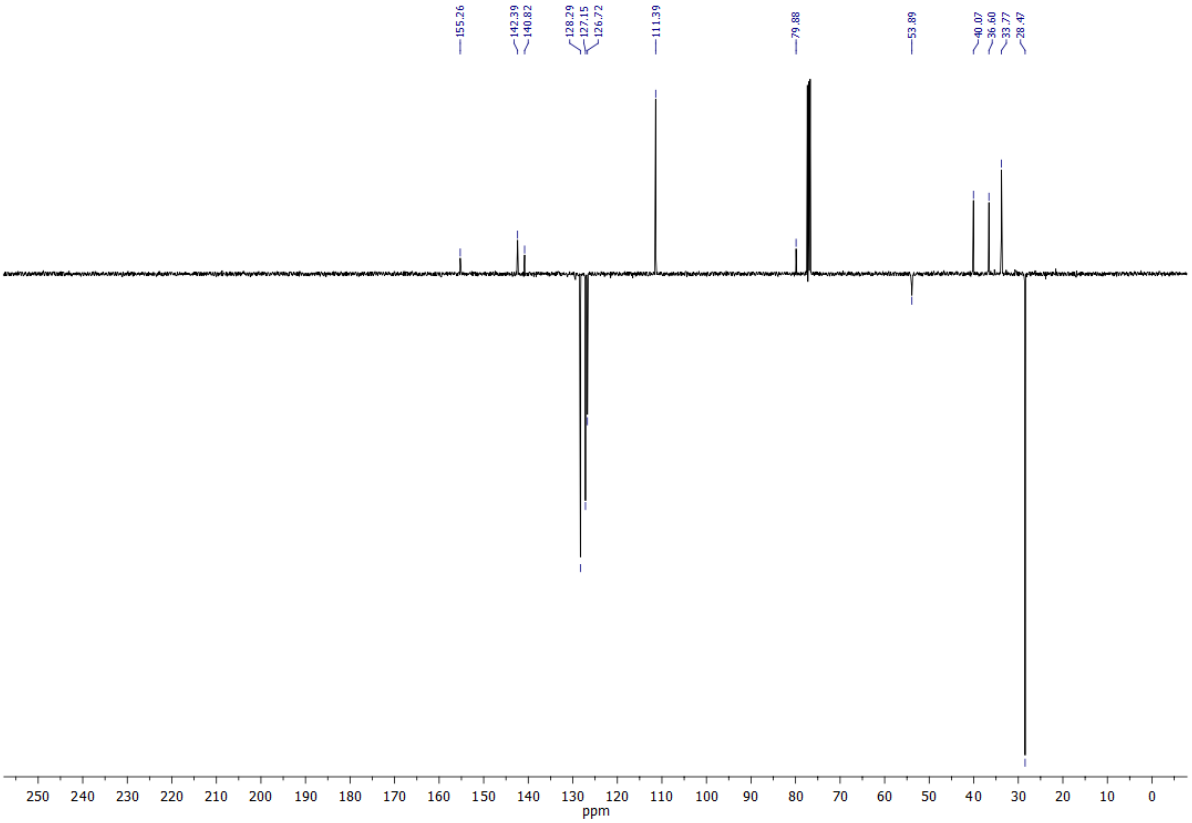


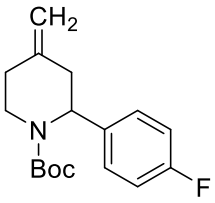

**3a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



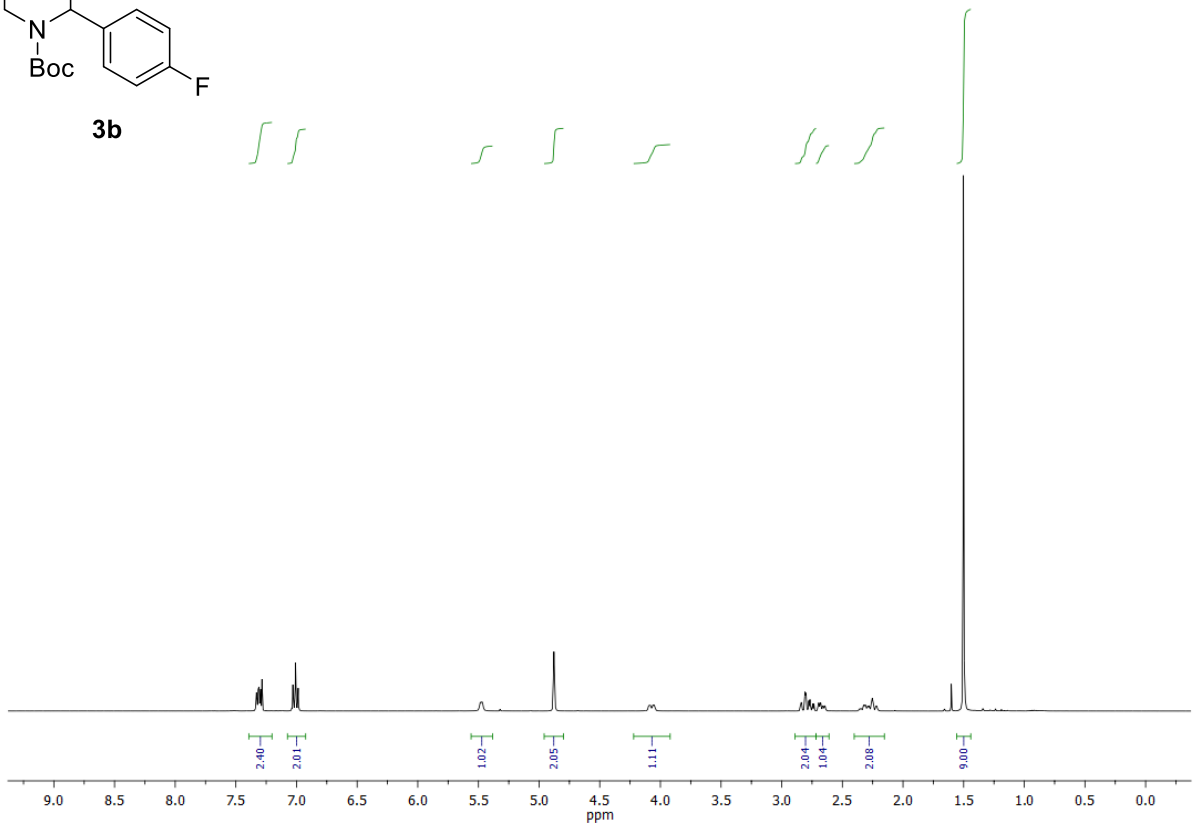

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



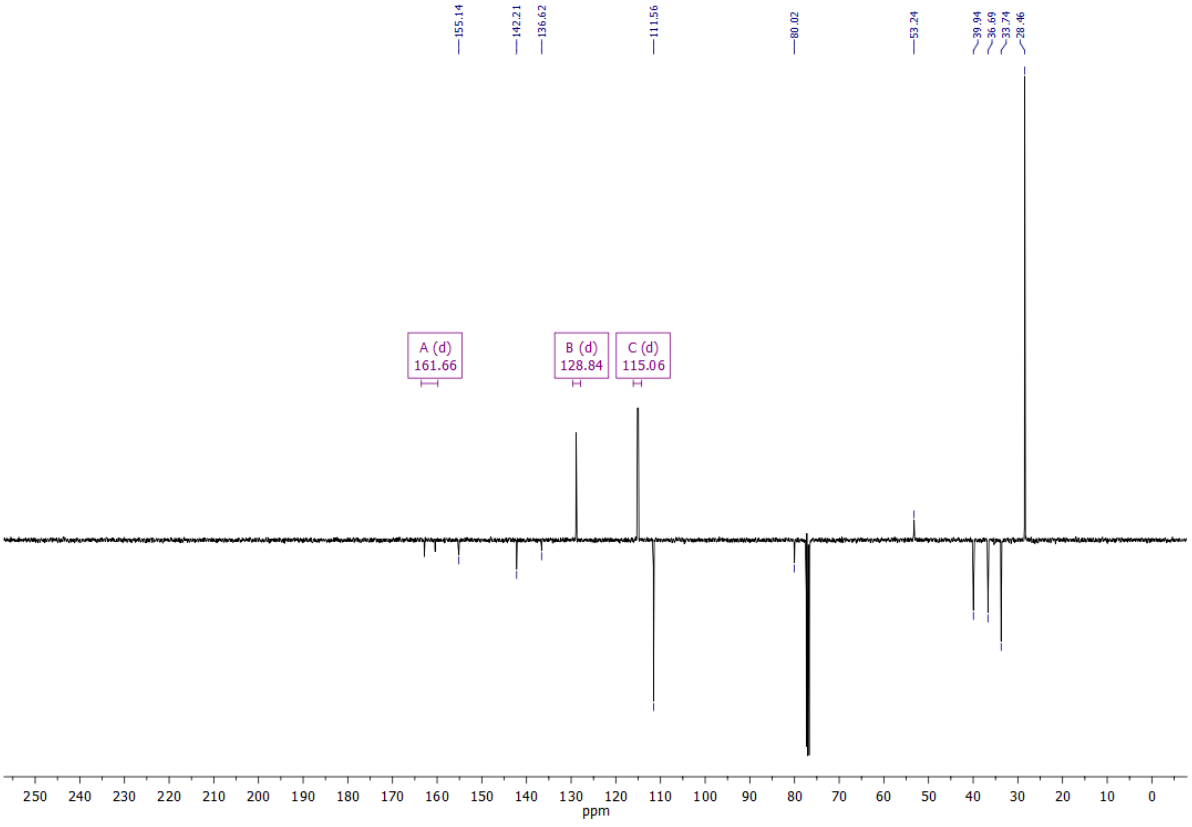



**3b**

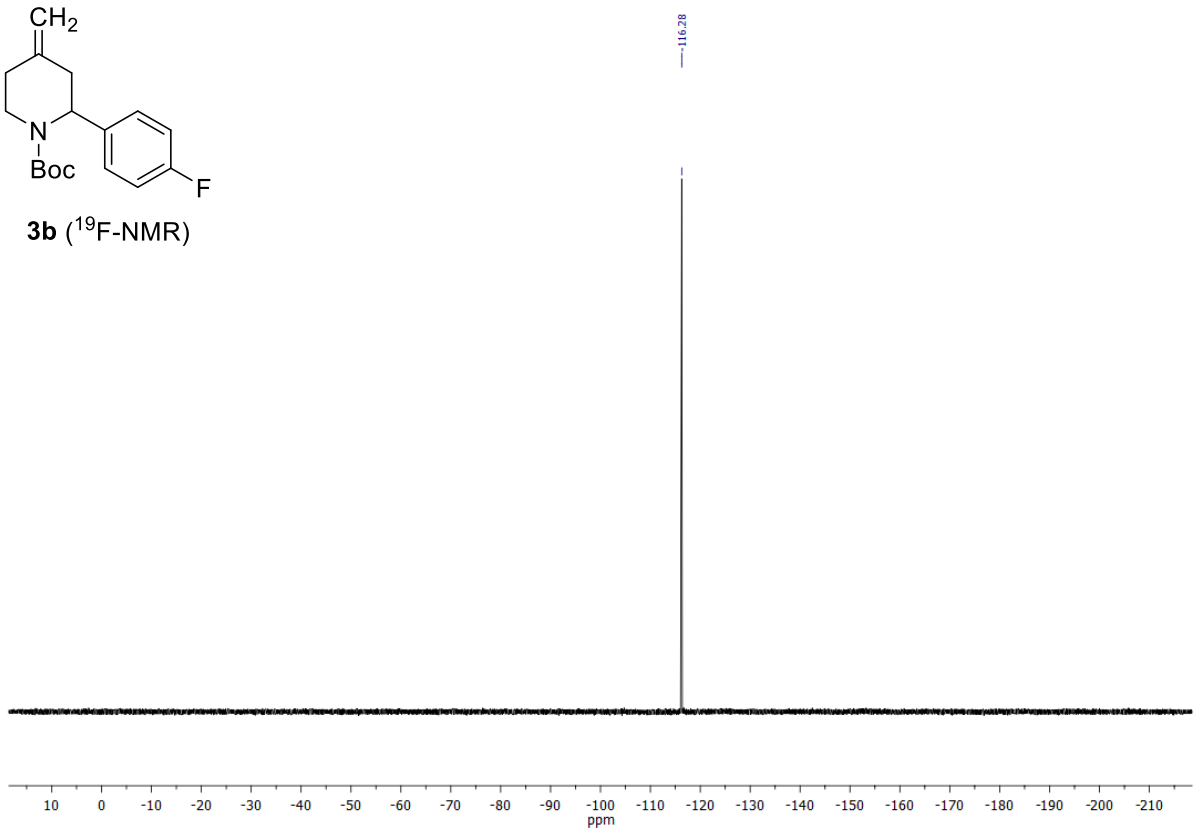
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):

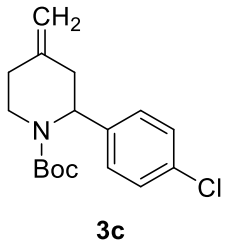



$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):



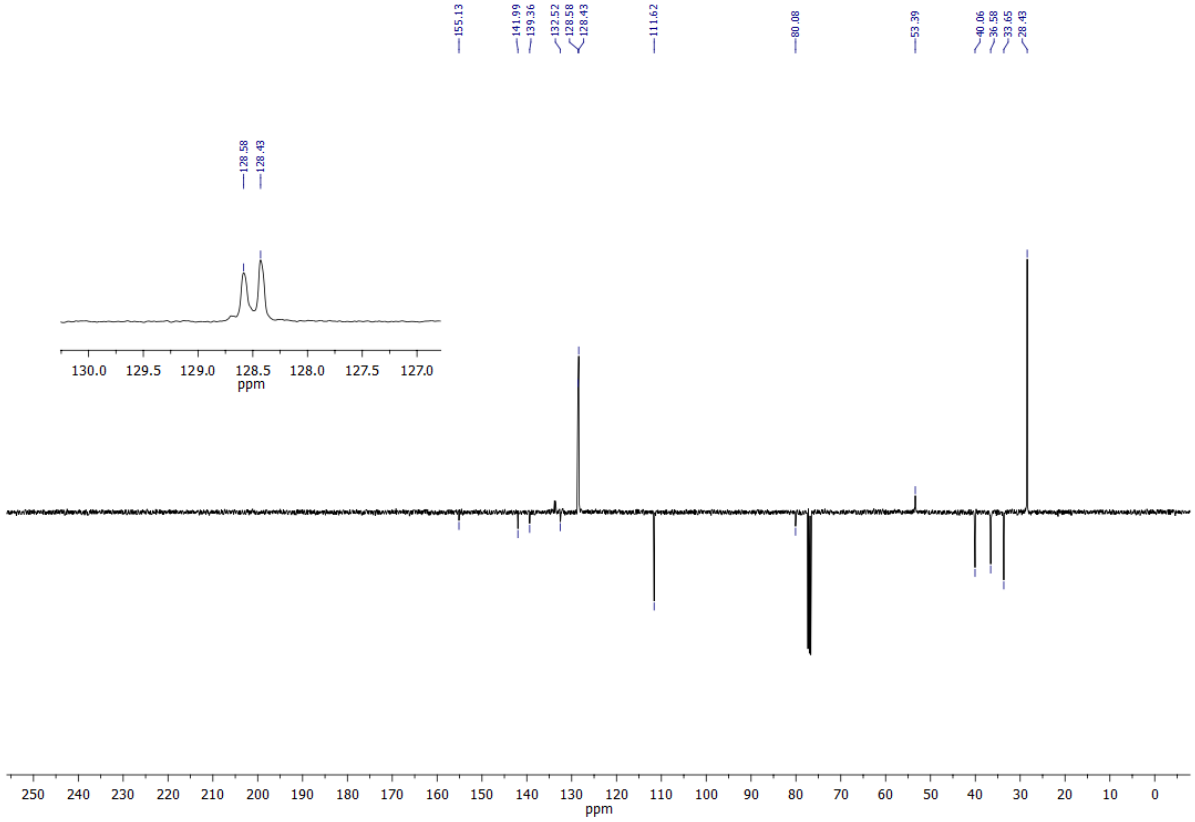


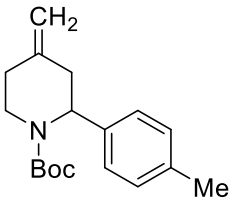

**3c**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



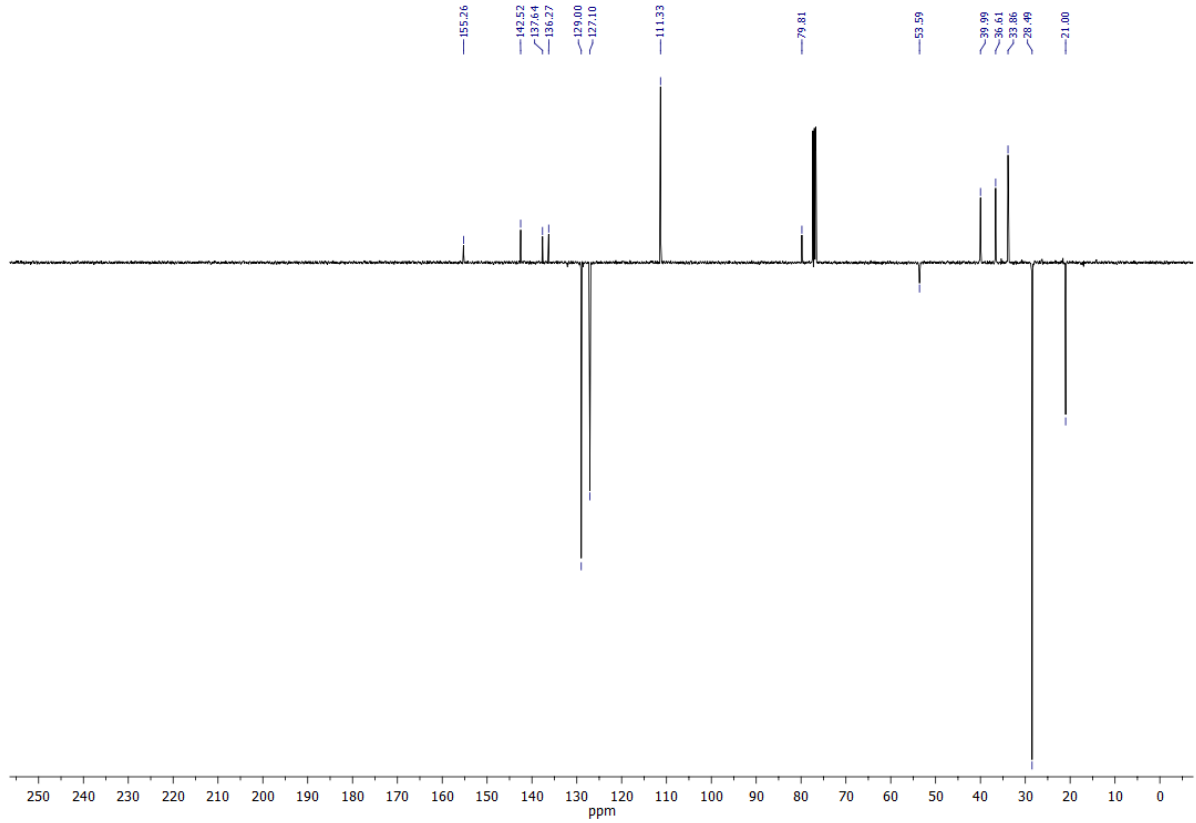


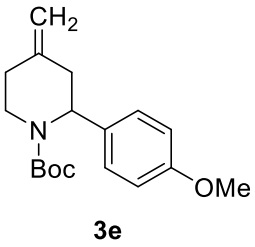

**3d**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



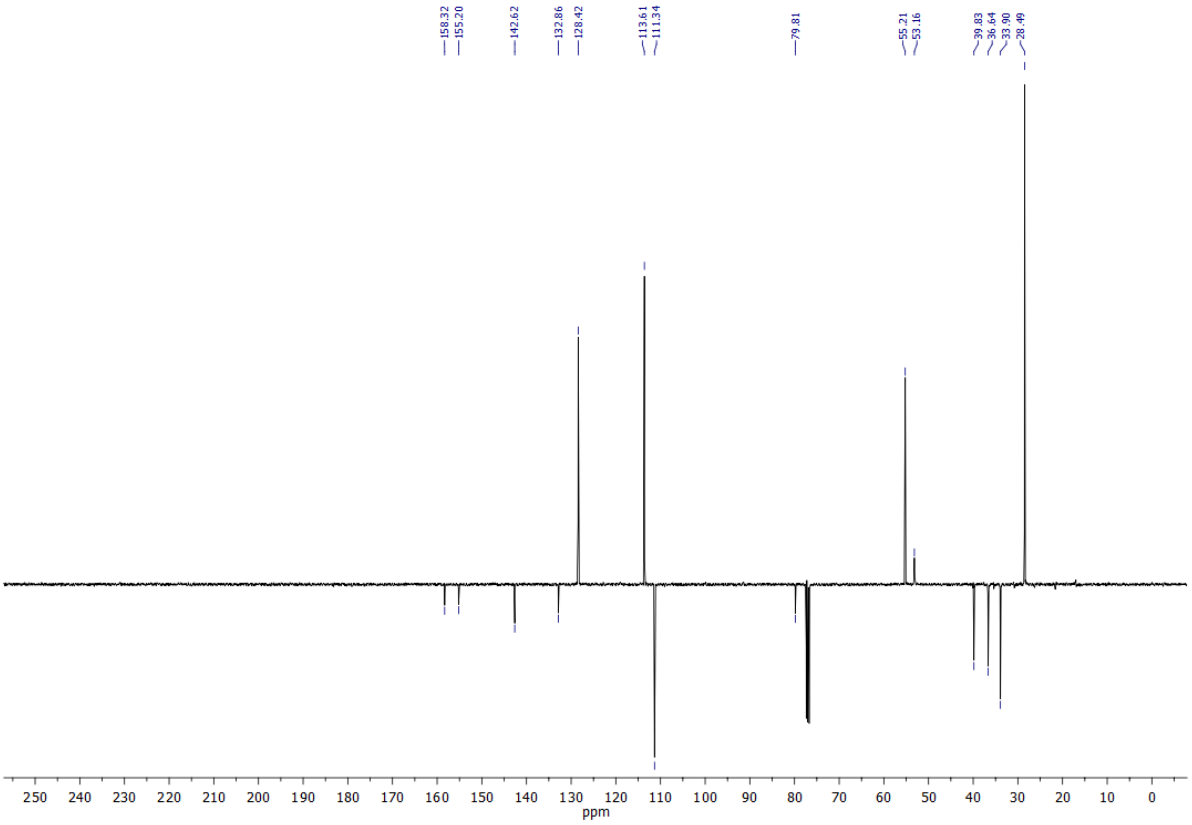


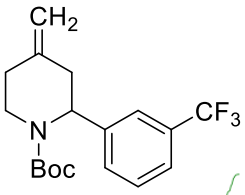

**3e**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



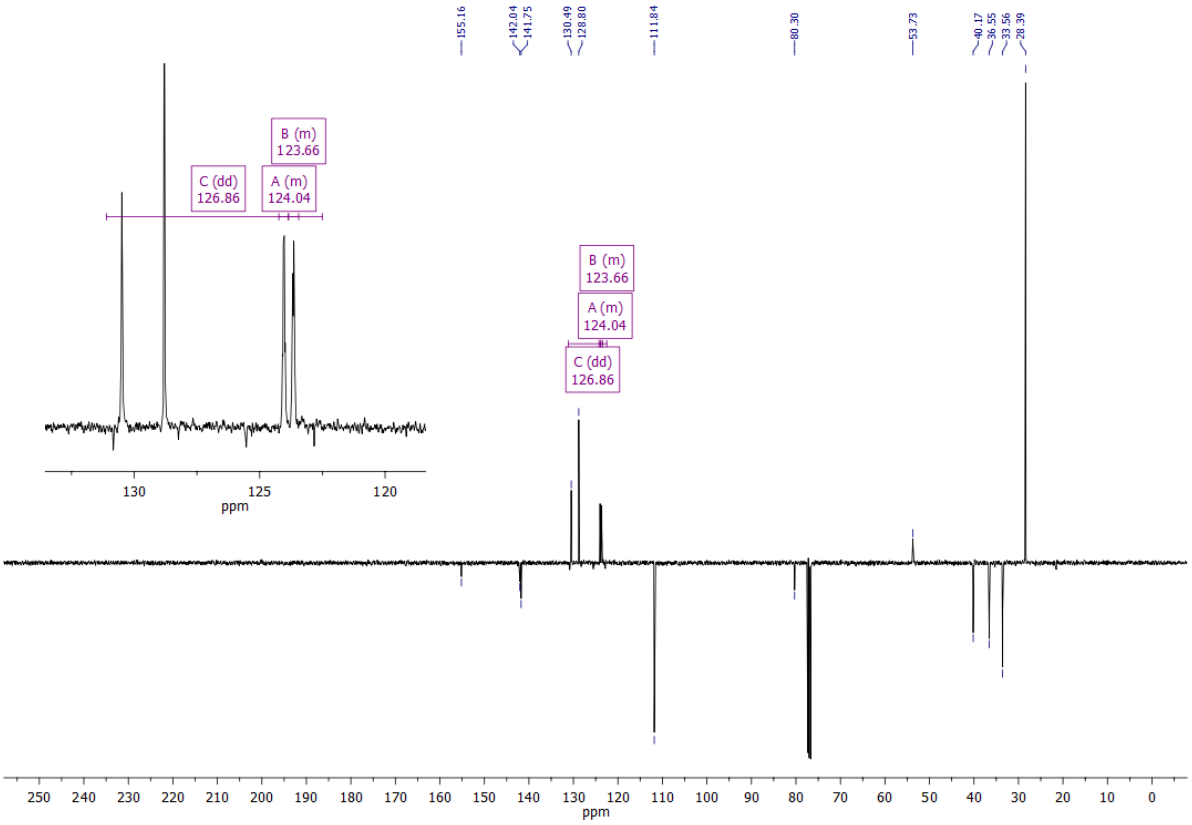



3f

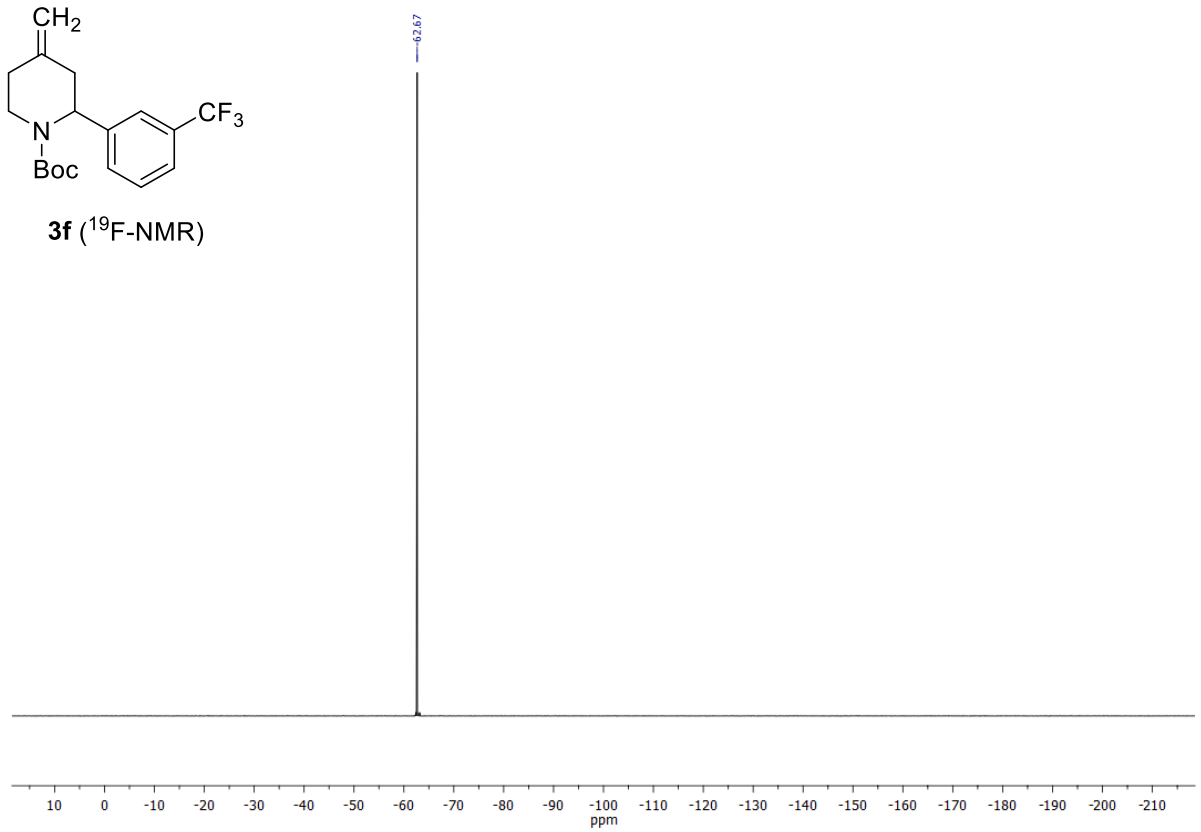
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



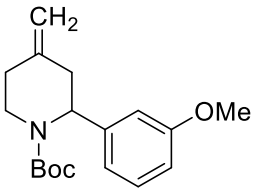

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):




**3f** ($^{19}$F-NMR)

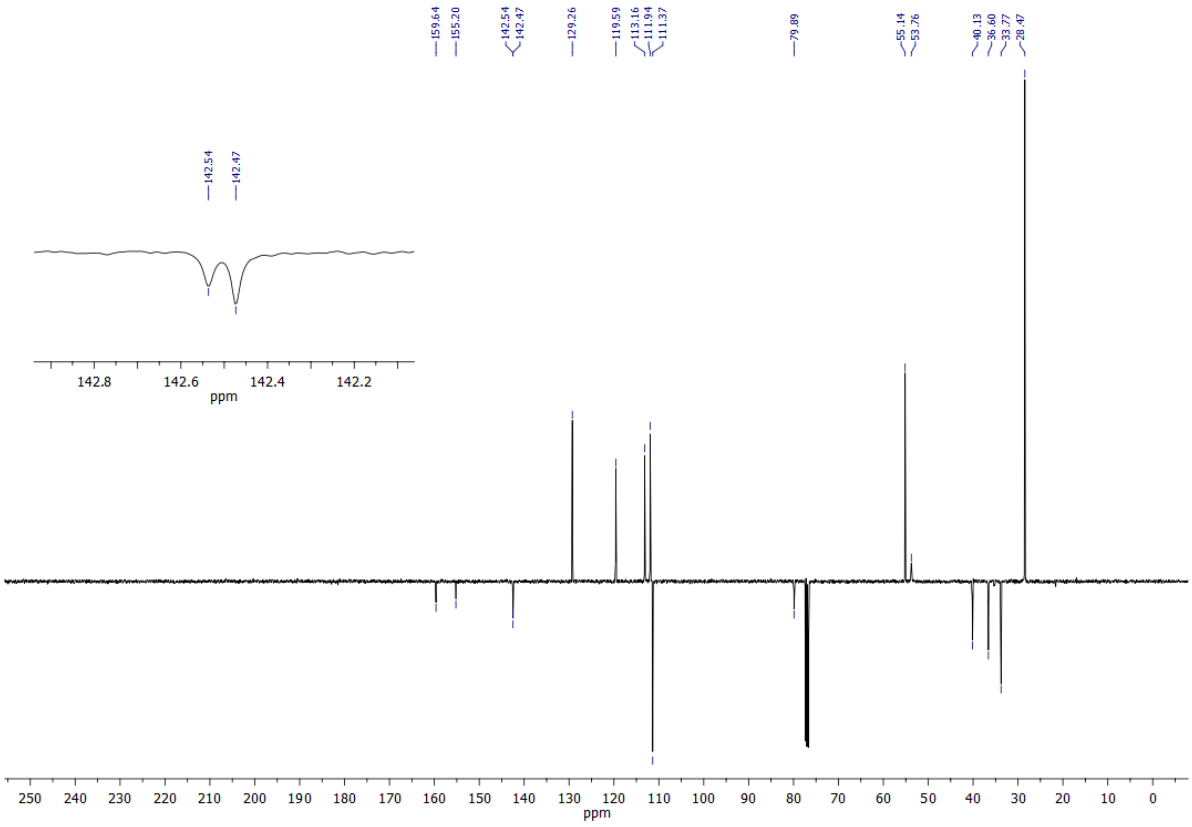


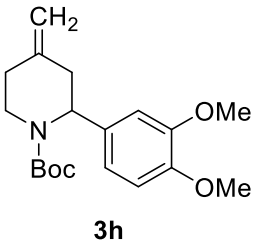

**3g**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



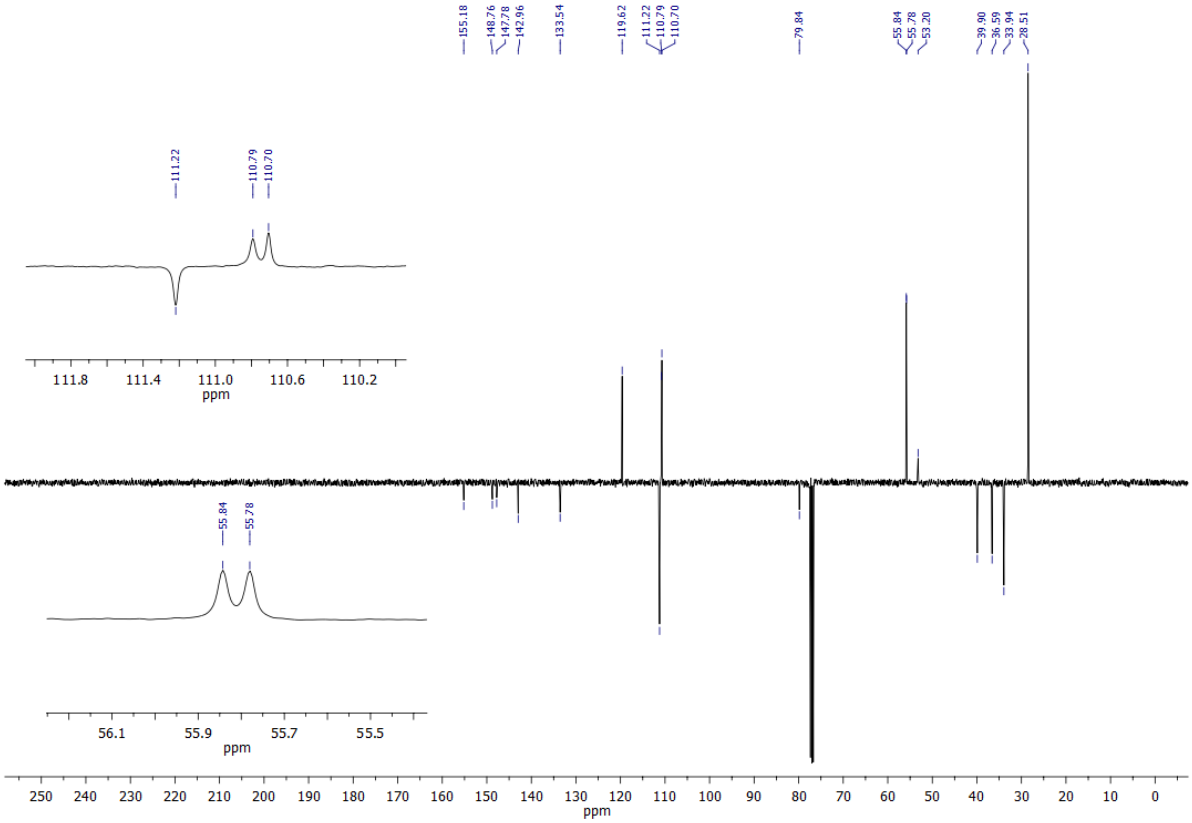


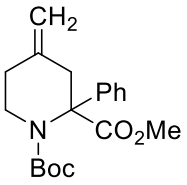

**3h**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



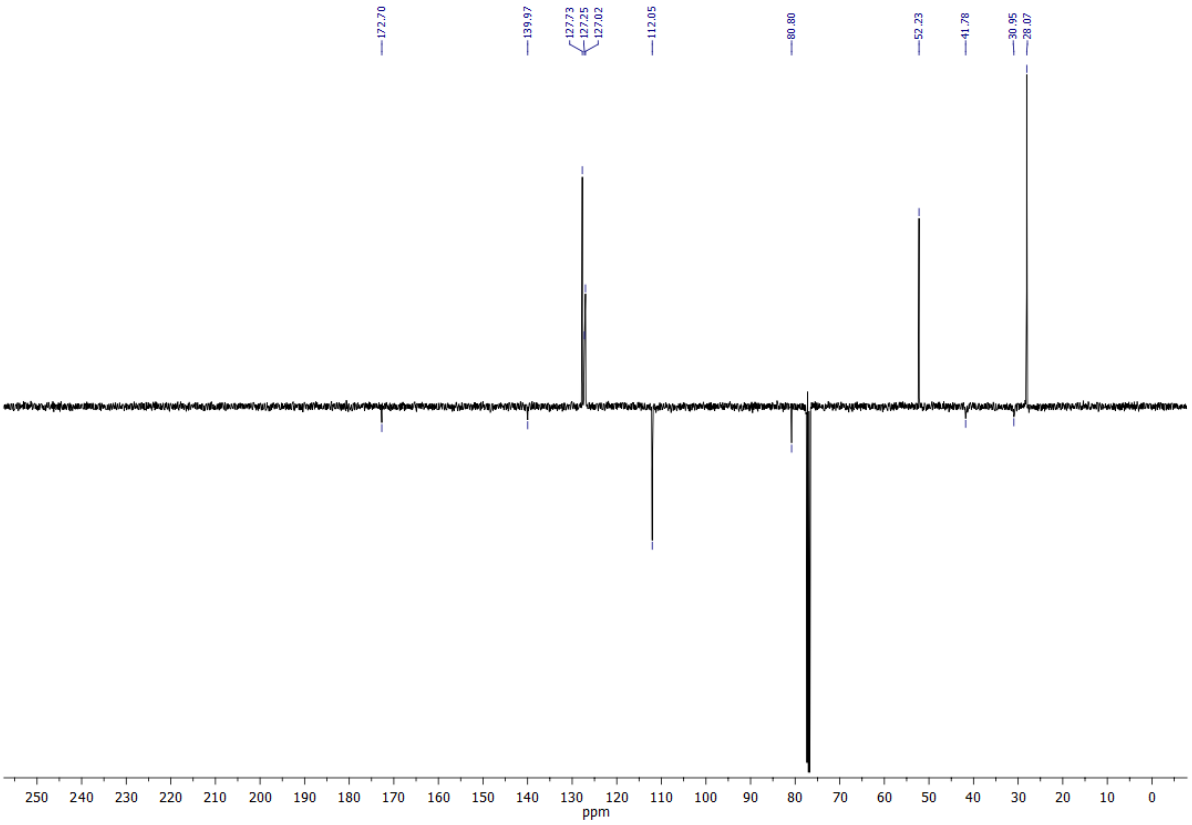


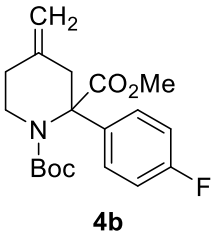

**4a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



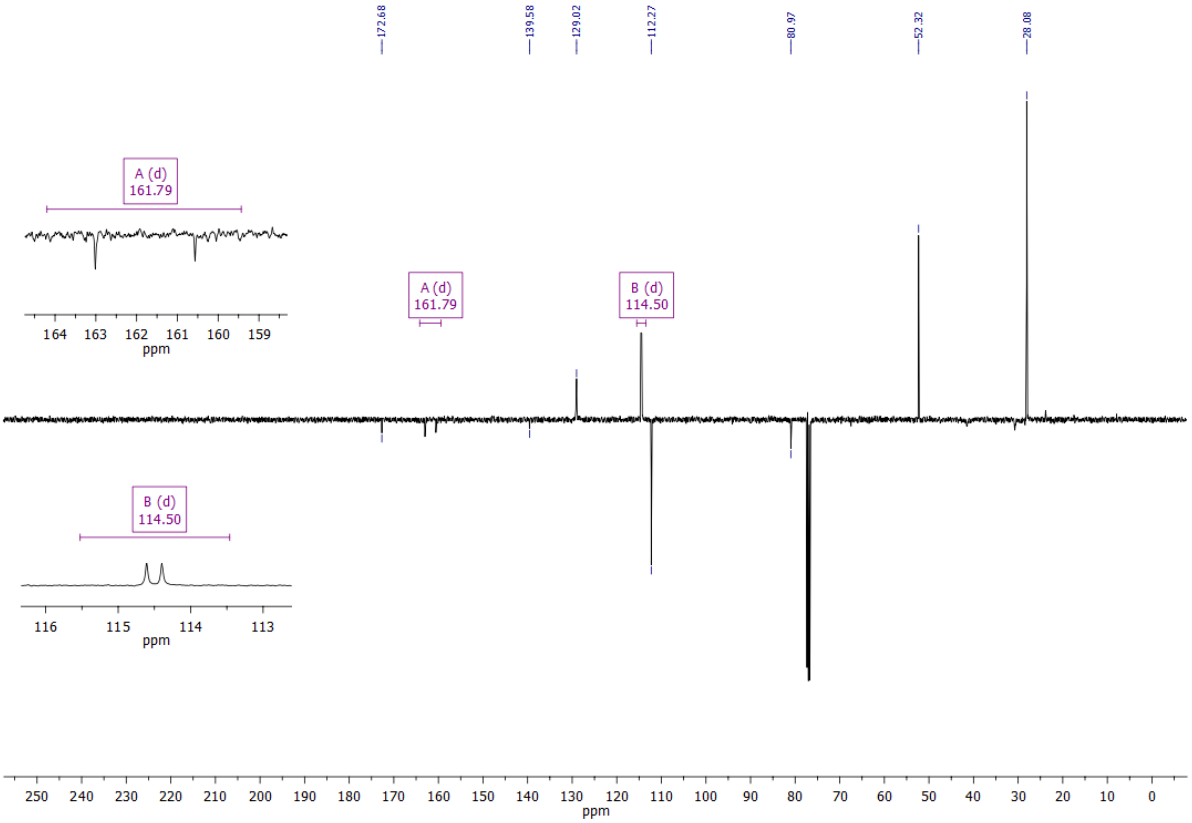



**4b**

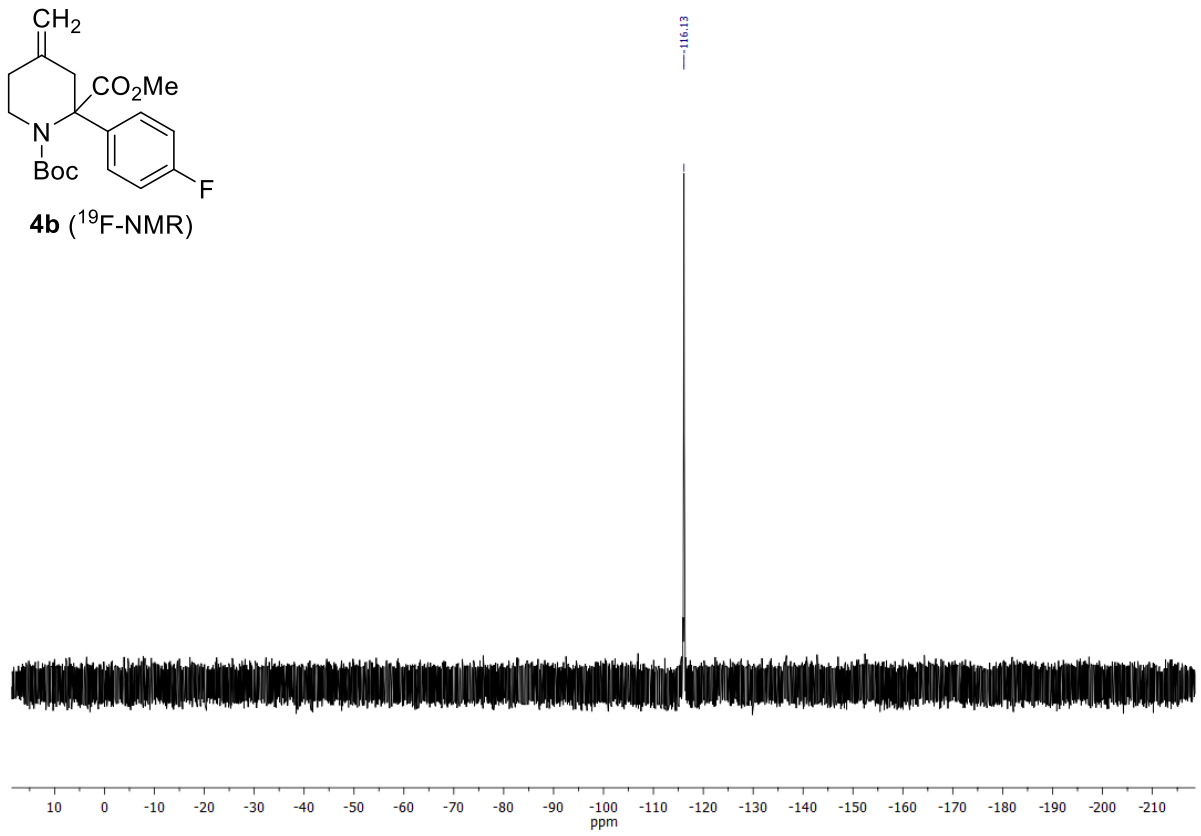
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):

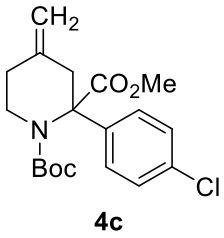



$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):



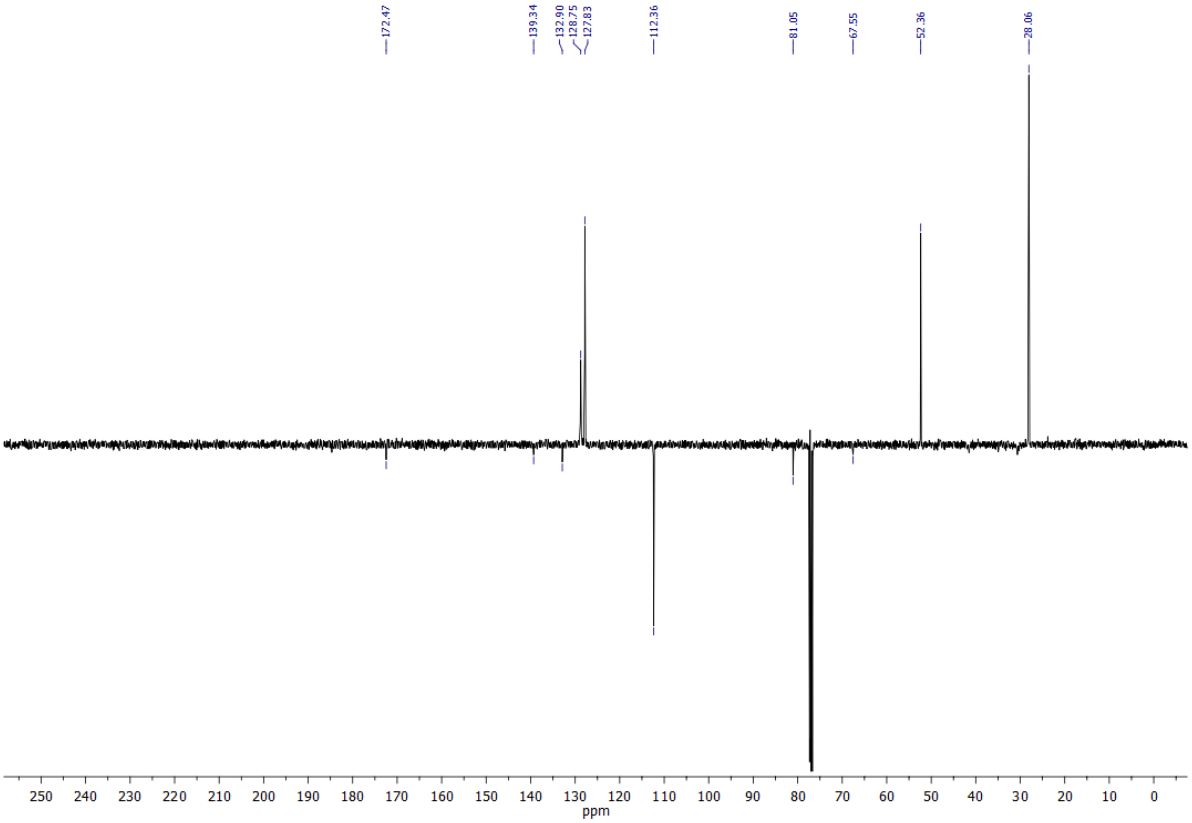


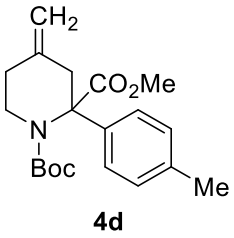

**4c**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



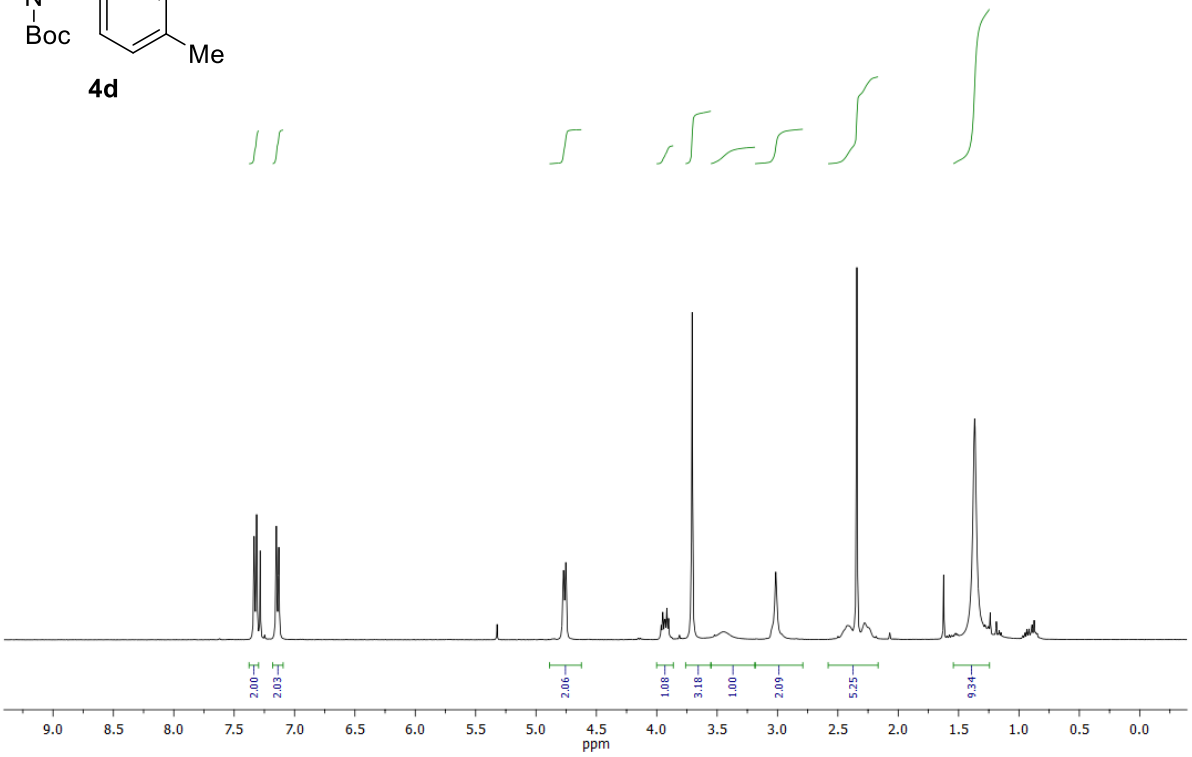

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



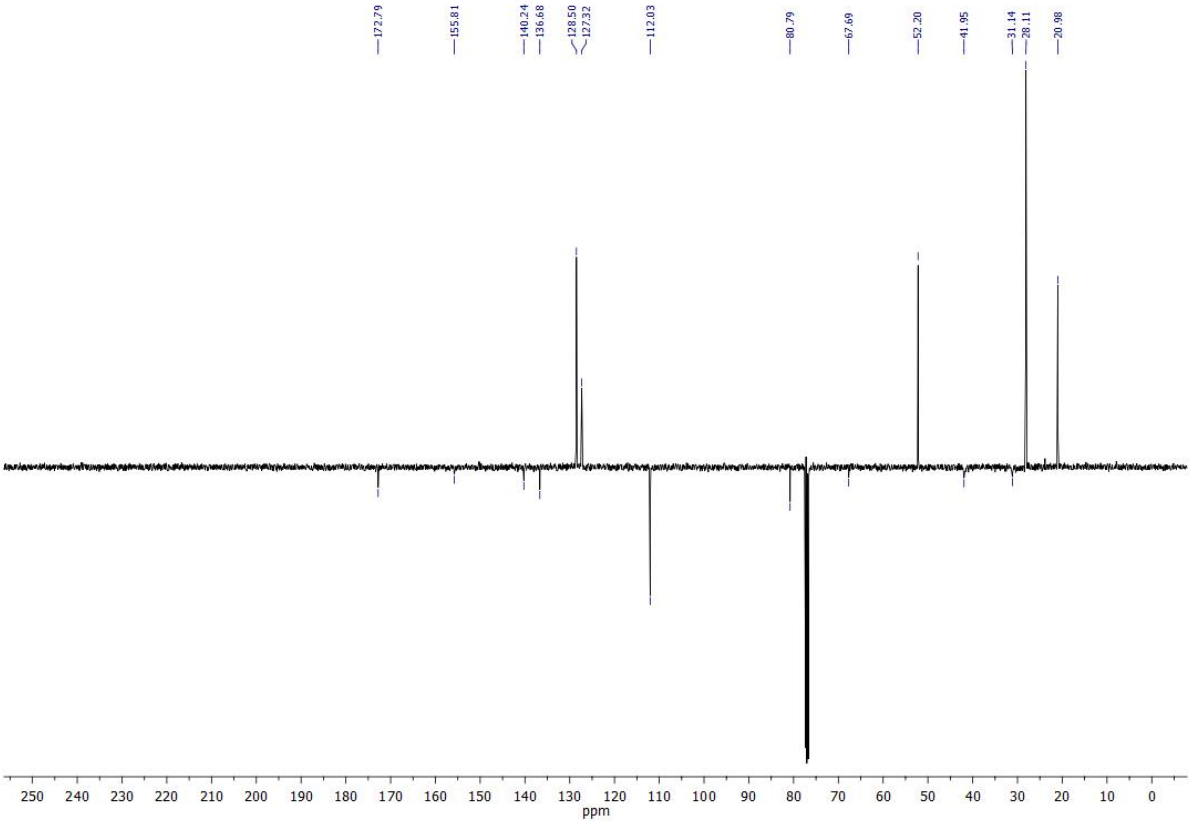


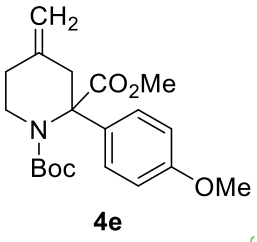

**4d**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



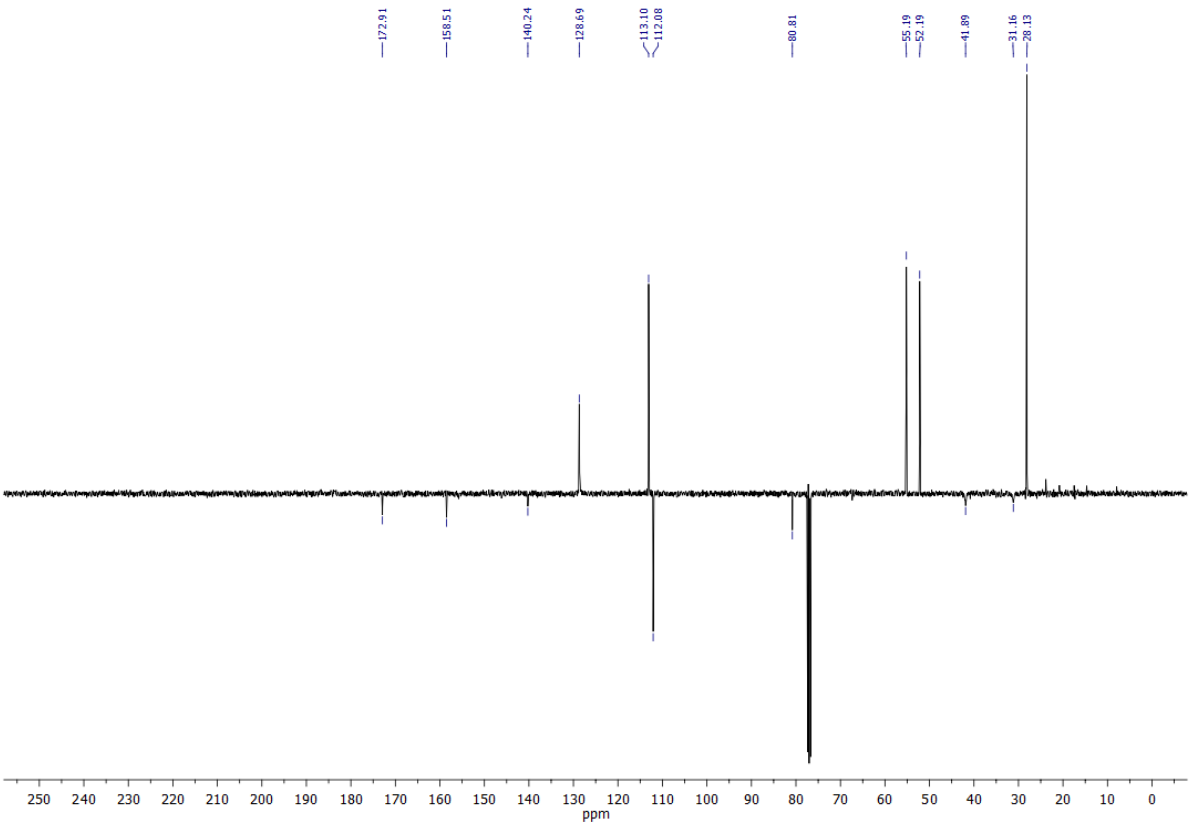


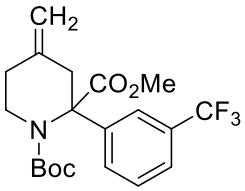

**4e**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



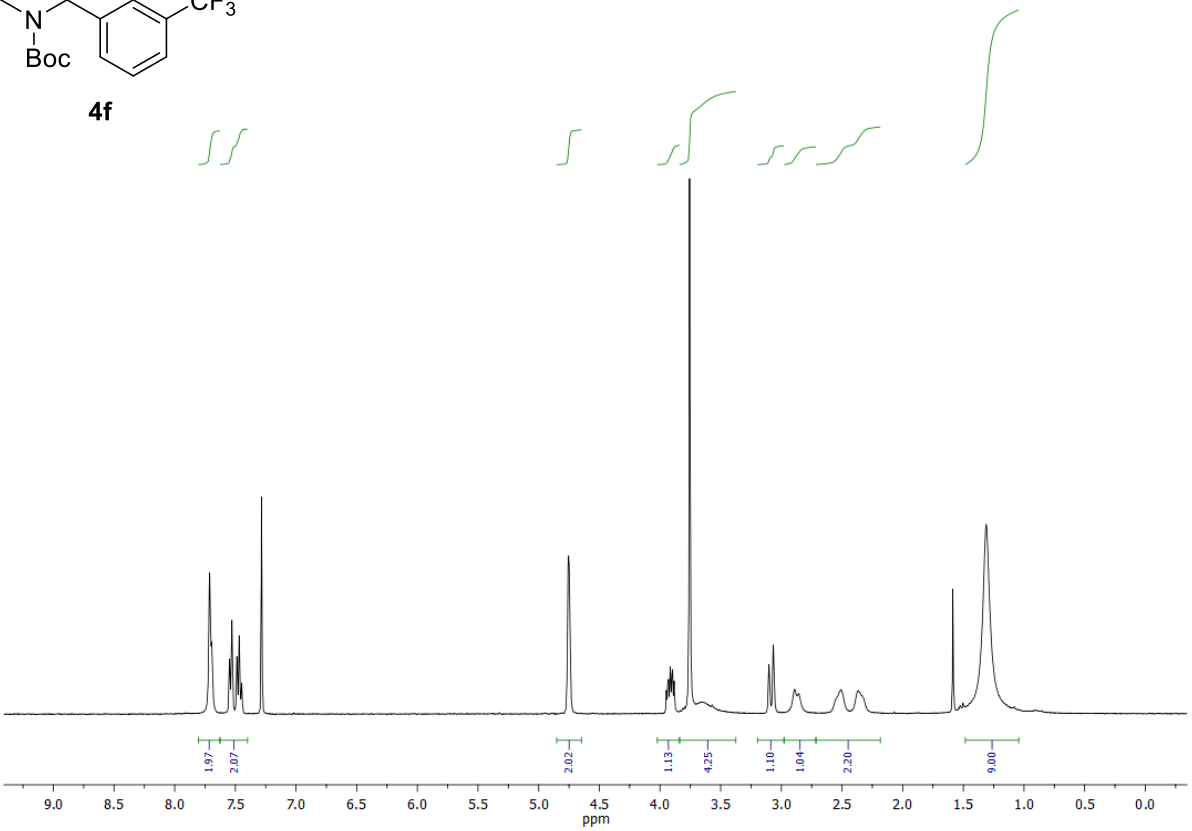

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



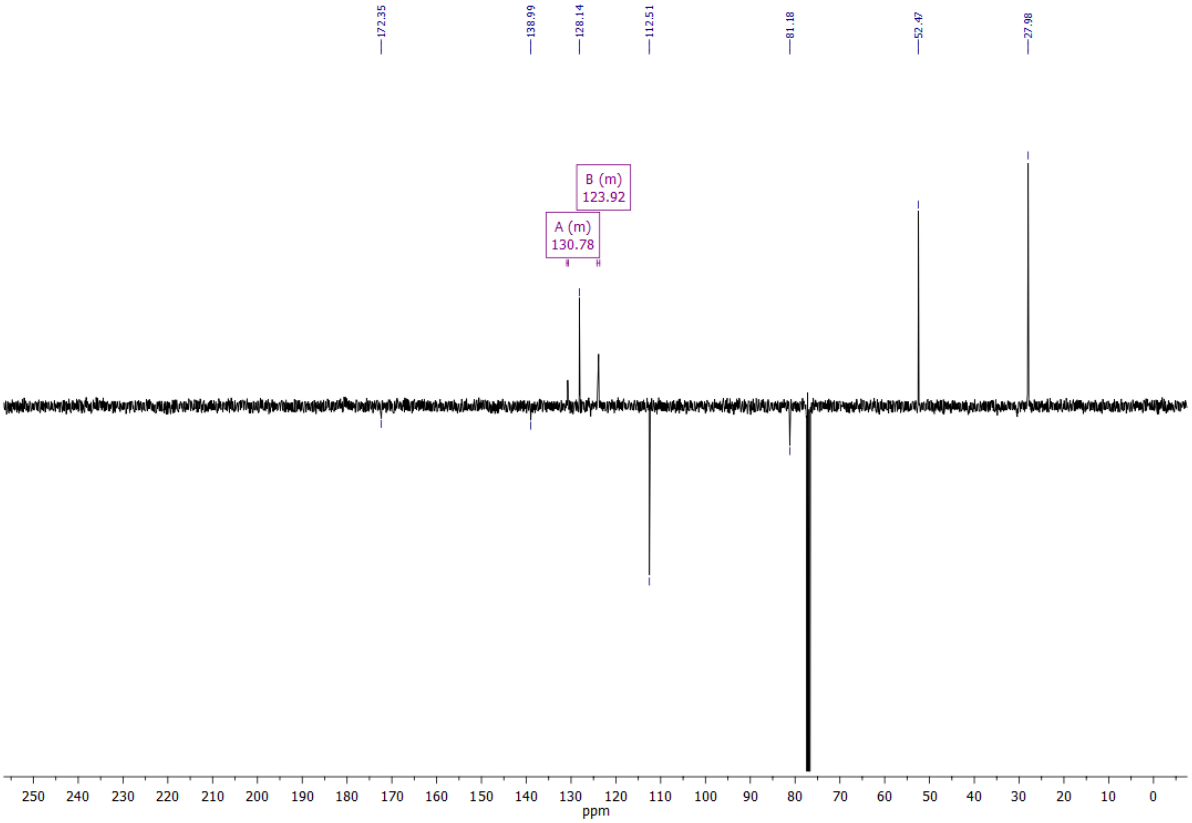



**4f**

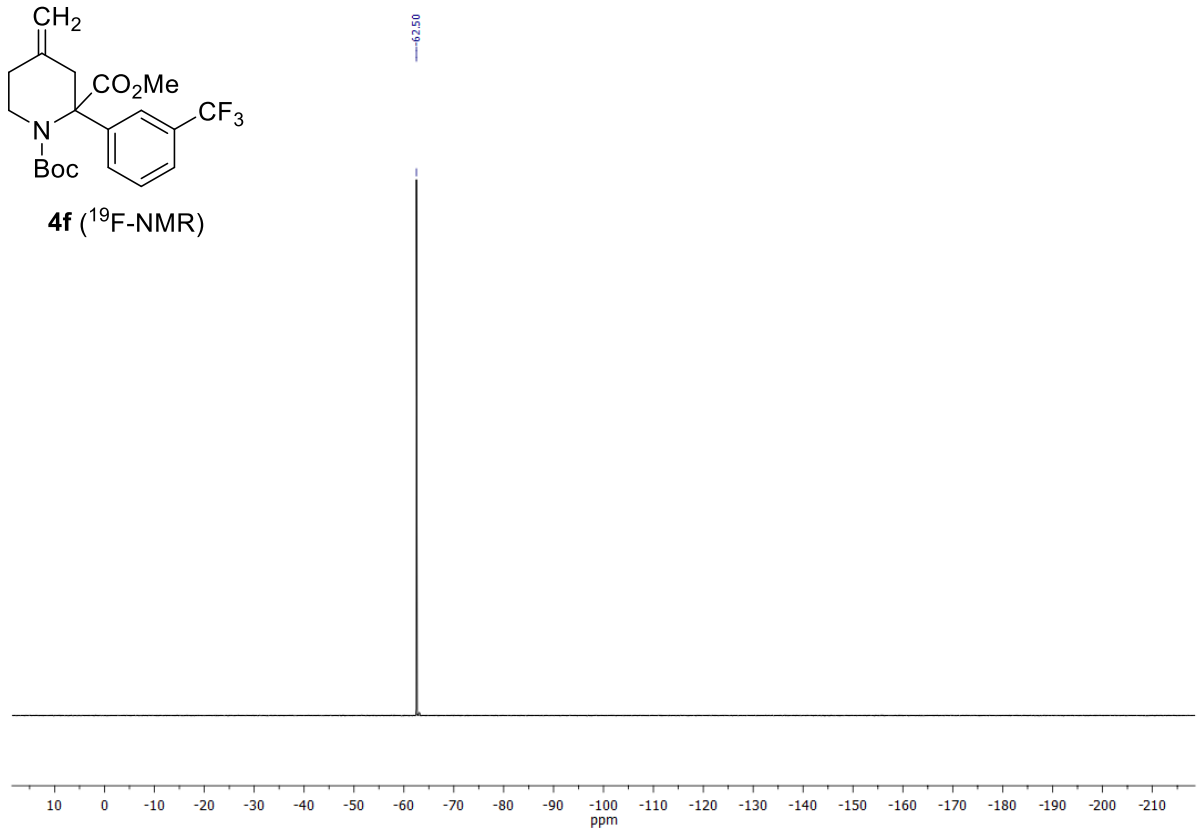
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



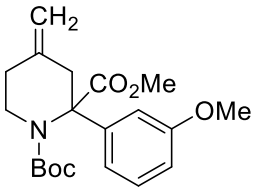

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):




**4f** ($^{19}$F-NMR)

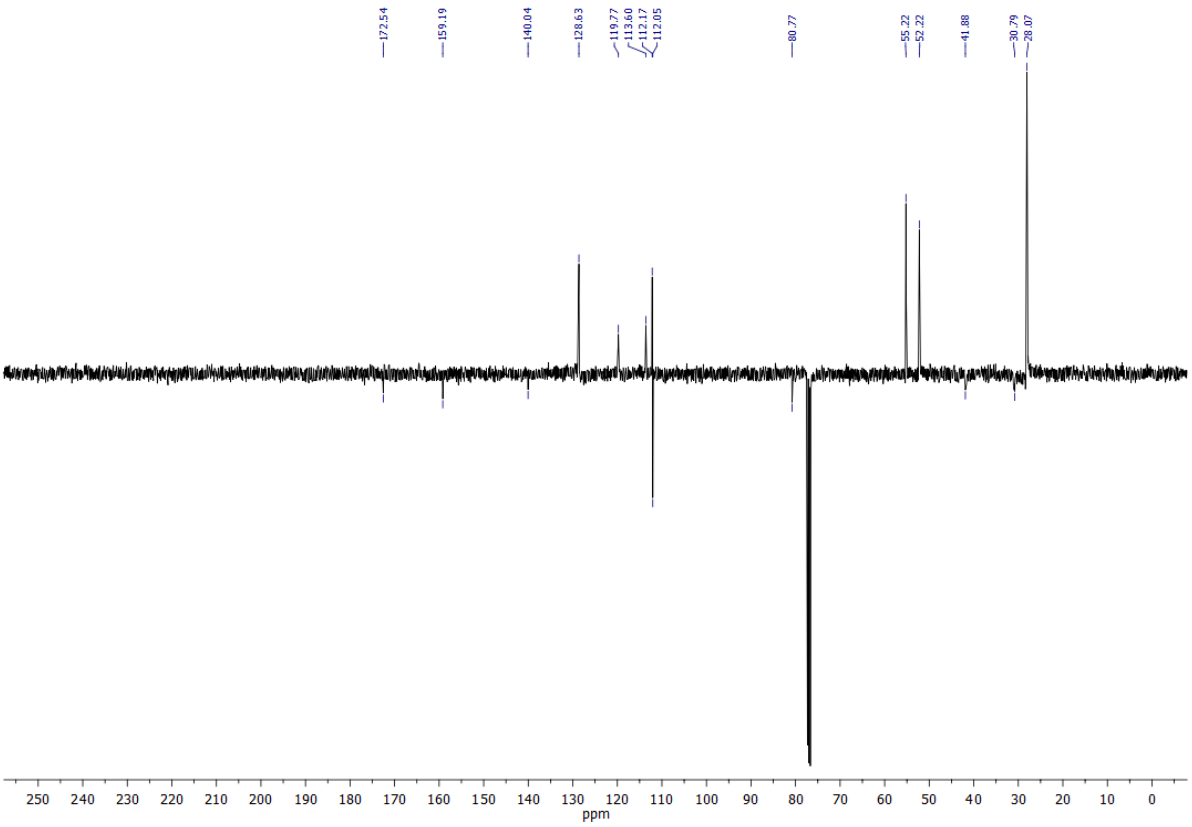


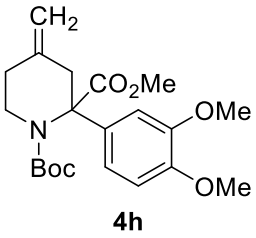

**4g**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



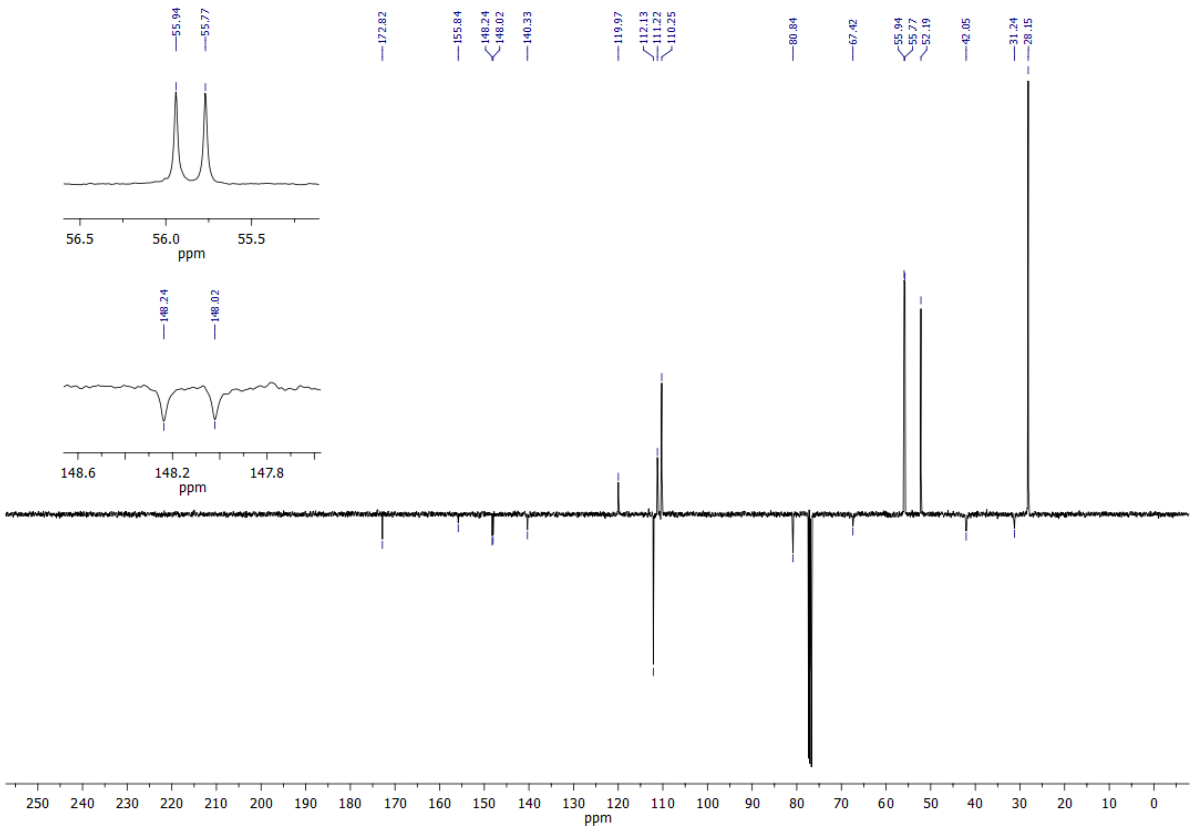


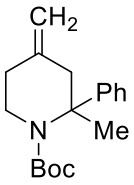

**4h**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



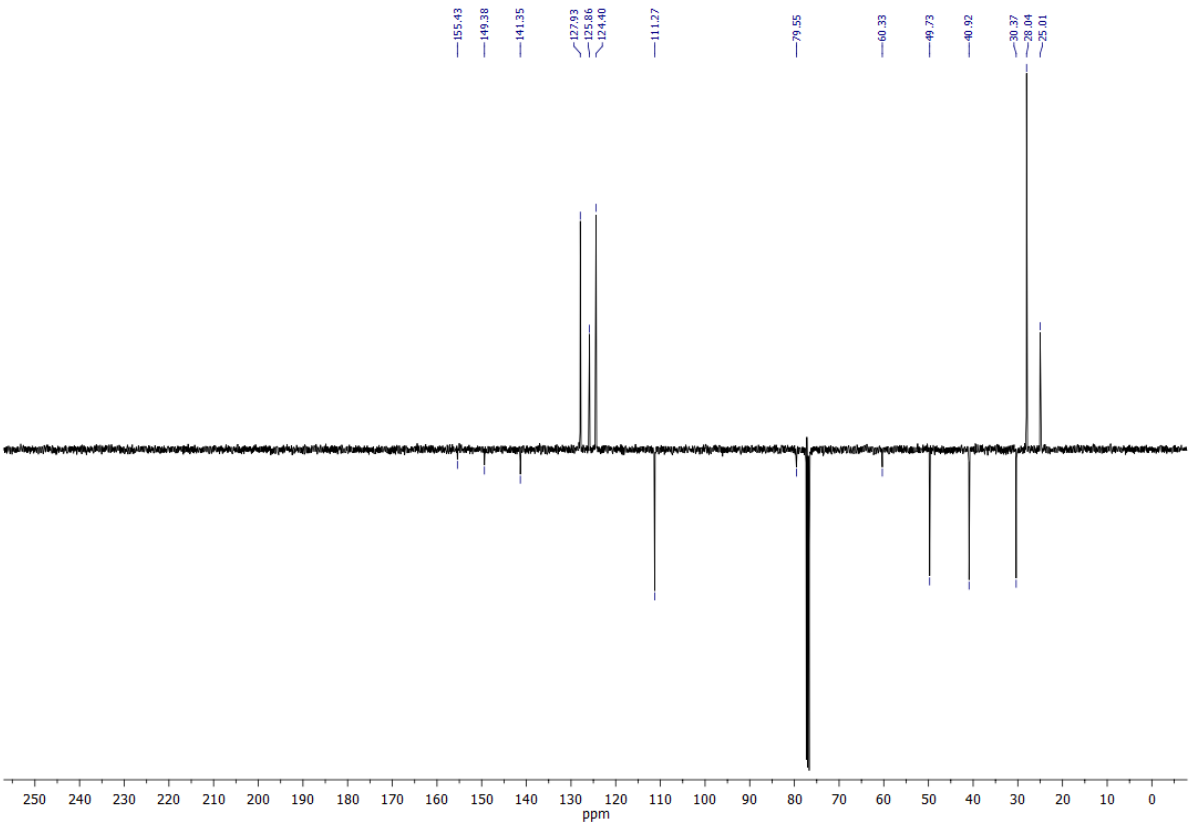


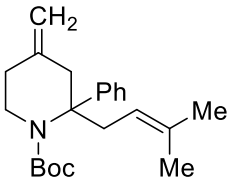

**5a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



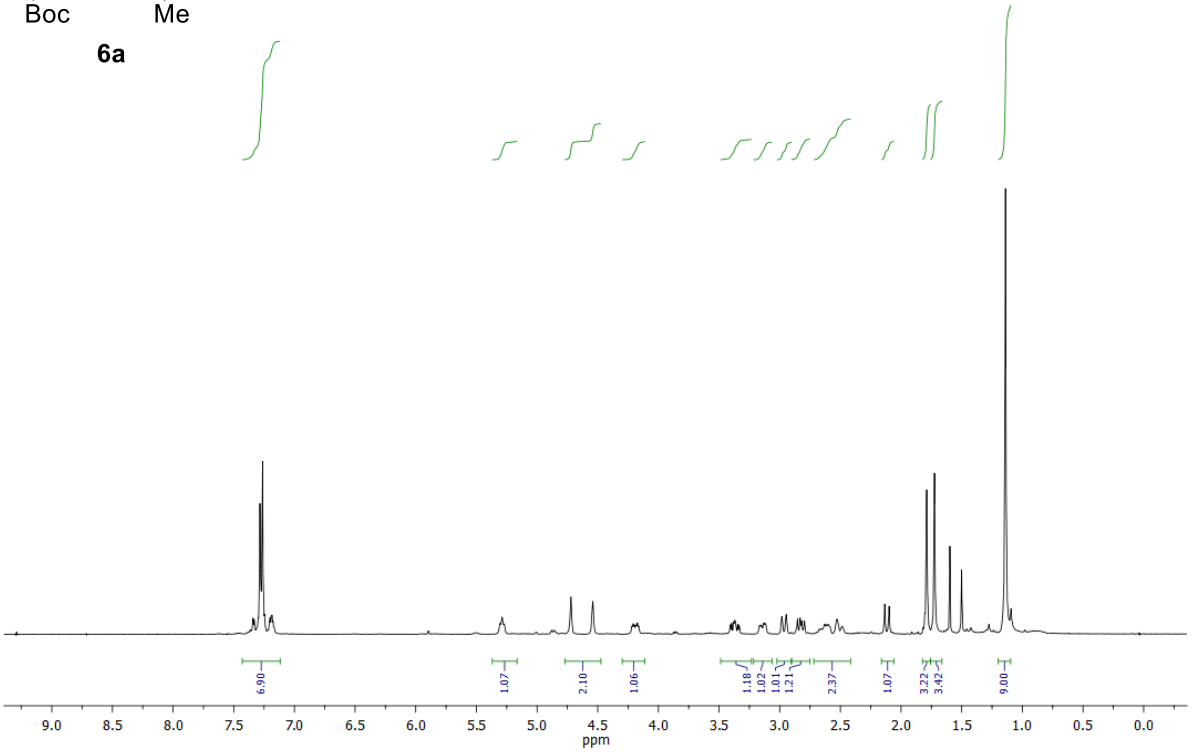

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



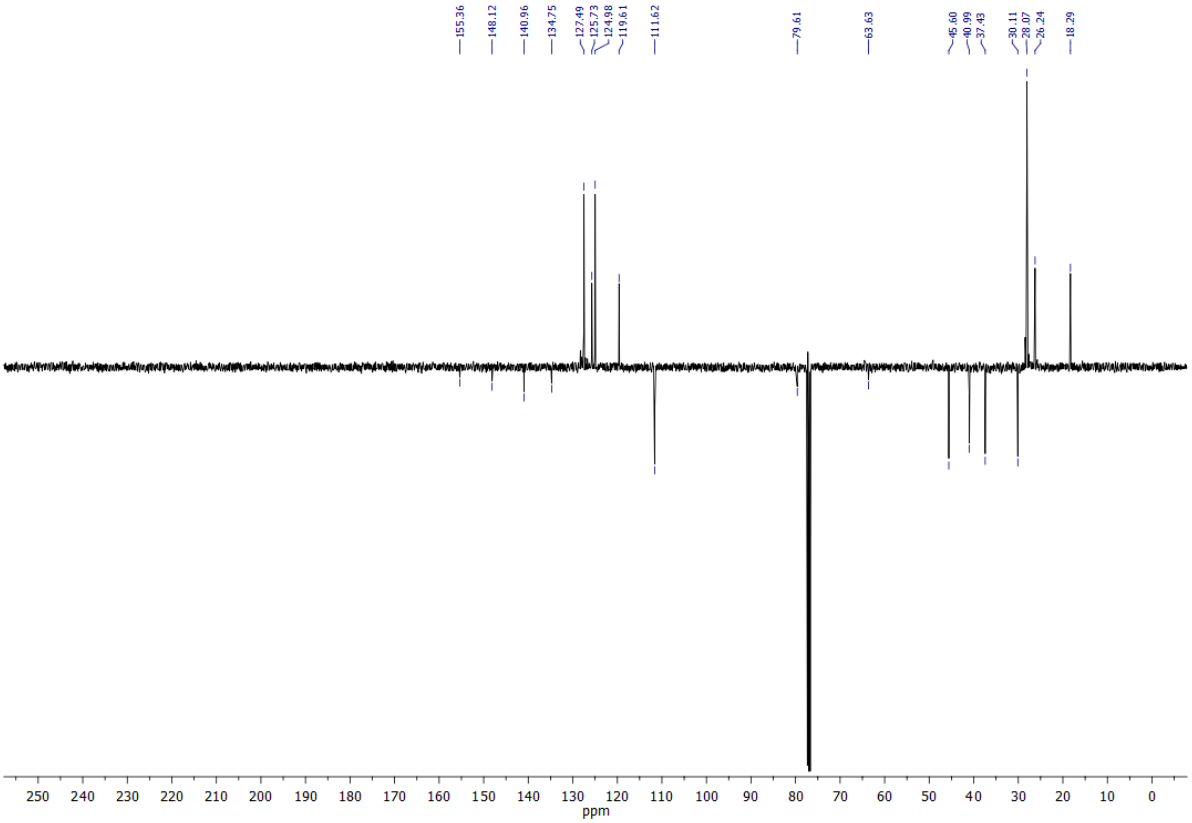


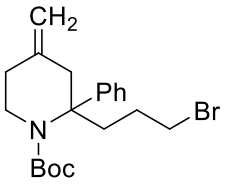

**6a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



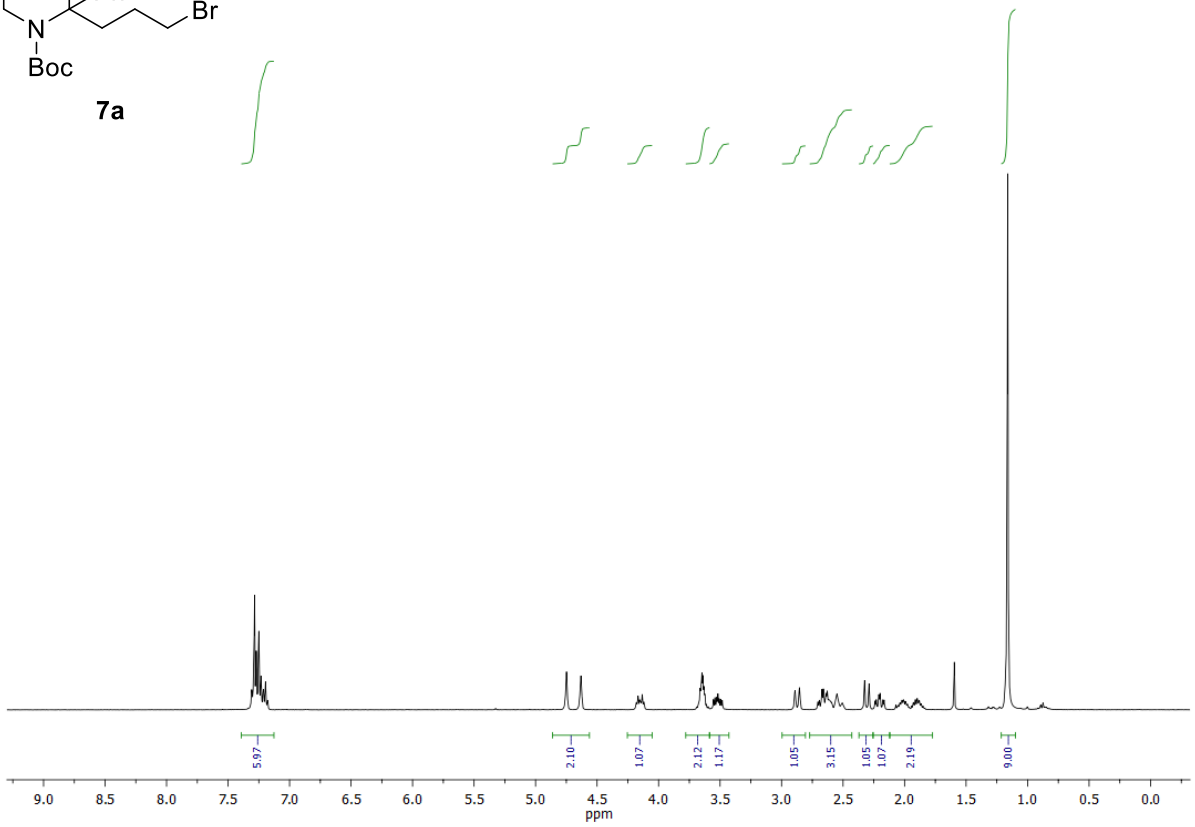

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



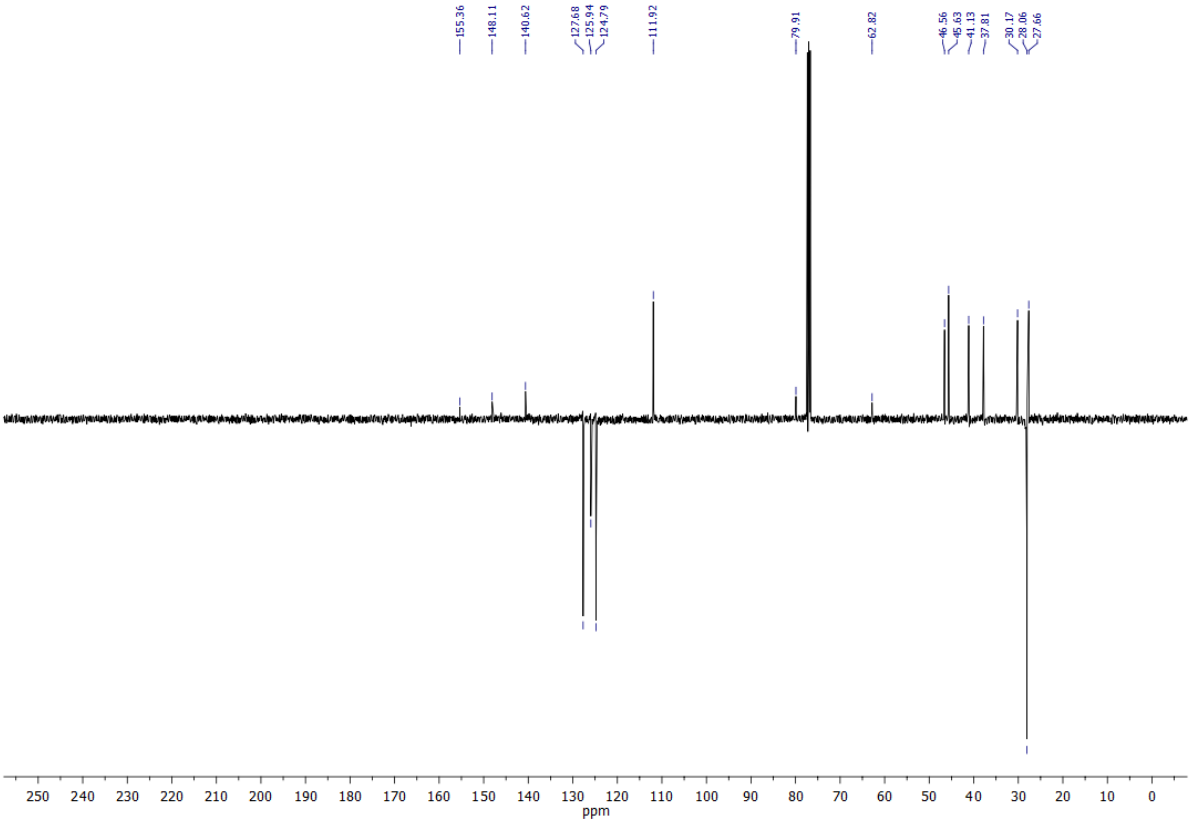


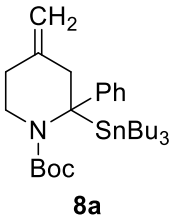

**7a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



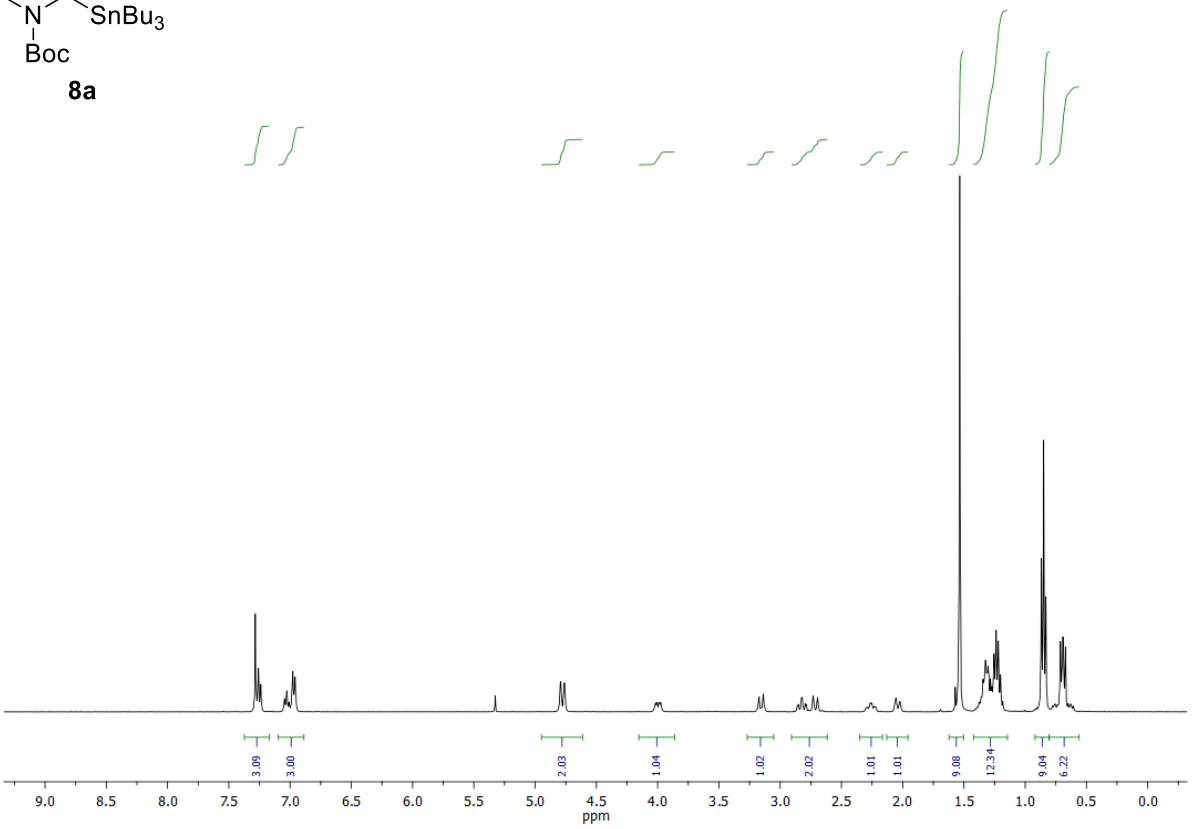

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



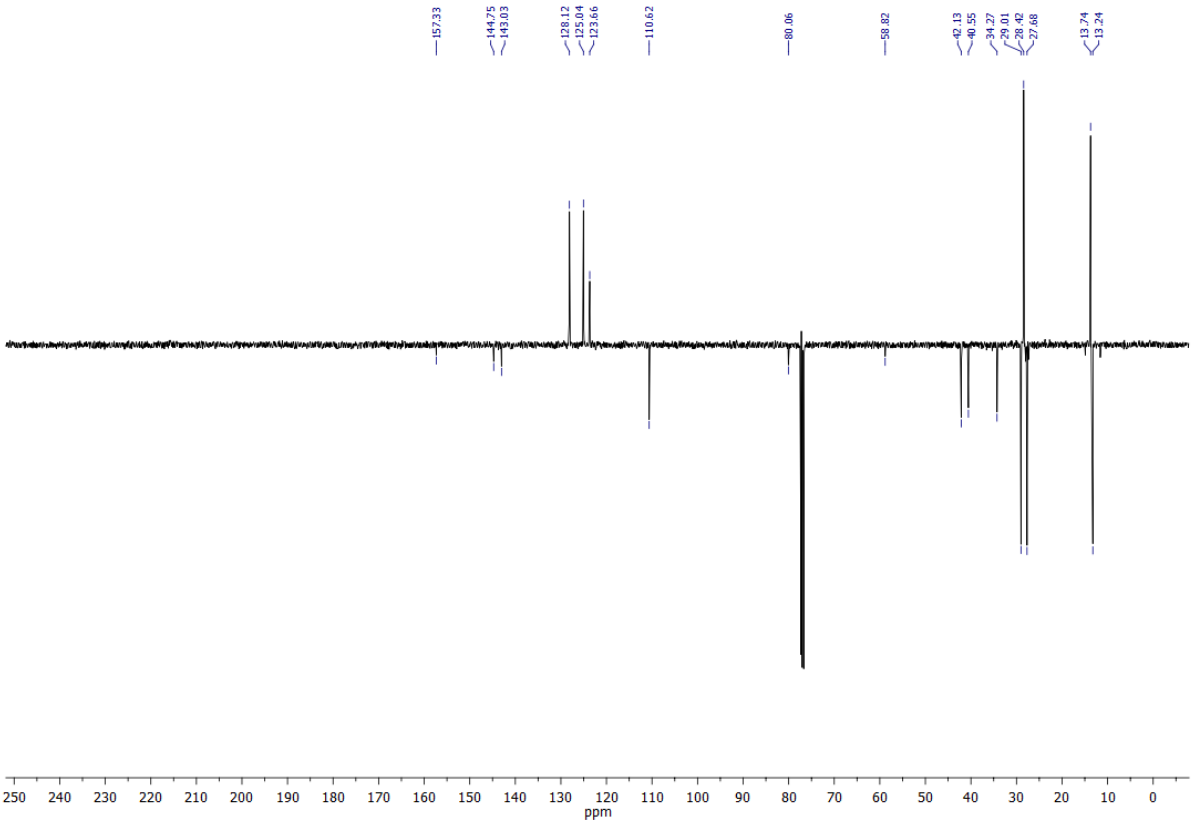


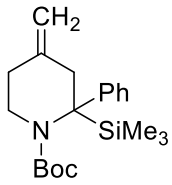

**8a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



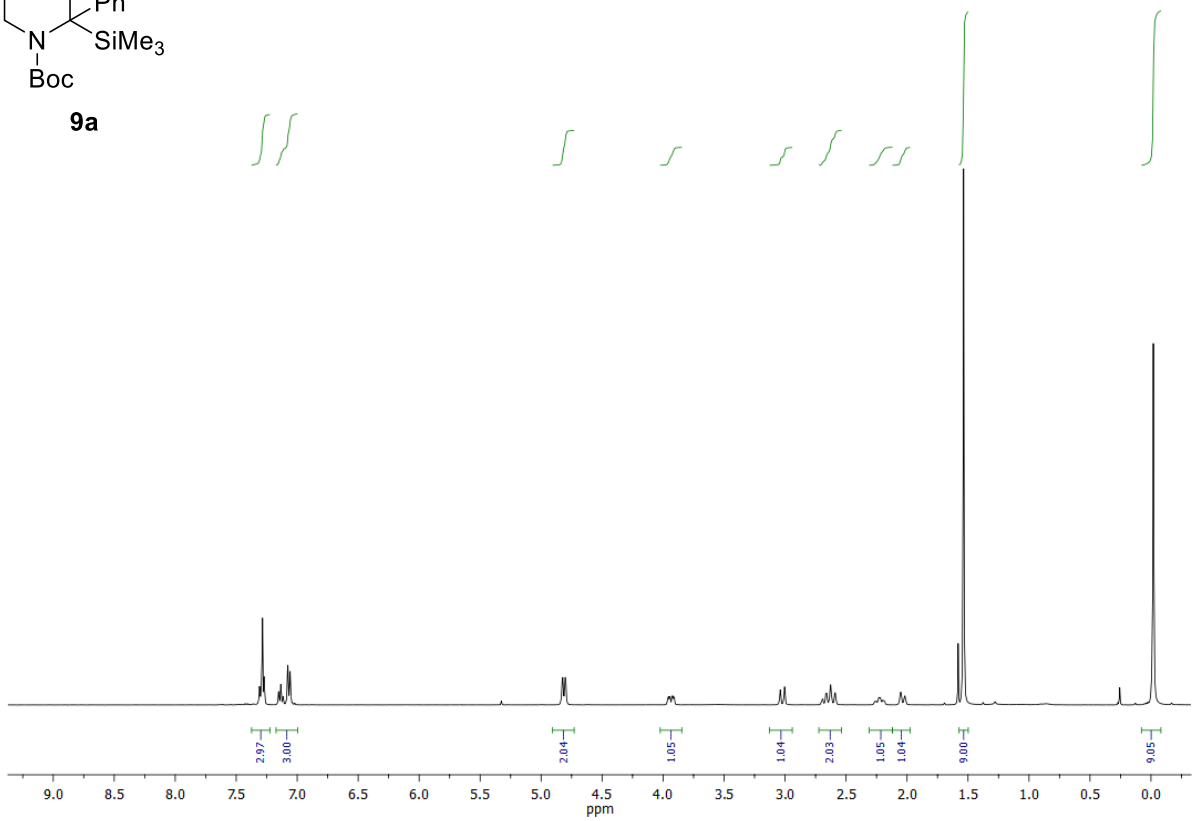

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



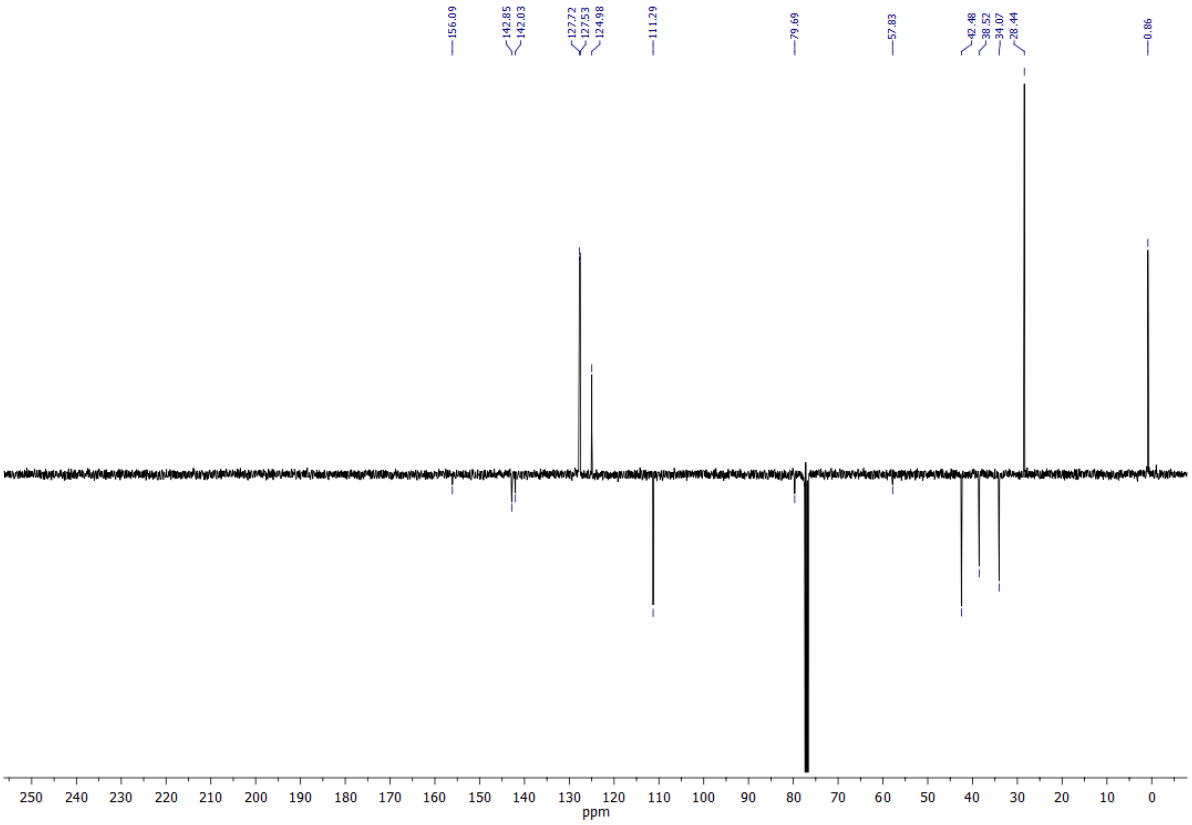


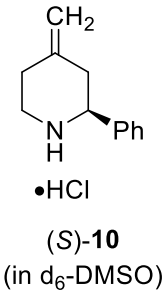

**9a**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



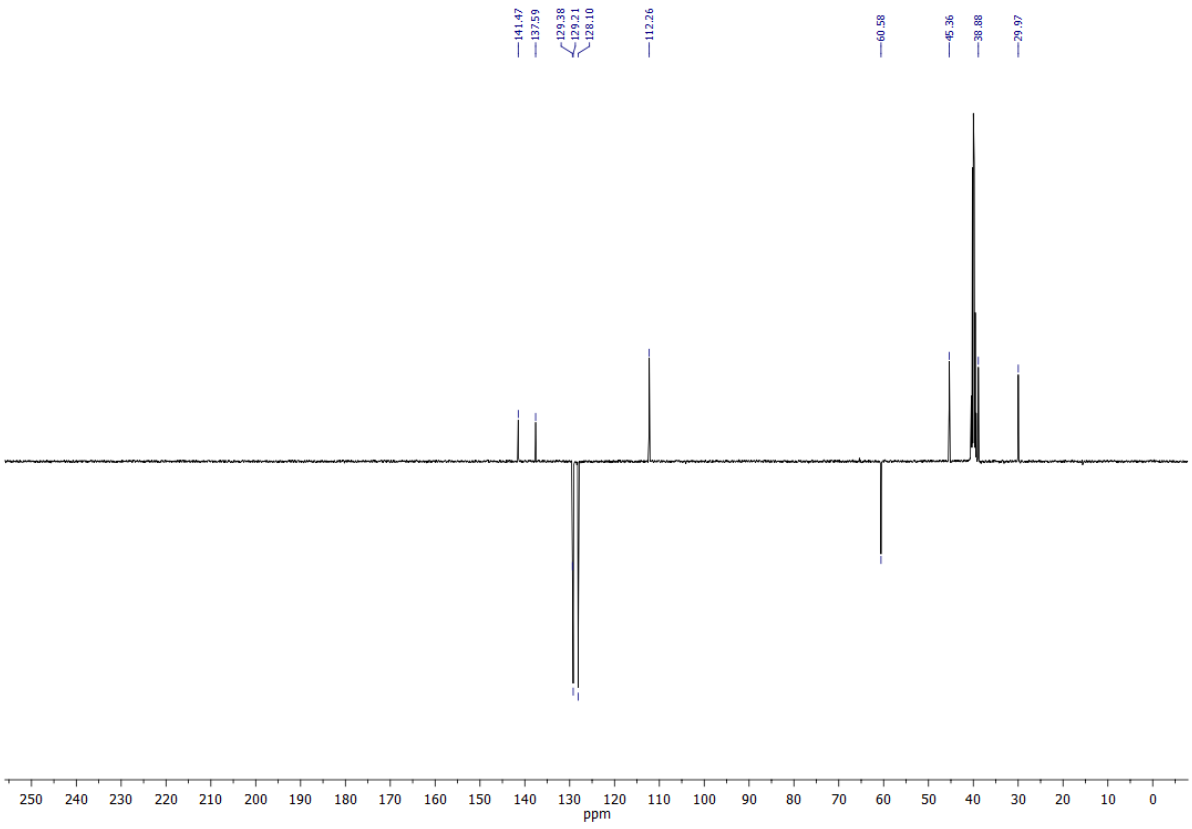


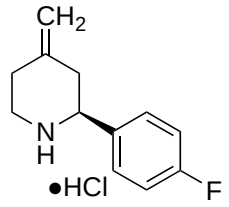

(*S*)-**10**
(in $d_6$-DMSO)

$^{1}$H NMR spectrum ($d_6$-DMSO, 400 MHz):



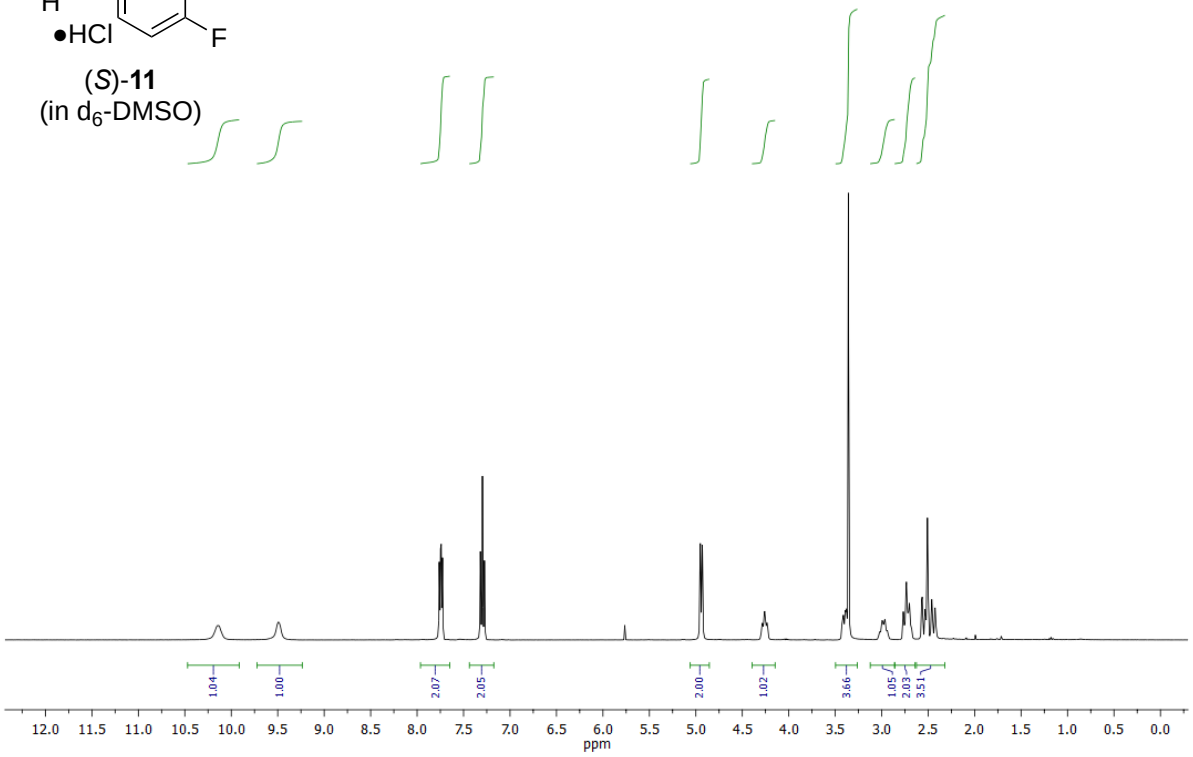

$^{13}$C{1H} NMR spectrum ($d_6$-DMSO, 100 MHz):



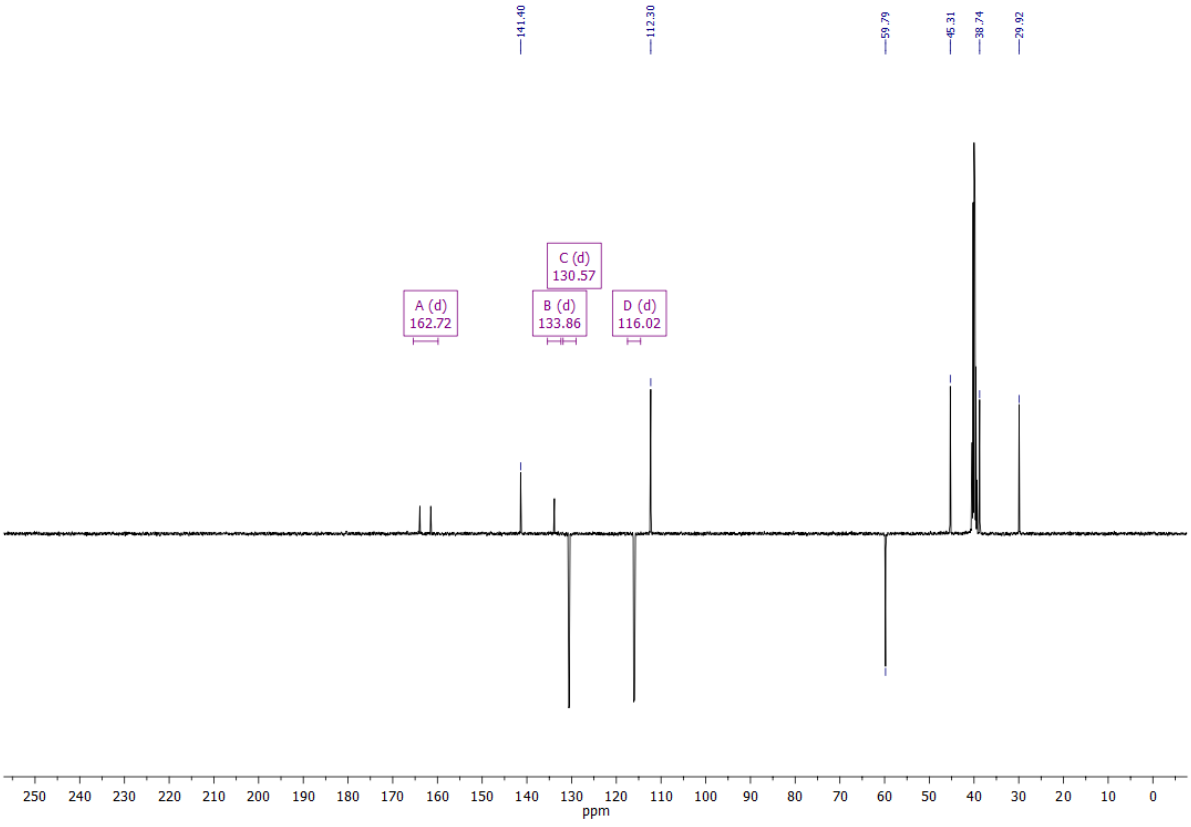



(*S*)-**11**
(in $d_6$-DMSO)

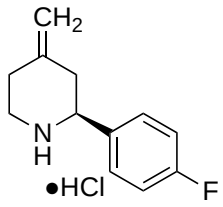
$^{1}$H NMR spectrum ($d_6$-DMSO, 400 MHz):



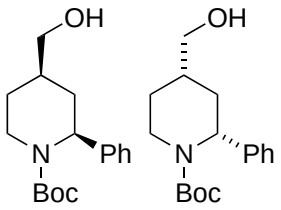

$^{13}$C{1H} NMR spectrum ($d_6$-DMSO, 100 MHz):



$^{19}$F NMR spectrum (d$_6$-DMSO, 377 MHz):




(*S*)-**11**
($^{19}$F-NMR in d$_6$-DMSO)

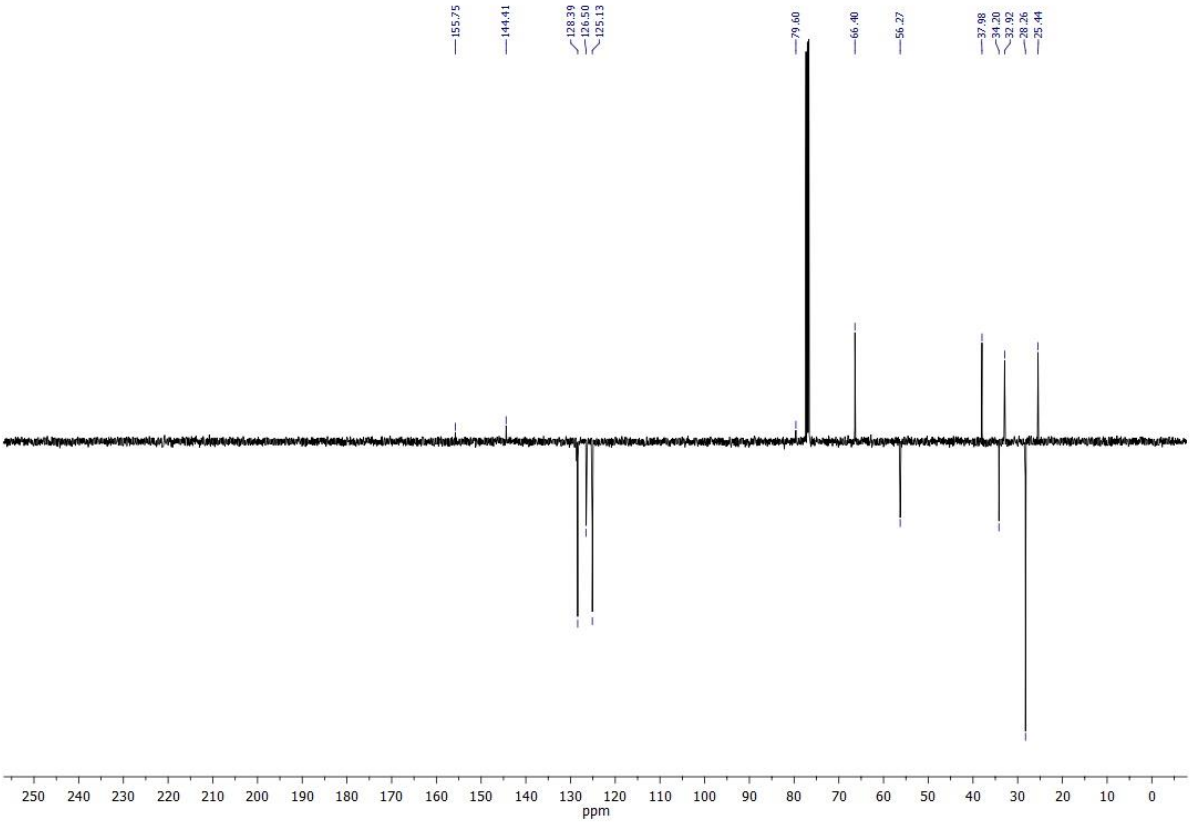


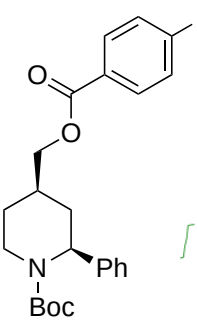

**12**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



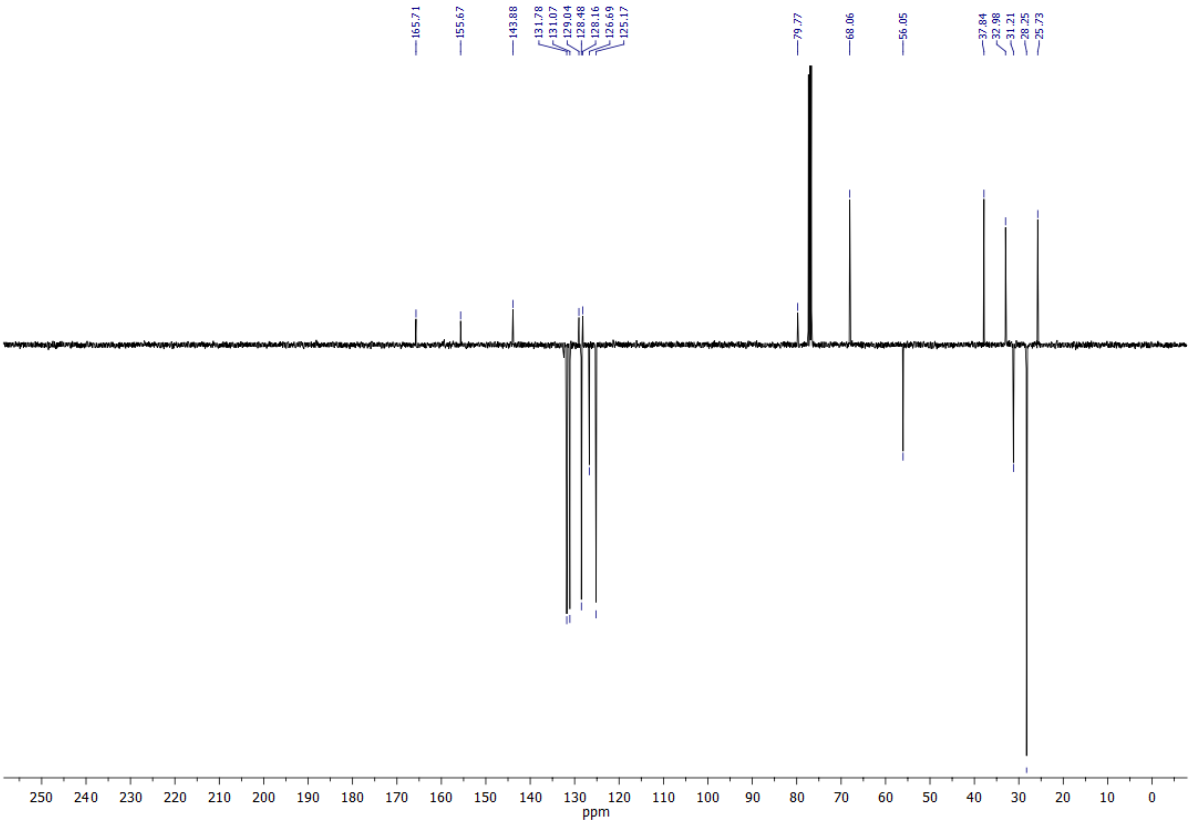


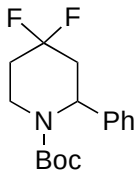

(2*S*,4*R*)-**13**

$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):




$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



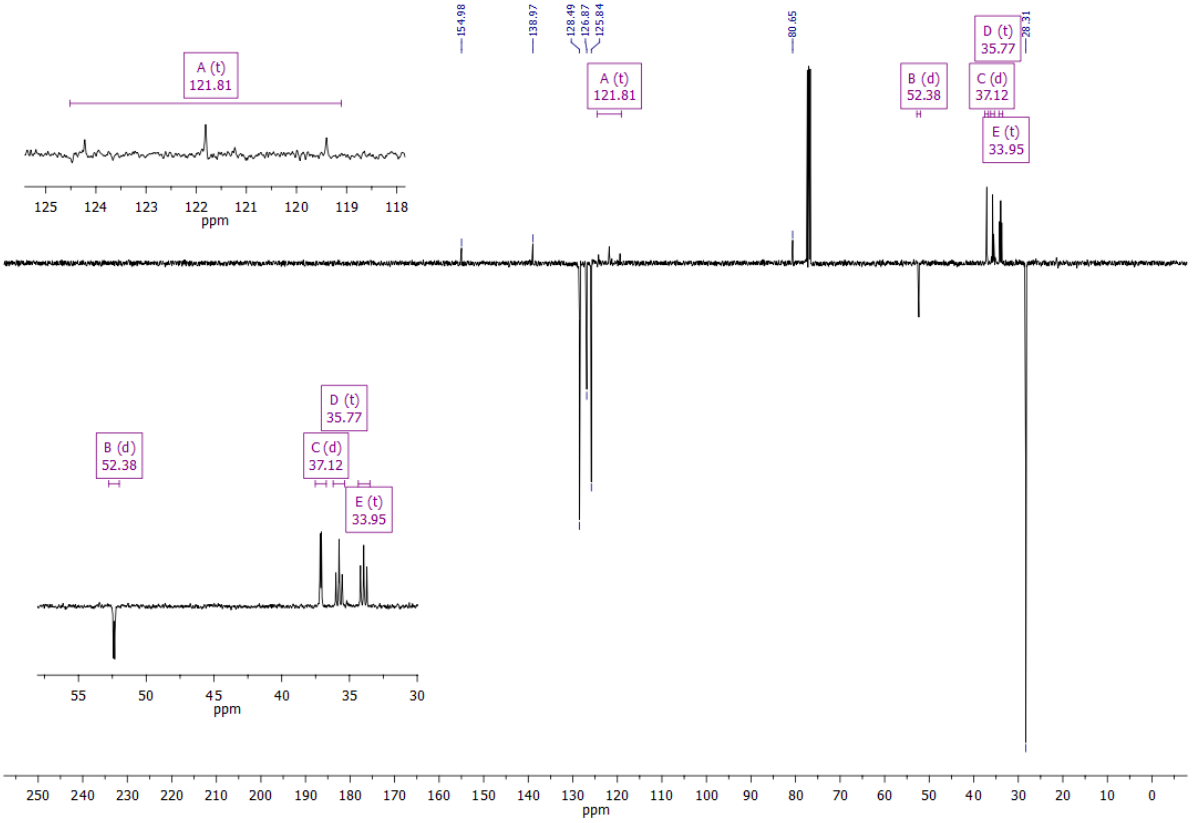



**14**

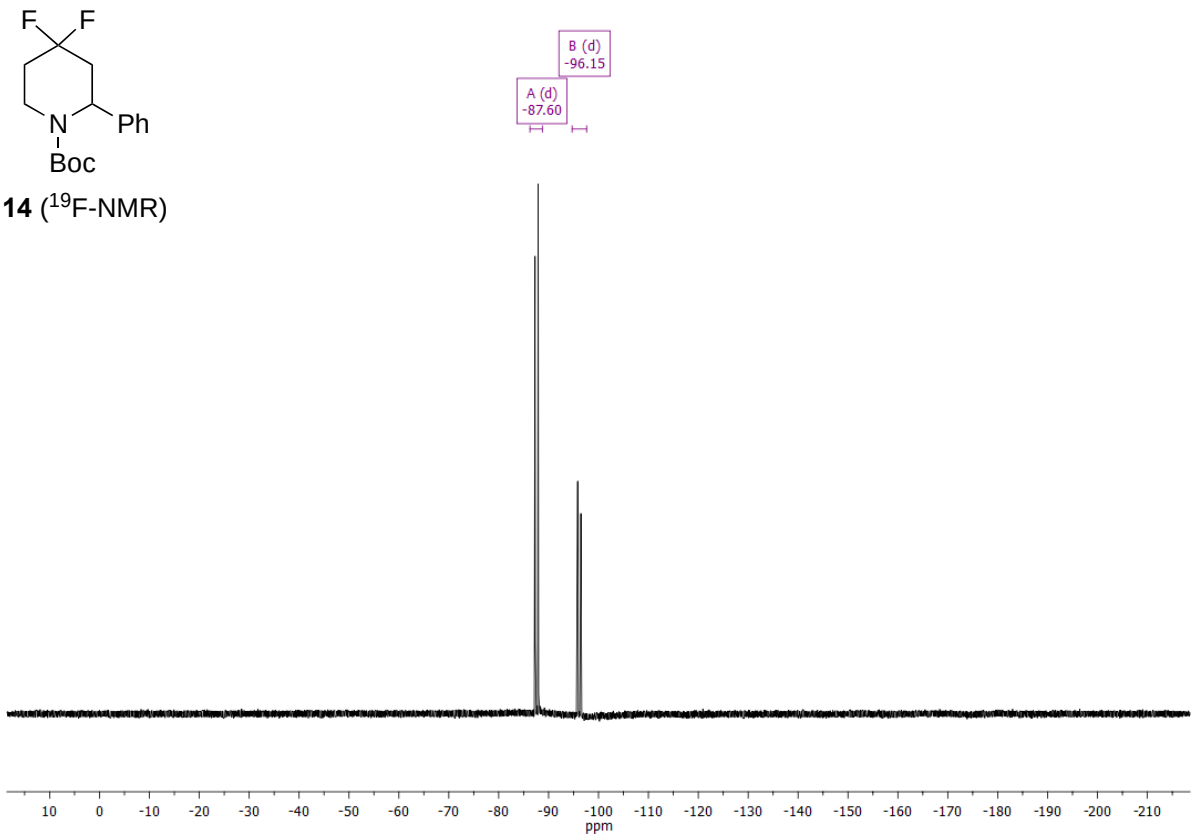
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



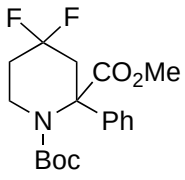

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):

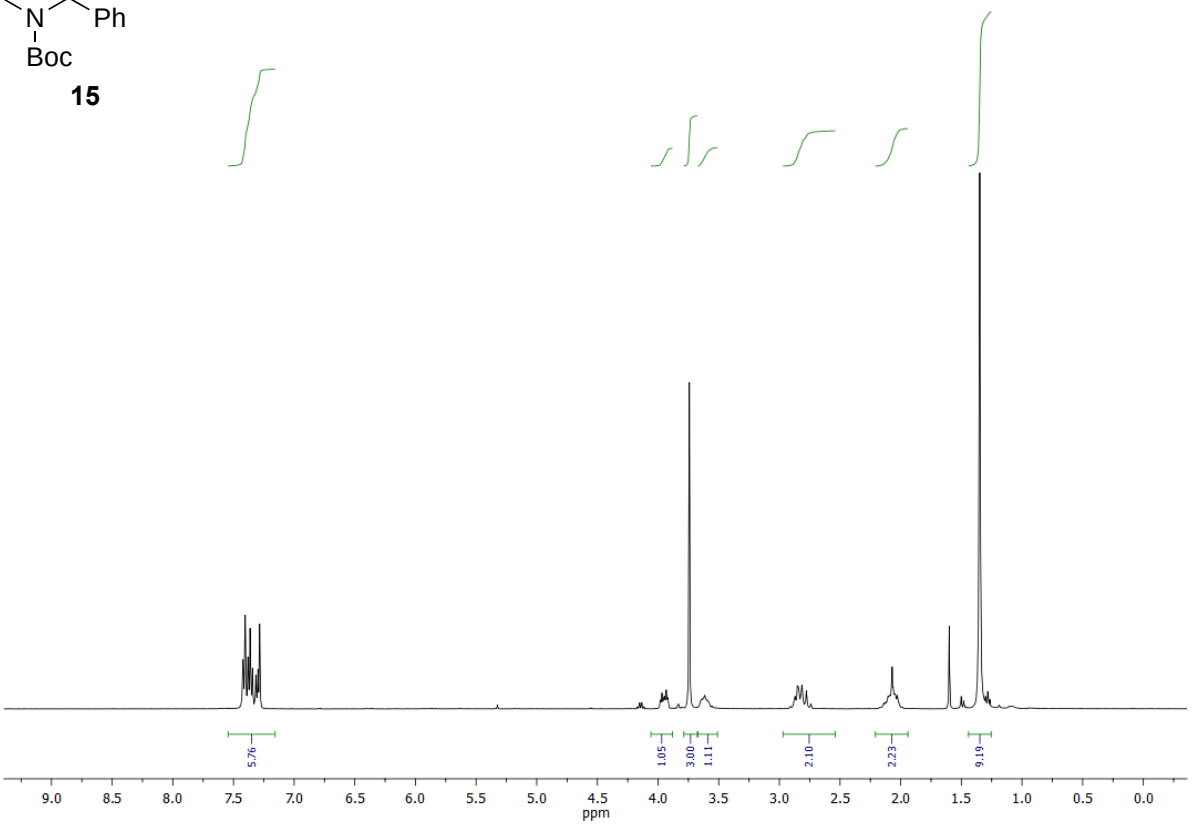



**14** ($^{19}$F-NMR)

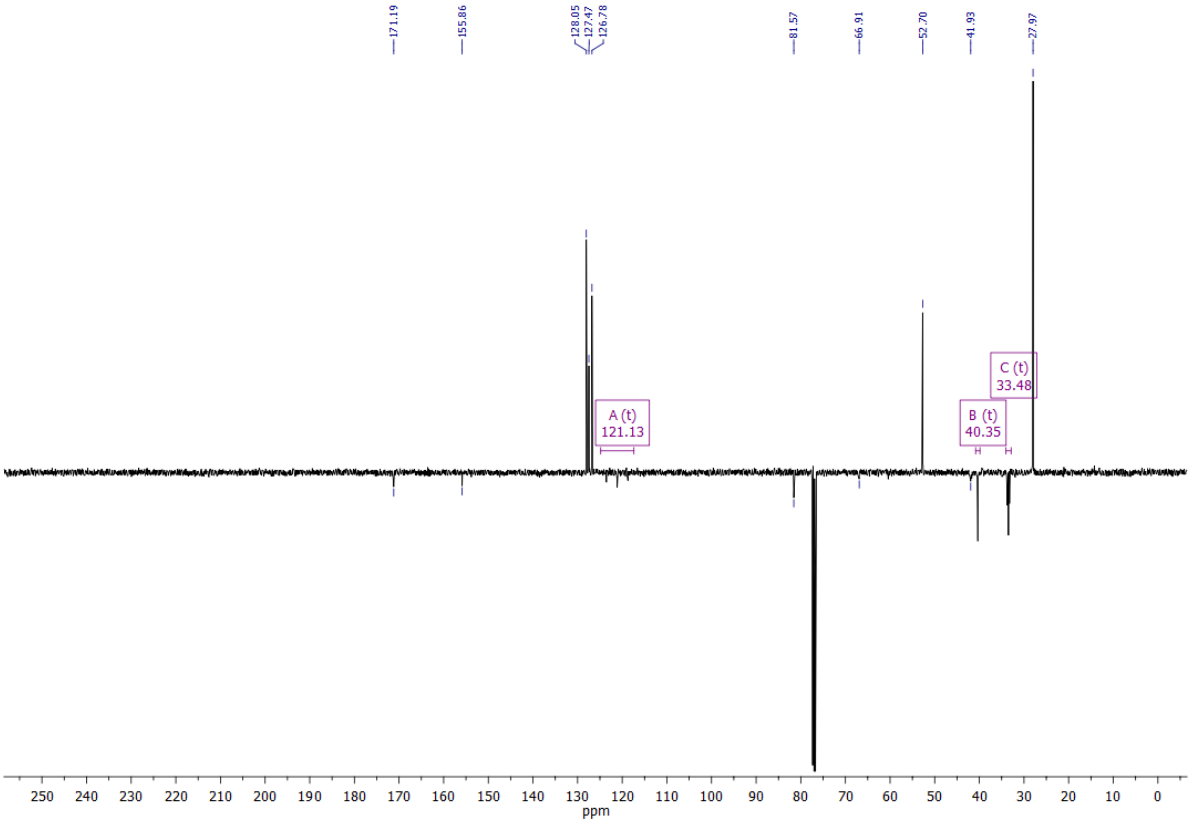



**15**

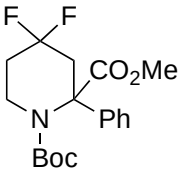
$^{1}$H NMR spectrum ($CDCl_3$, 400 MHz):



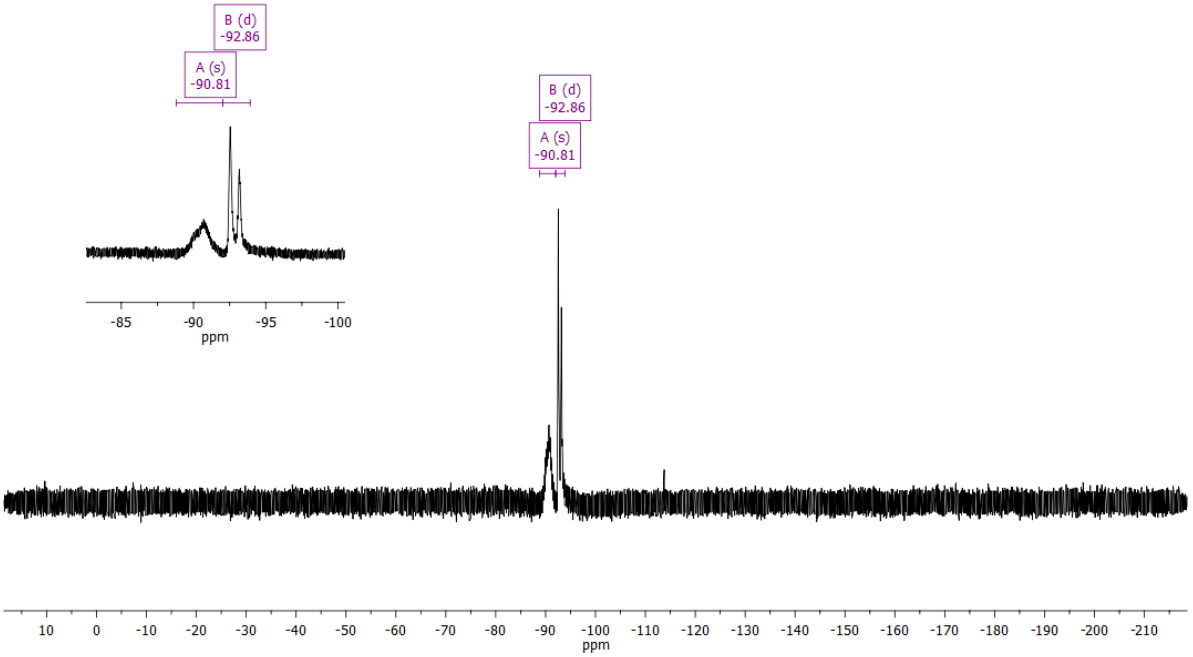

$^{13}$C{1H} NMR spectrum ($CDCl_3$, 100 MHz):



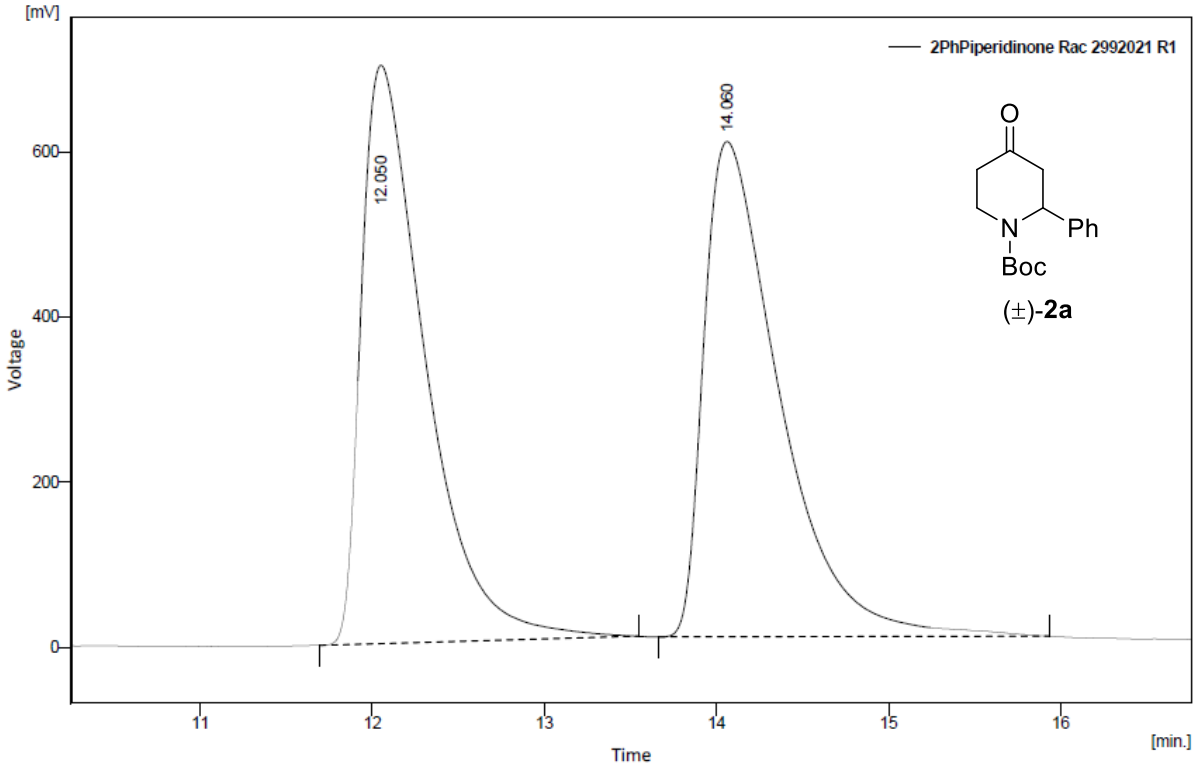
$^{19}$F NMR spectrum ($CDCl_3$, 377 MHz):

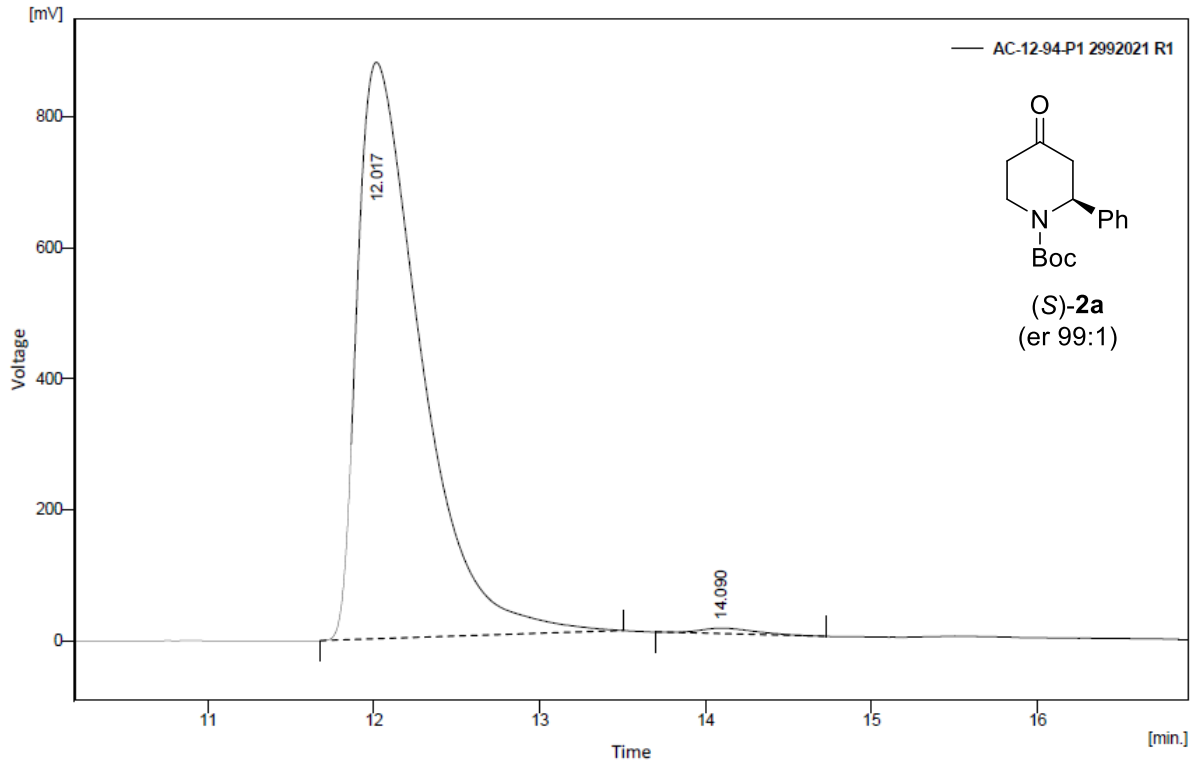


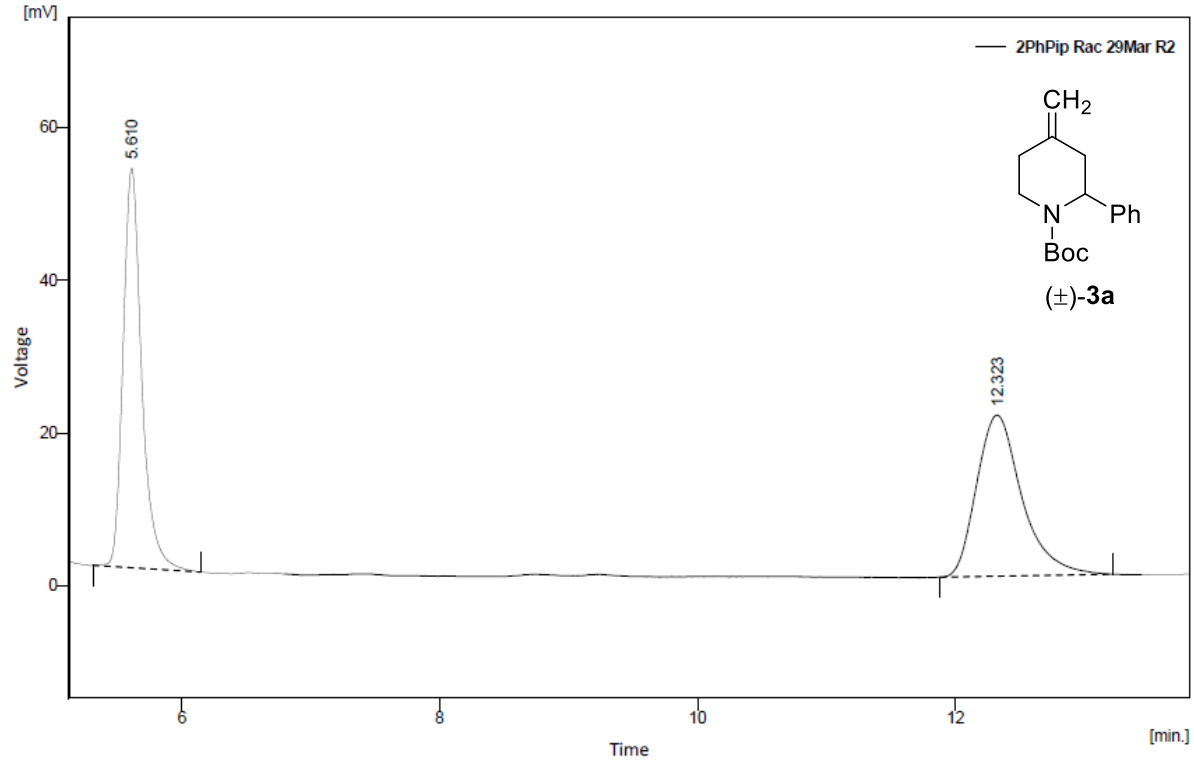

**15** ($^{19}$F-NMR)

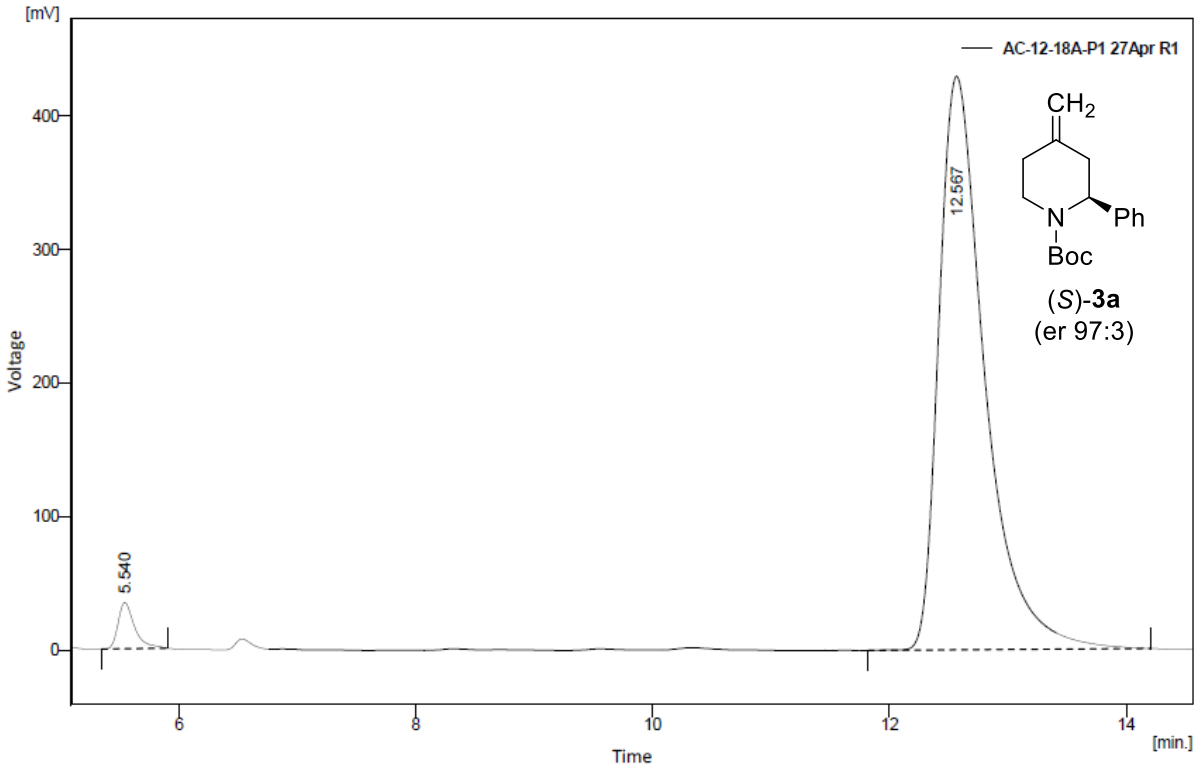


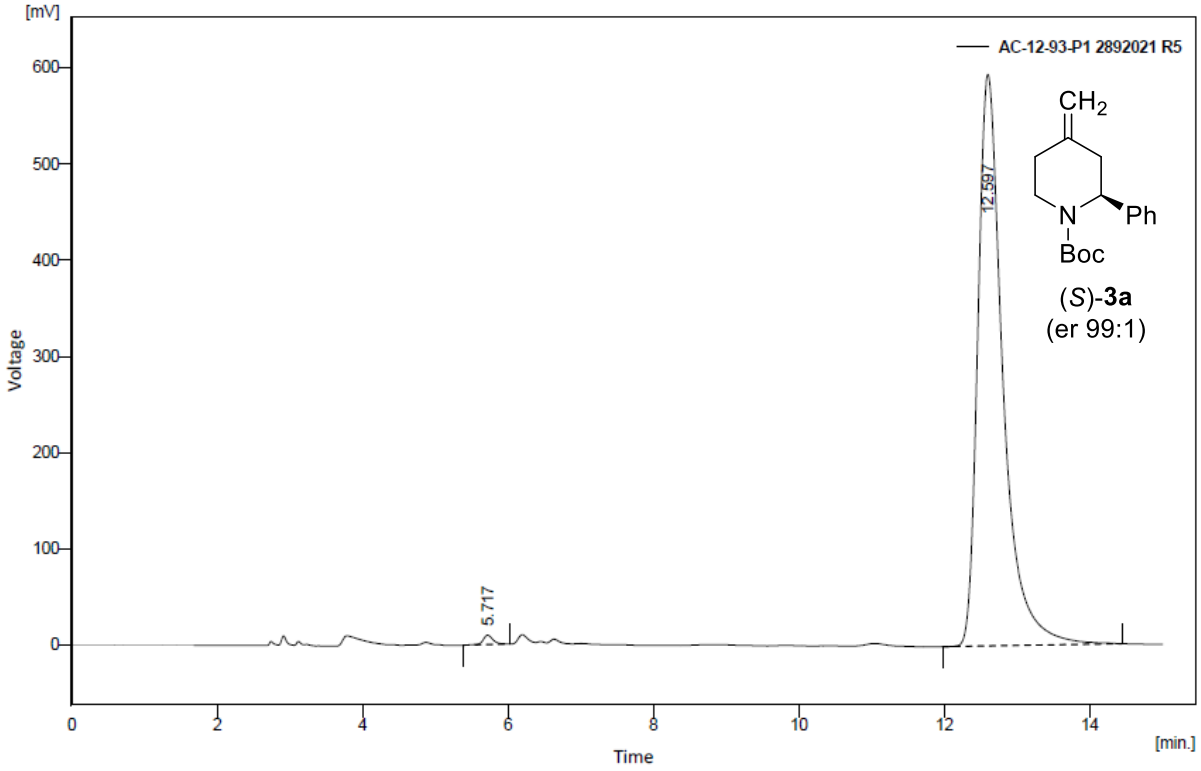
## 5. HPLC traces

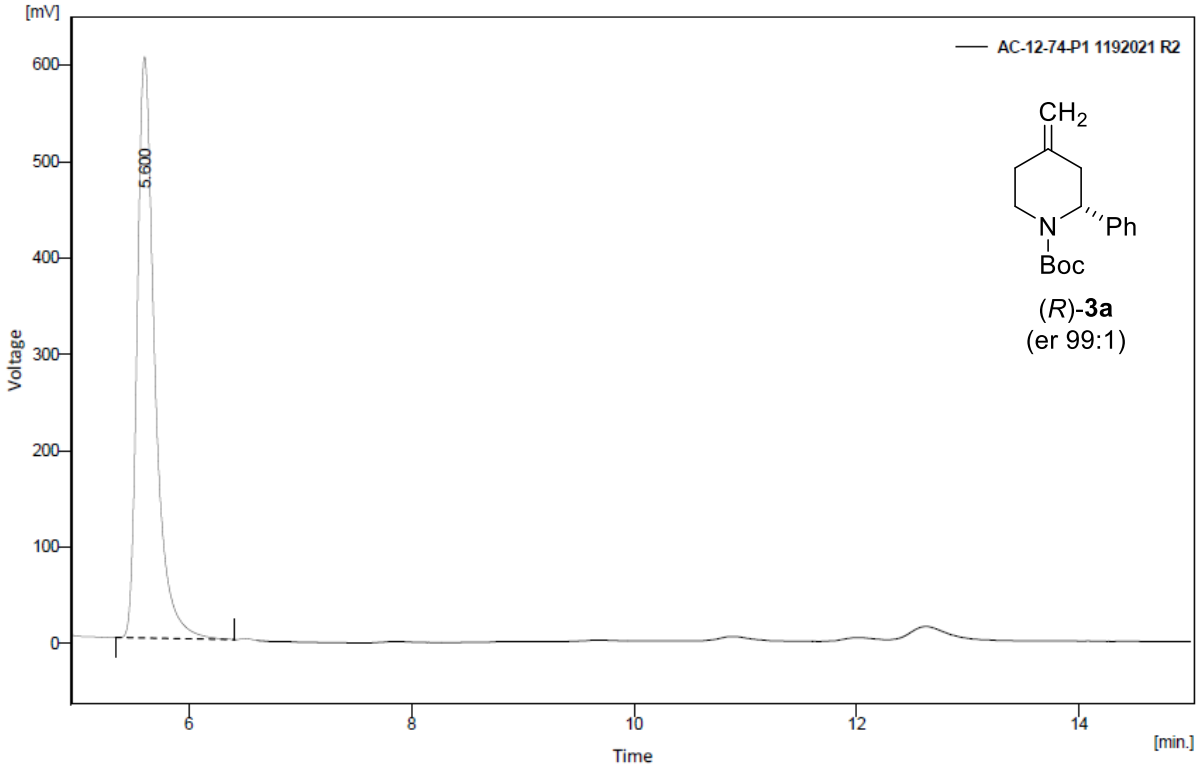


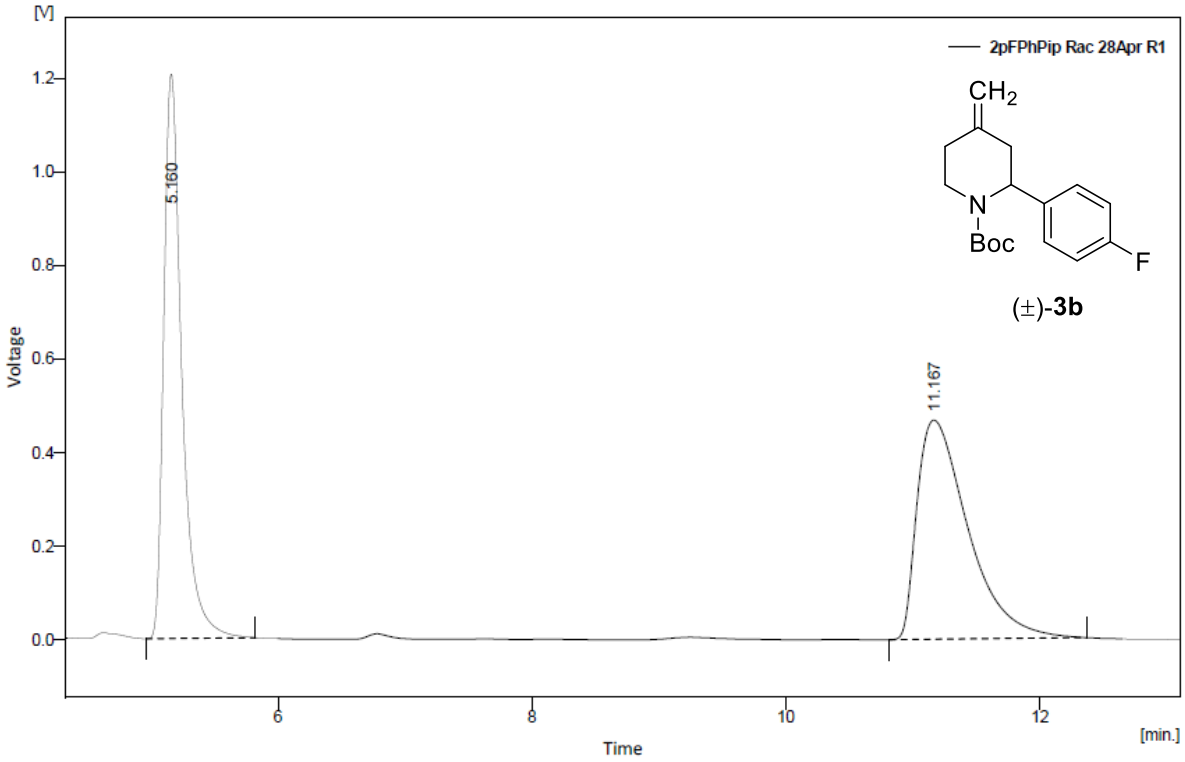

[mV]
2PhPip Rac 29Mar R2
5.610
12.323
Voltage
Time
[min.]
(±)-3a


[mV]
AC-12-18A-P1 27Apr R1
5.540
12.567
Voltage
Time
[min.]
(S)-3a
(er 97:3)


[mV]
AC-12-93-P1 2892021 R5
CH2
Ph
N
Boc
(S)-3a
(er 99:1)
12.597
5.717
Voltage
Time
[min.]

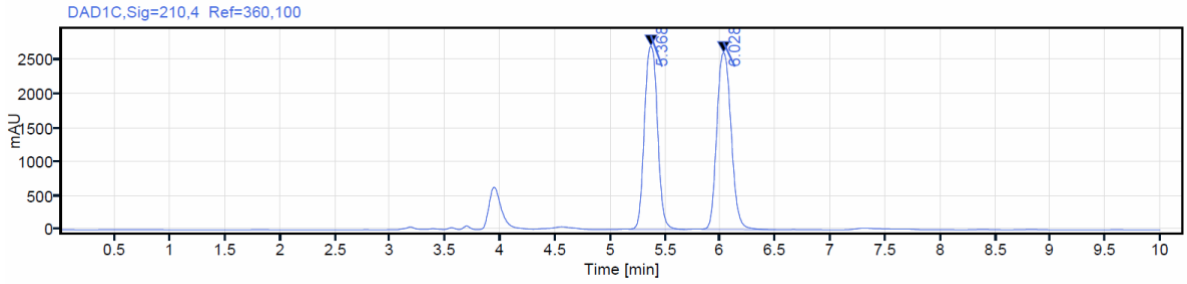

[mV]
AC-12-74-P1 1192021 R2
CH2
Ph
N
Boc
(R)-3a
(er 99:1)
5.600
Voltage
Time
[min.]

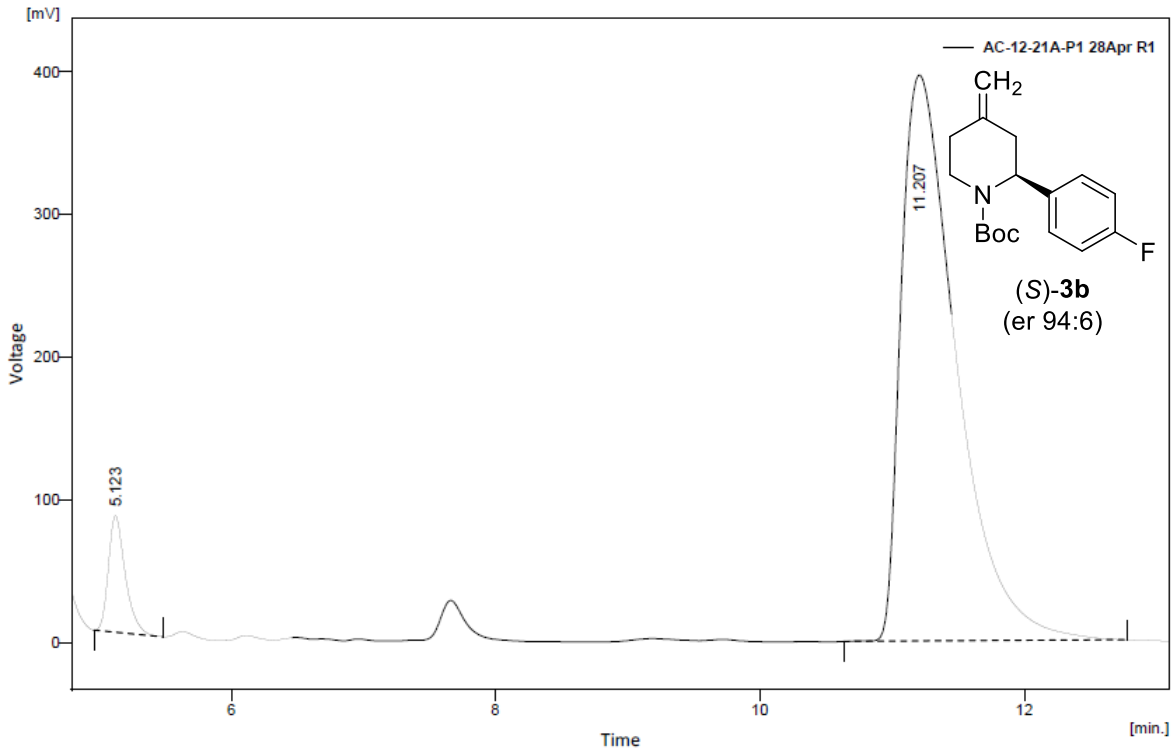
HPLC of (±)-**3b** with a Phenomenex Cellulose-2 column:




HPLC of (±)-**3b** from Agilent system fitted with a Chiralcel OX-H column:

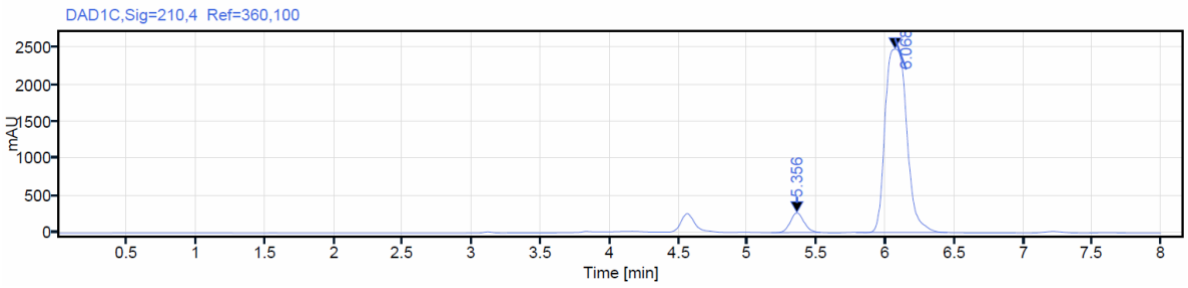
| Chiralcel OX-H Column | | | |
|---|---|---|---|
| | | | |
| | $R_t$/min | Area/mAU.s | Area/% |
| 1 | 5.368 | 22318.85 | 48.57 |
| 2 | 6.028 | 23632.81 | 51.43 |
| | Total | 45951.66 | 100.00 |





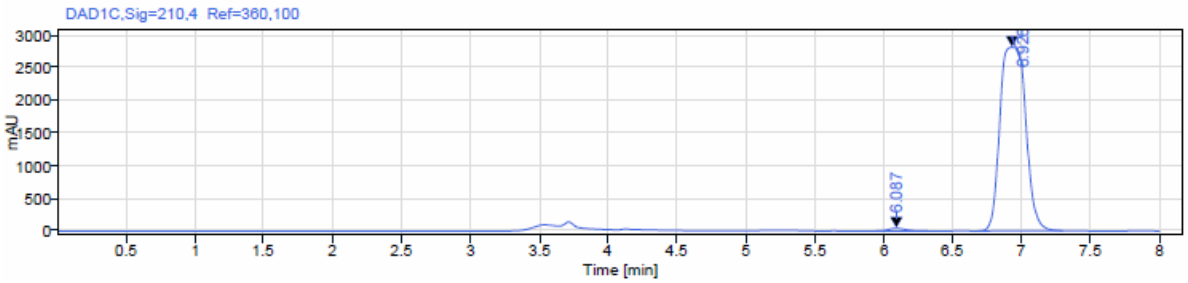

HPLC of (*S*)-**3b** (er 94:6) from Agilent system fitted with a Chiralcel OX-H column:

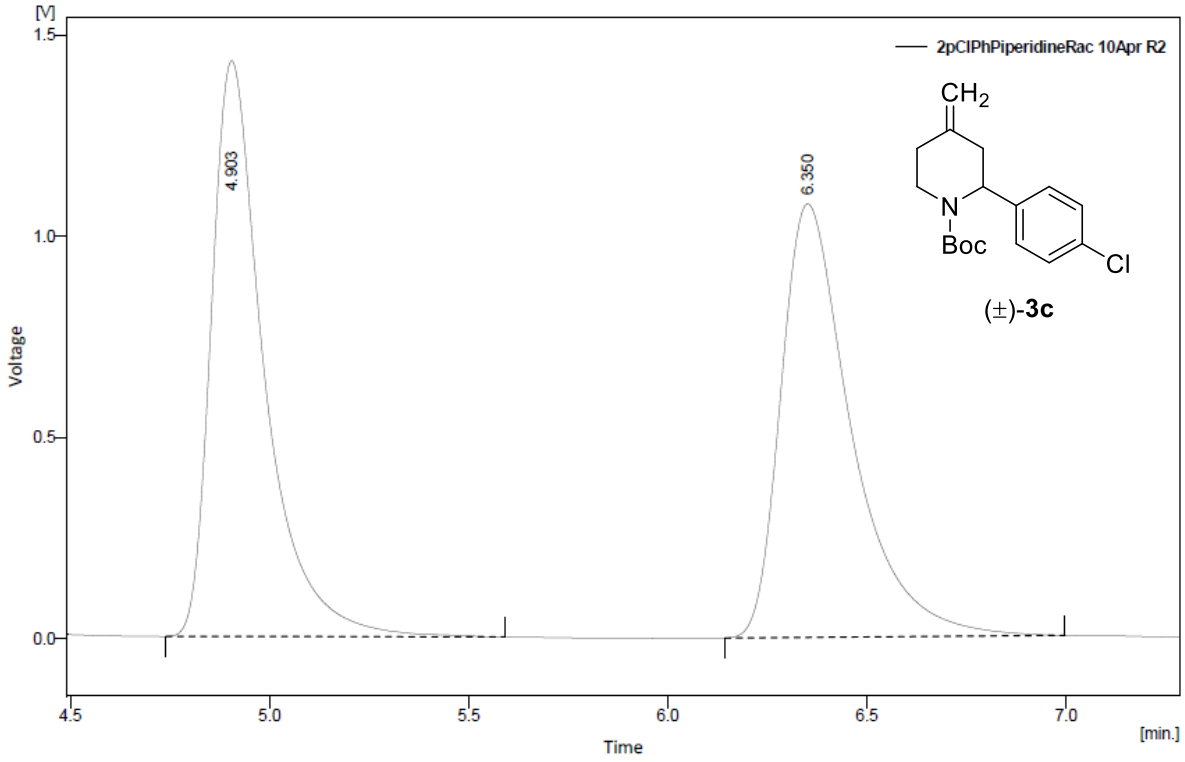
| Chiralcel OX-H Column | | | |
|---|---|---|---|
| | | | |
| | $R_t$/min | Area/mAU.s | Area/% |
| 1 | 5.356 | 1818.44 | 6.33 |
| 2 | 6.068 | 26888.92 | 93.67 |
| | Total | 28707.36 | 100.00 |

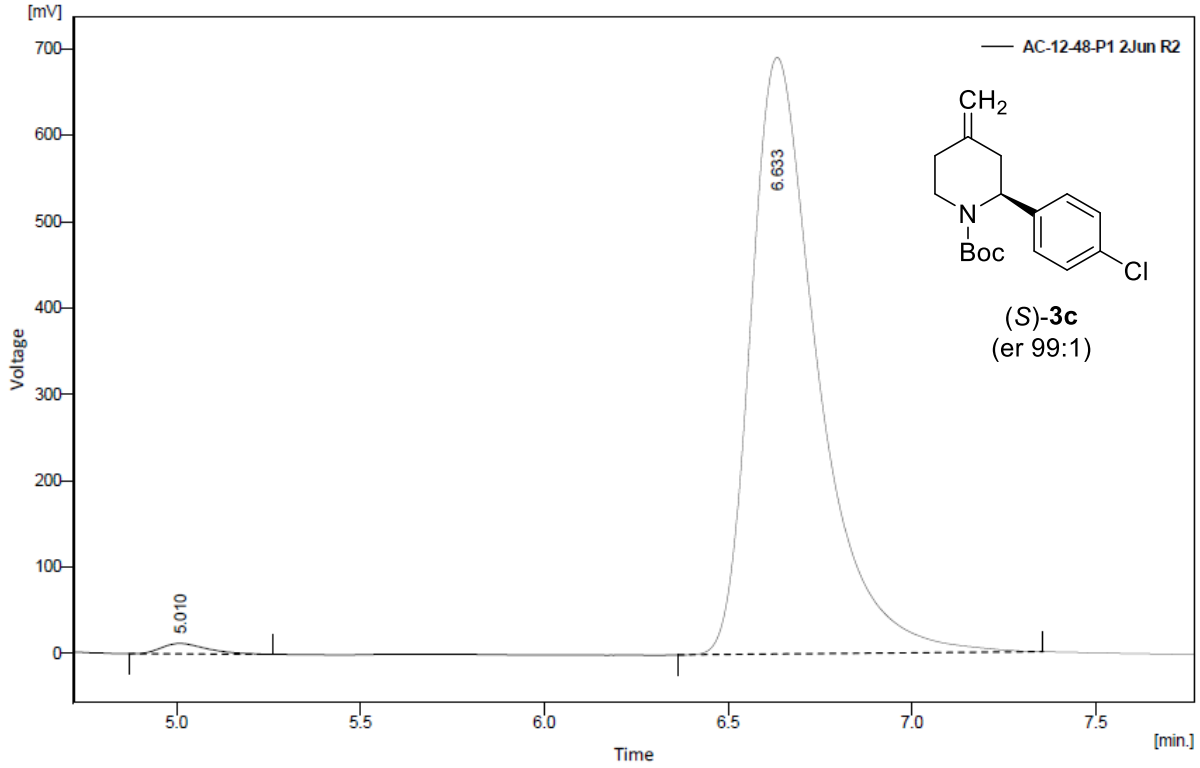


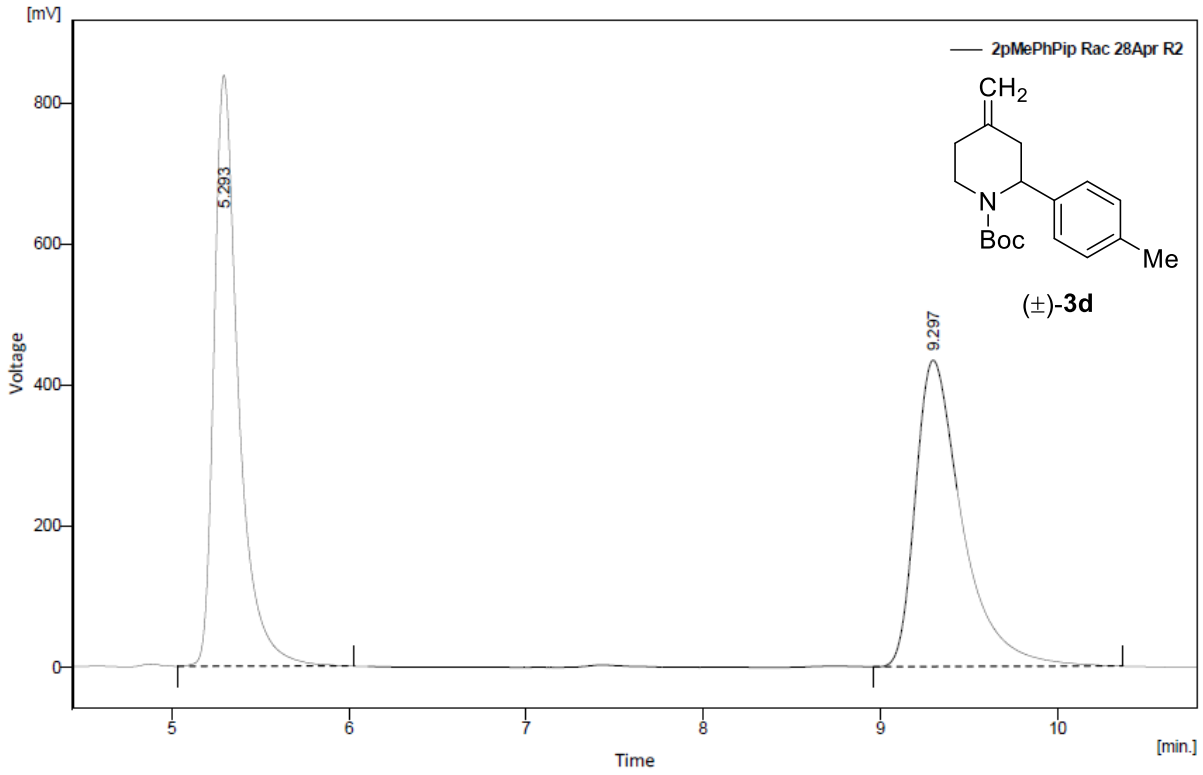
HPLC of (*S*)-**3b** (er 99:1) from Agilent system fitted with a Chiralcel OX-H column:

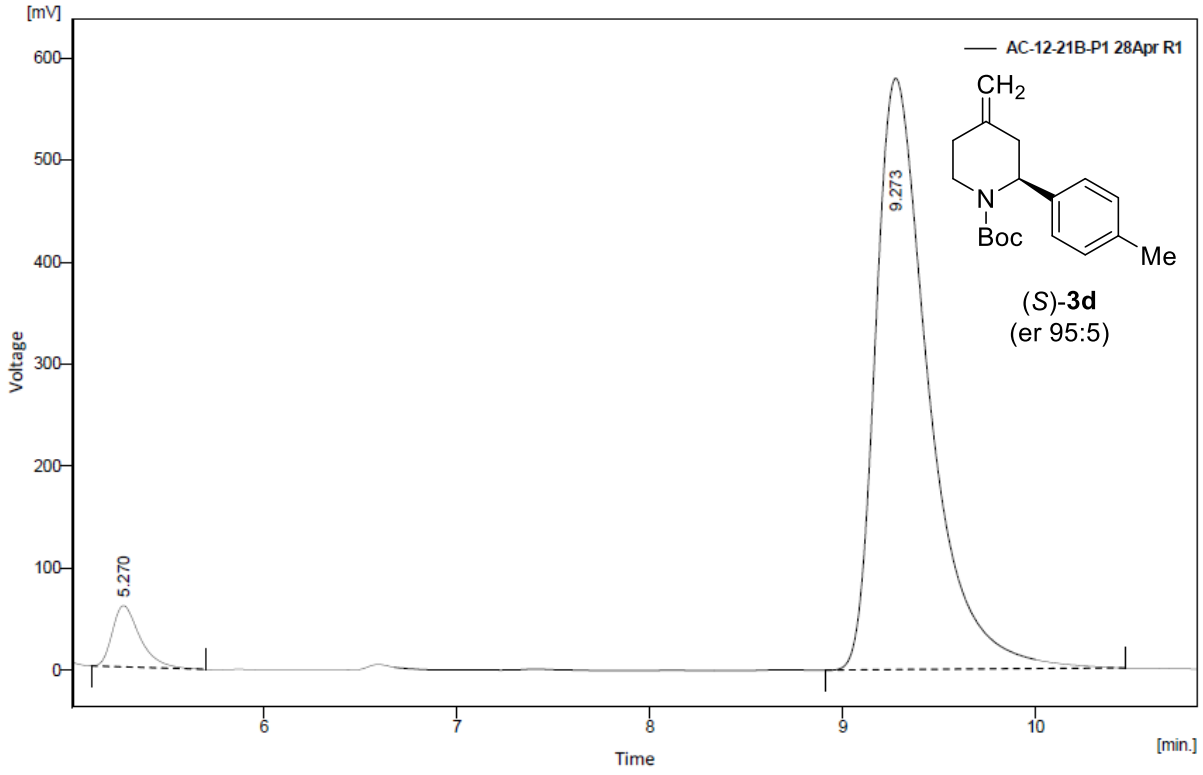
| Chiralcel OX-H Column | | | |
|---|---|---|---|
| | | | |
| | $R_f$/min | Area/mAU.s | Area/% |
| 1 | 6.087 | 357.89 | 0.97 |
| 2 | 6.926 | 36630.58 | 99.03 |
| | Total | 36988.47 | 100.00 |

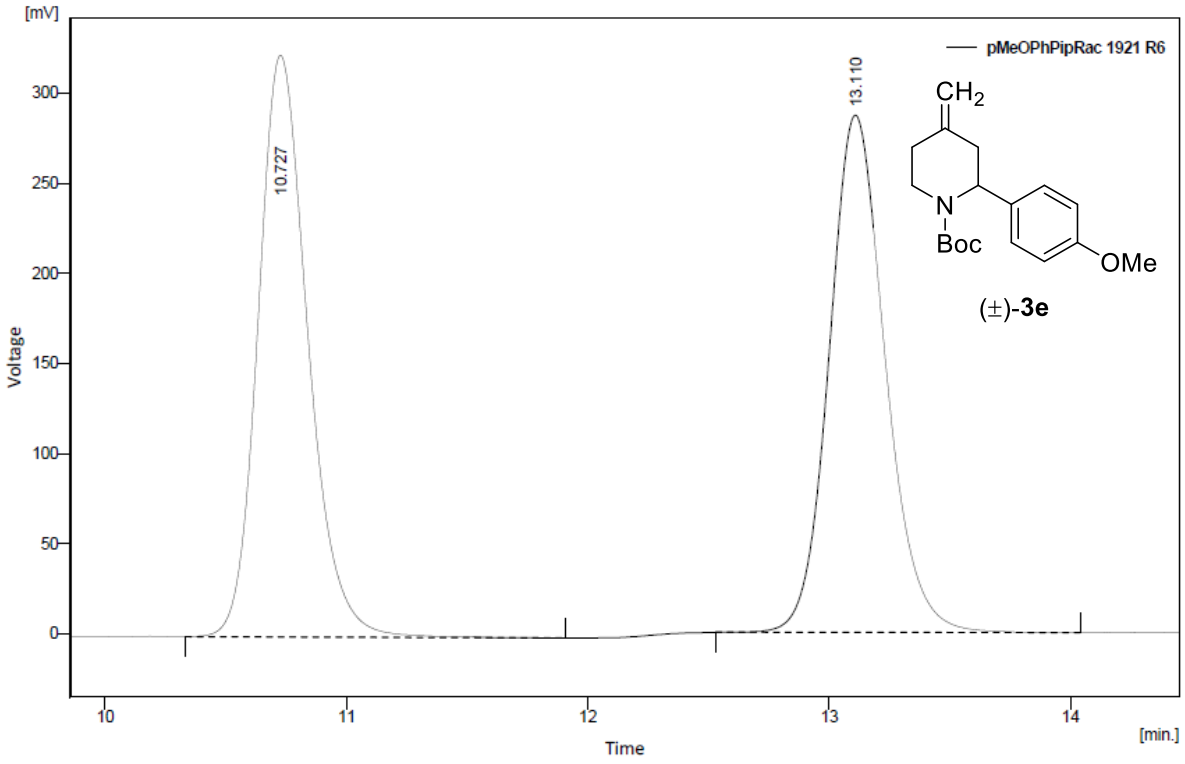


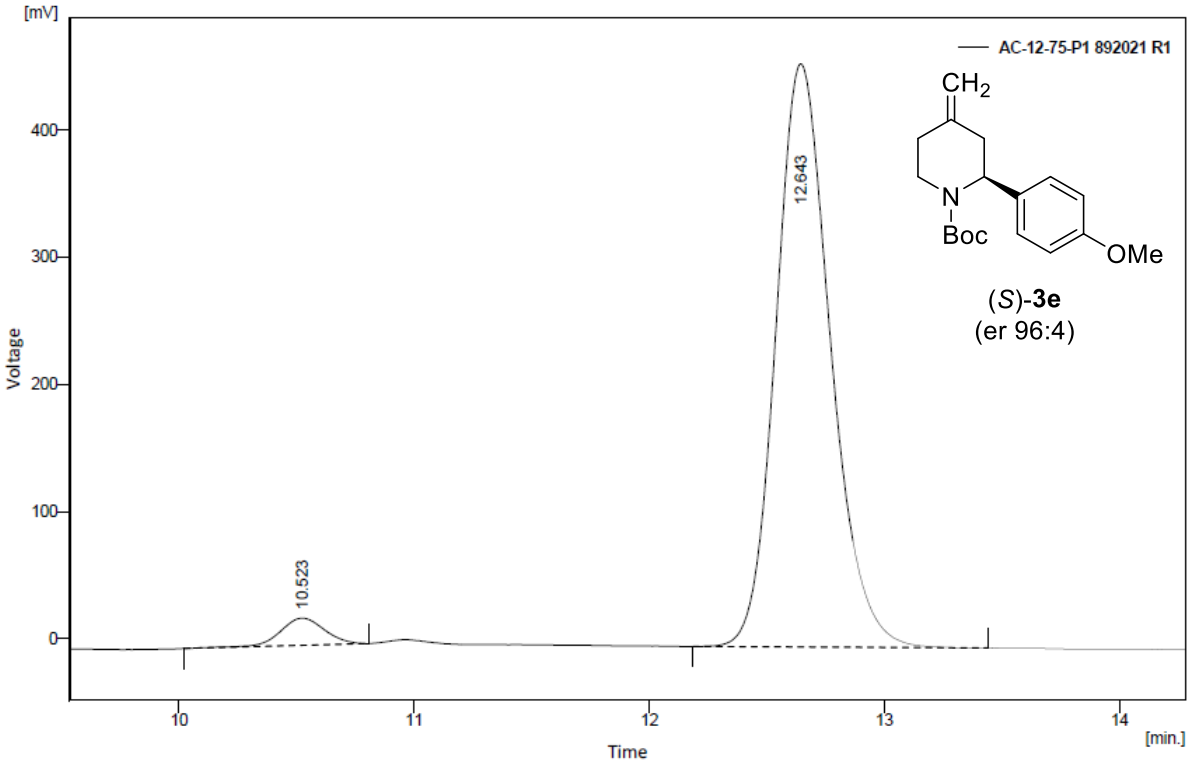

[V]
1.5
1.0
0.5
0.0
Voltage
2pClPhPiperidineRac 10Apr R2
4.903
6.350
CH2
N
Boc
Cl
(±)-3c
4.5
5.0
5.5
6.0
6.5
7.0
[min.]
Time

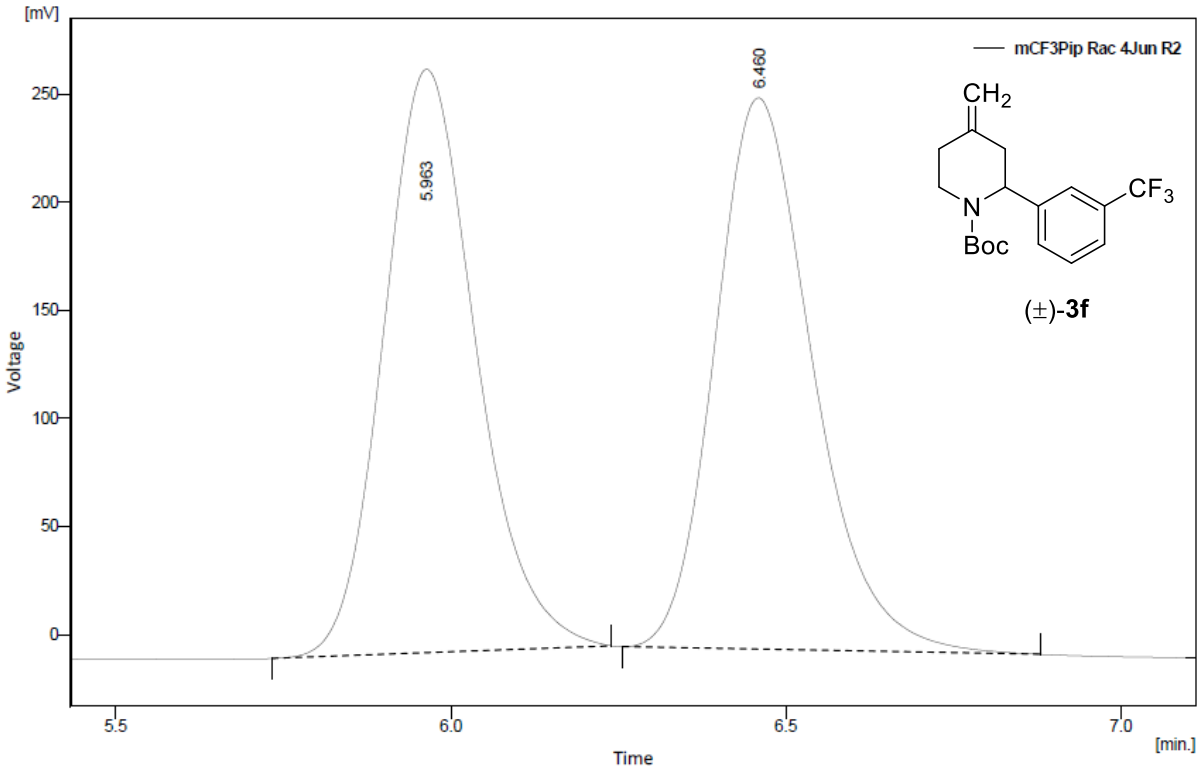

[mV]
700
600
500
400
300
200
100
0
Voltage
AC-12-48-P1 2Jun R2
6.633
5.010
CH2
N
Boc
Cl
(S)-3c
(er 99:1)
5.0
5.5
6.0
6.5
7.0
7.5
[min.]
Time

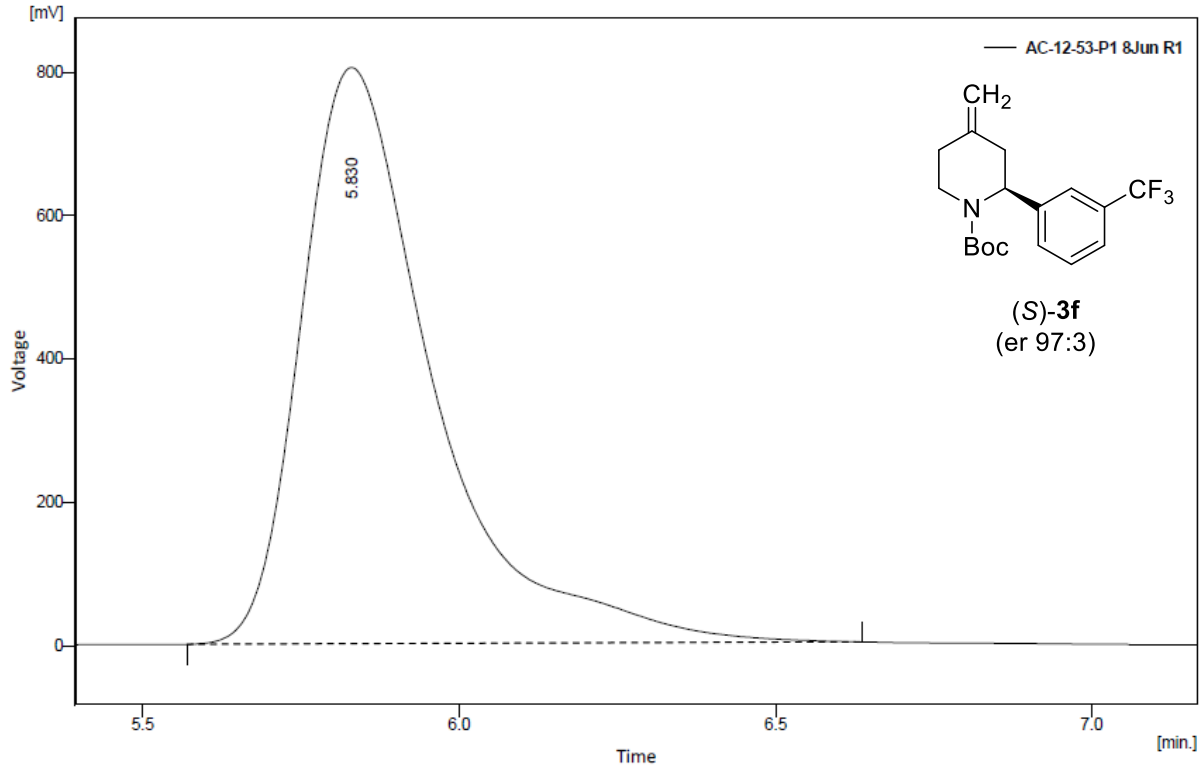

[mV]
800
600
400
200
0
Voltage
2pMePhPip Rac 28Apr R2
5.293
9.297
CH2
N
Boc
Me
(±)-3d
5
6
7
8
9
10
Time
[min.]

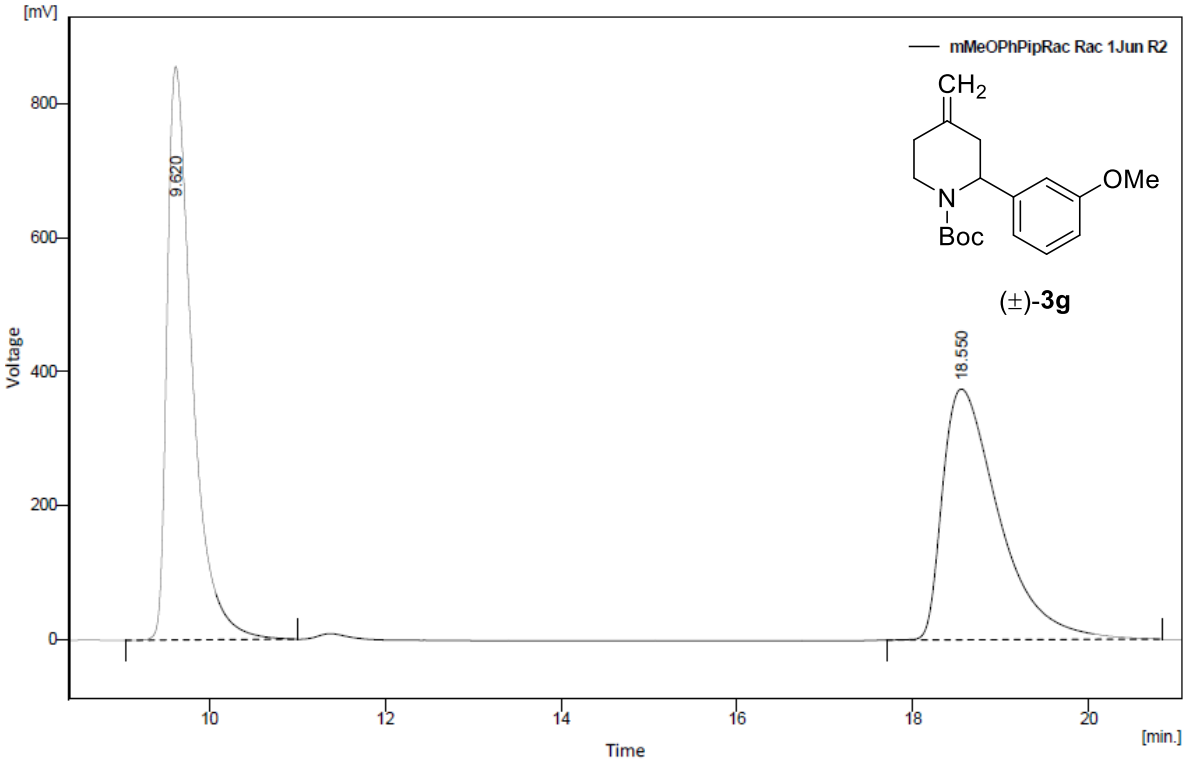

[mV]
600
500
400
300
200
100
0
Voltage
AC-12-21B-P1 28Apr R1
5.270
9.273
CH2
N
Boc
Me
(S)-3d
(er 95:5)
6
7
8
9
10
Time
[min.]

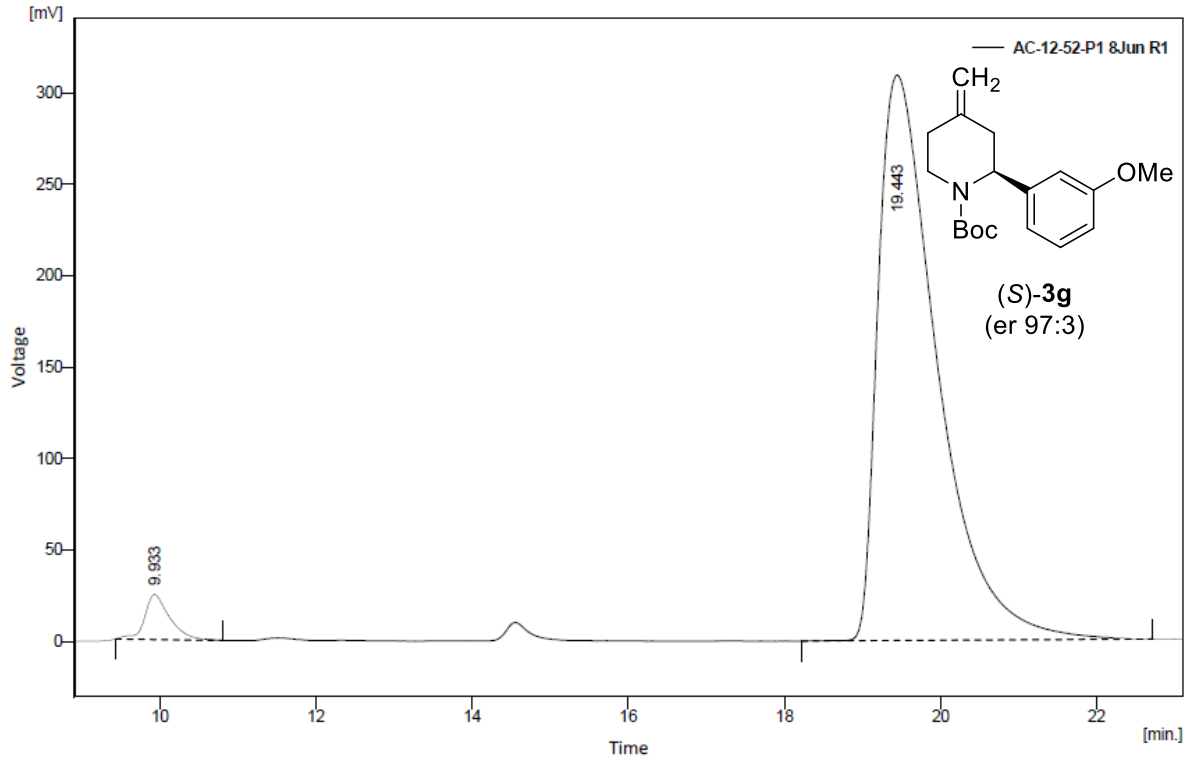

[mV]
pMeOPhPipRac 1921 R6
10.727
13.110
CH2
N
Boc
OMe
(±)-3e
Voltage
Time
[min.]

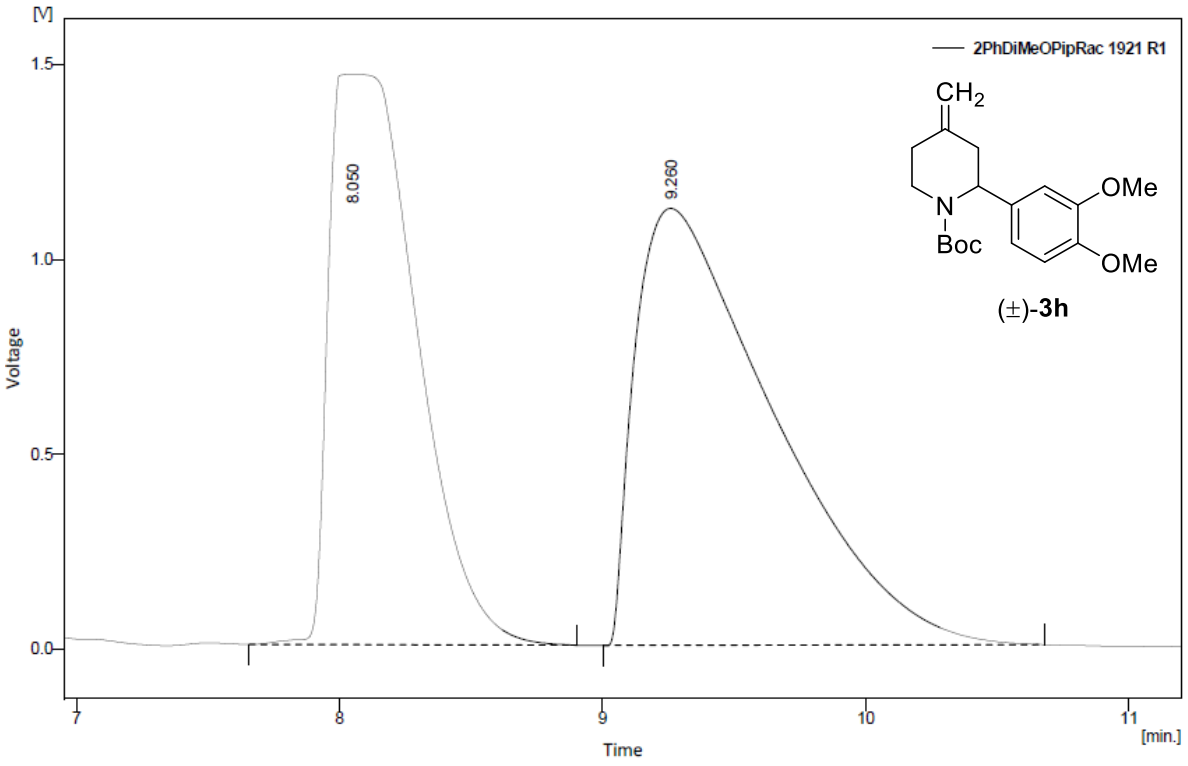

[mV]
AC-12-75-P1 892021 R1
10.523
12.643
CH2
N
Boc
OMe
(S)-3e
(er 96:4)
Voltage
Time
[min.]

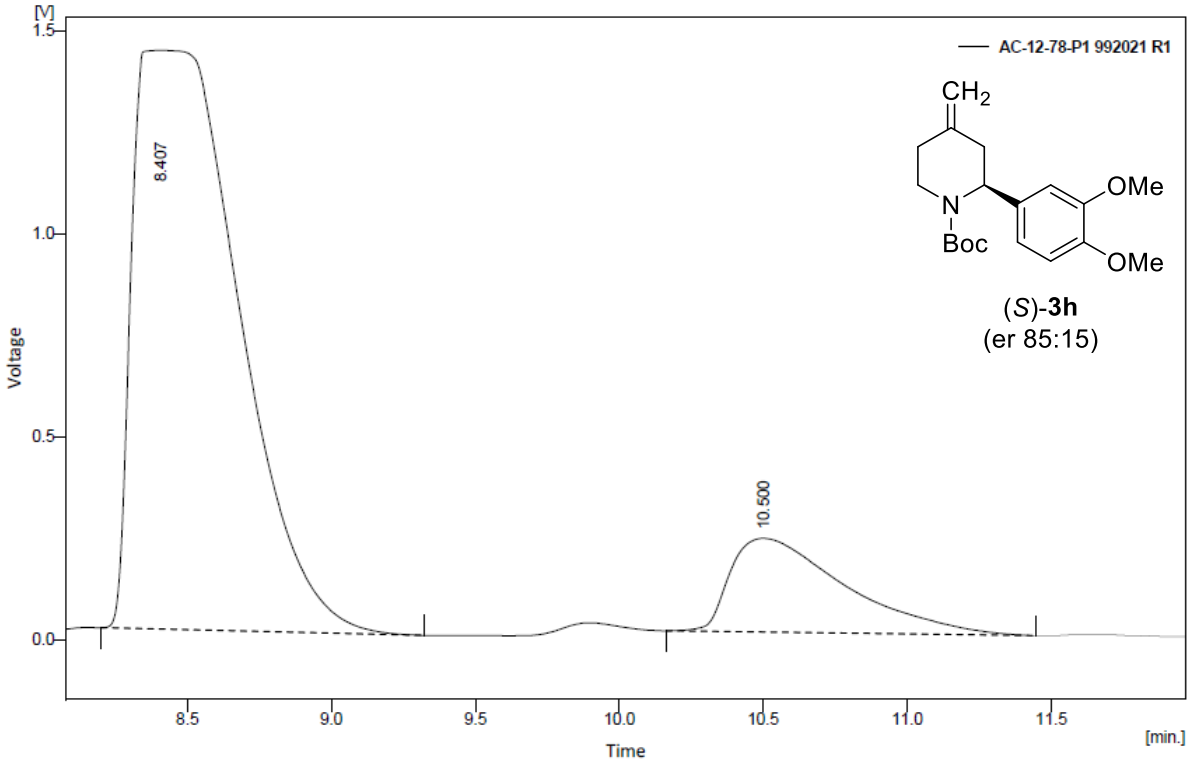

[mV]
mCF3Pip Rac 4Jun R2
5.963
6.460
CH2
CF3
N
Boc
(±)-3f
Voltage
Time
[min.]

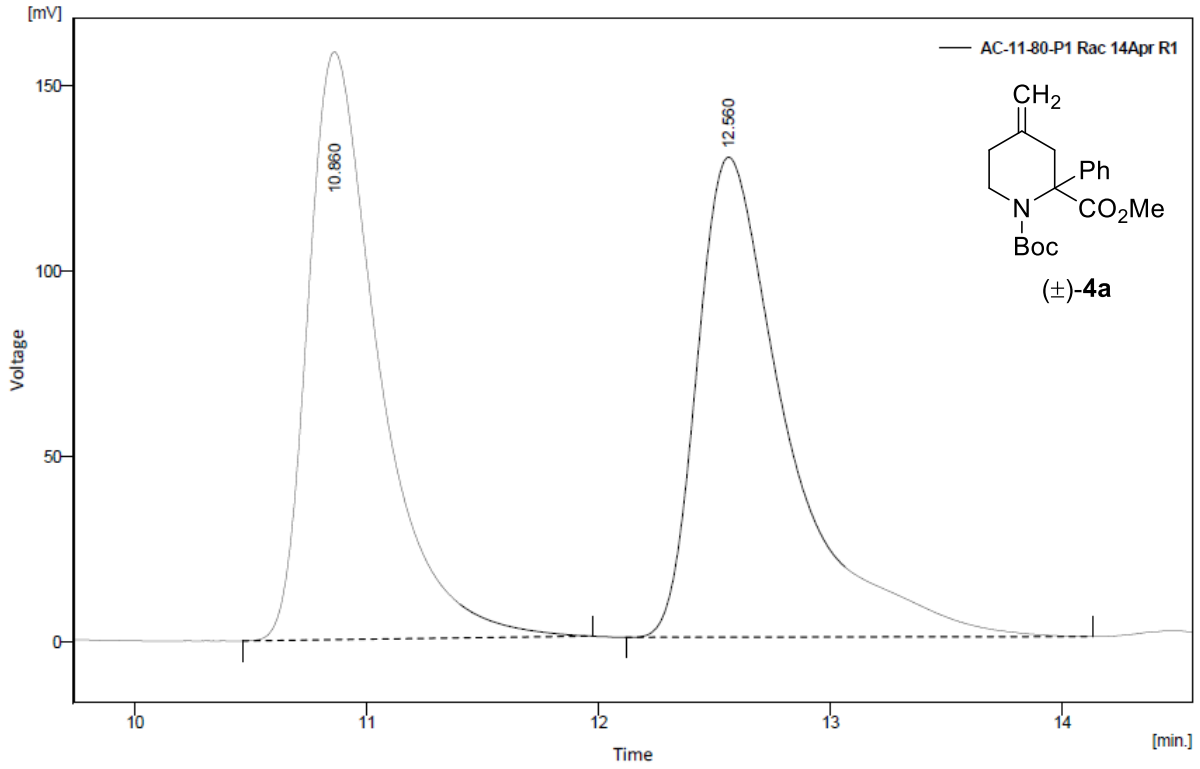

[mV]
AC-12-53-P1 8Jun R1
5.830
CH2
CF3
N
Boc
(S)-3f
(er 97:3)
Voltage
Time
[min.]

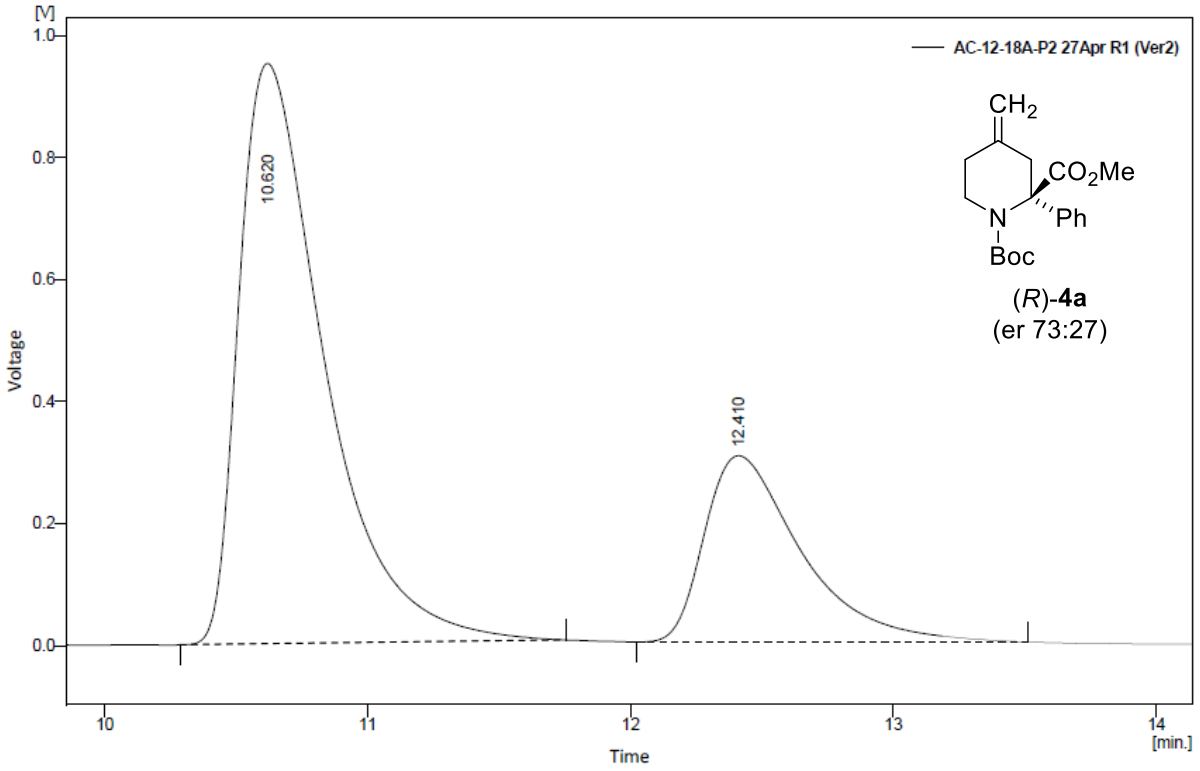

[mV]
mMeOPhPipRac Rac 1Jun R2
9.620
18.550
Voltage
Time
[min.]
(±)-3g

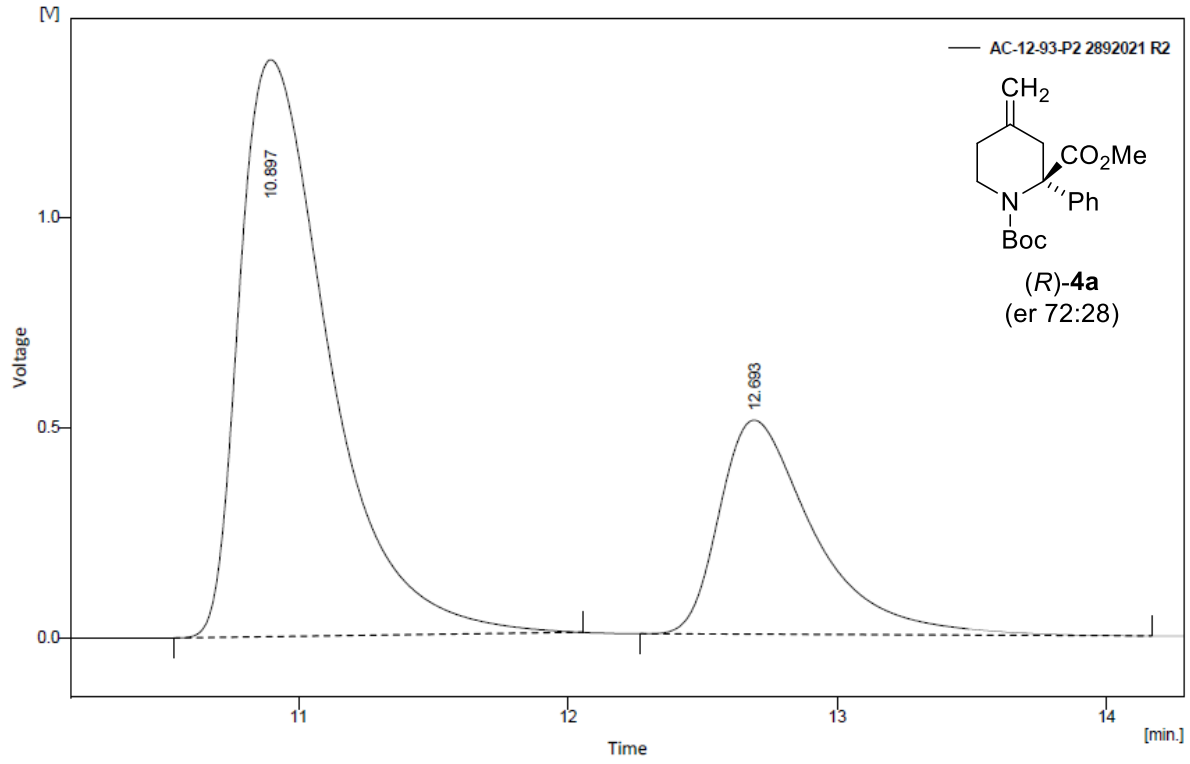

[mV]
AC-12-52-P1 8Jun R1
9.933
19.443
Voltage
Time
[min.]
(S)-3g
(er 97:3)

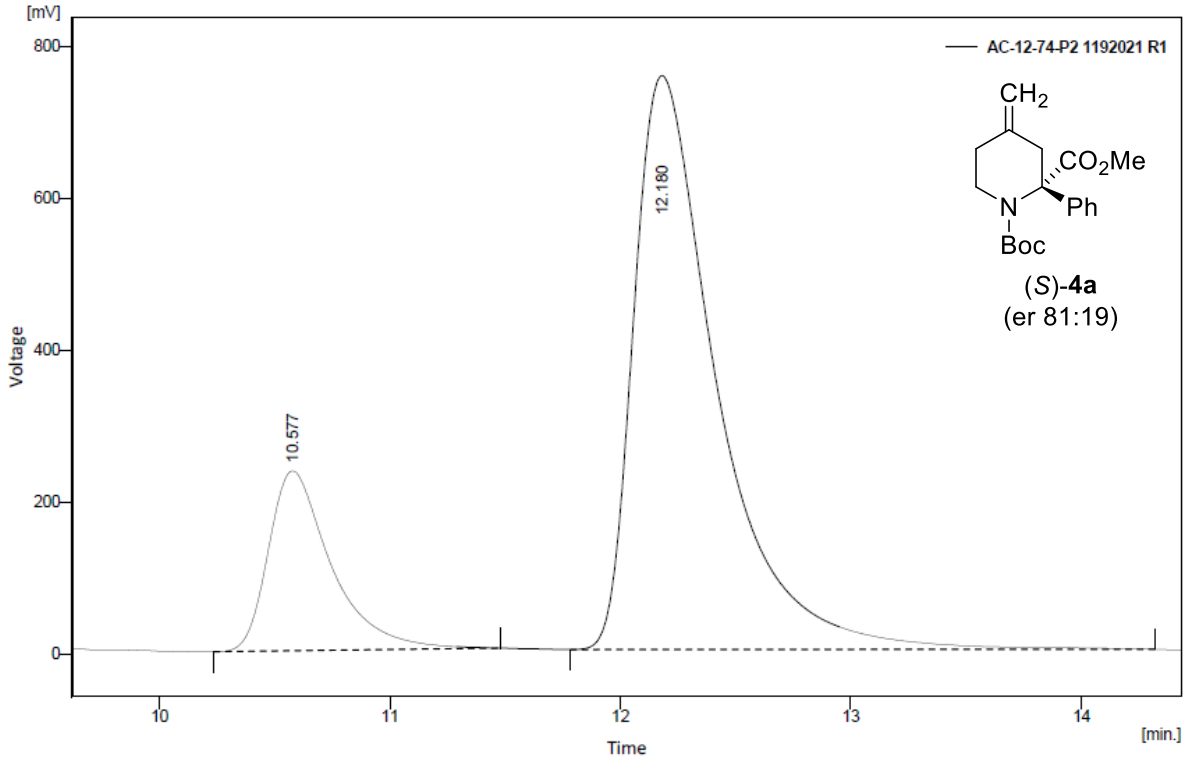

[V]
1.5
1.0
0.5
0.0
Voltage
2PhDiMeOPipRac 1921 R1
8.050
9.260
CH2
N
Boc
OMe
OMe
(±)-3h
7
8
9
10
11
[min.]
Time

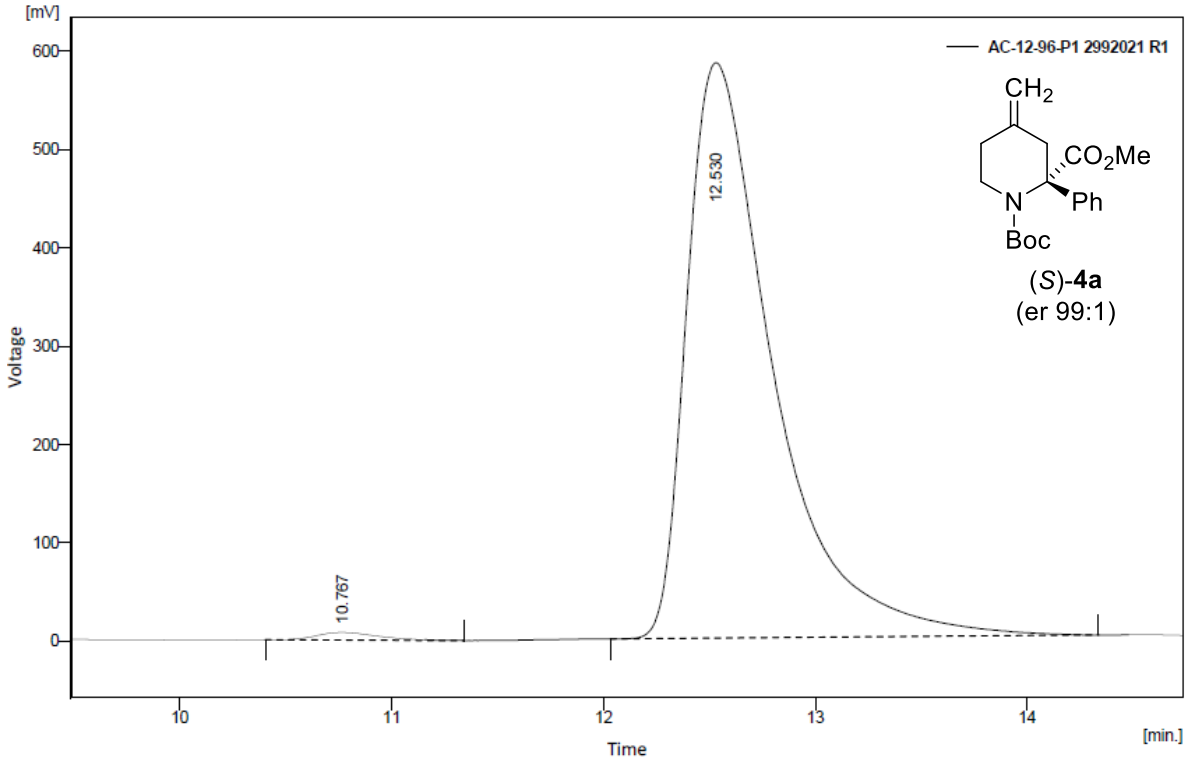

[V]
1.5
1.0
0.5
0.0
Voltage
AC-12-78-P1 992021 R1
8.407
10.500
CH2
N
Boc
OMe
OMe
(S)-3h
(er 85:15)
8.5
9.0
9.5
10.0
10.5
11.0
11.5
[min.]
Time

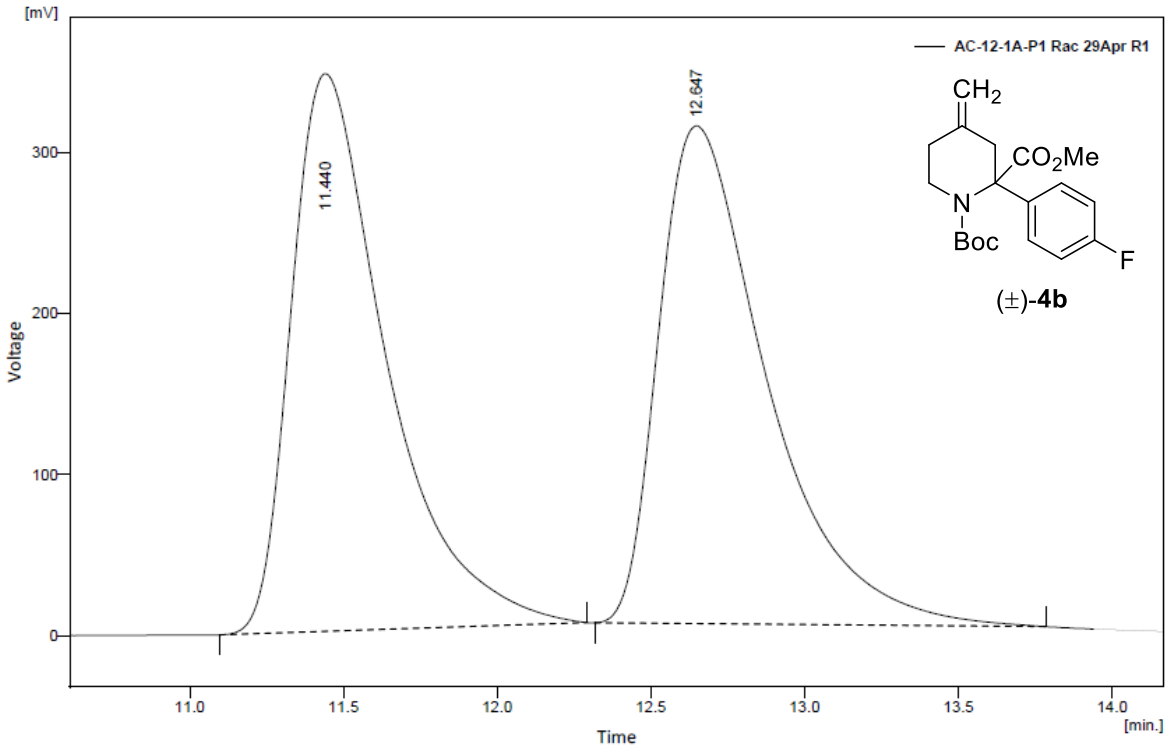

[mV]
150
100
50
0
Voltage
AC-11-80-P1 Rac 14Apr R1
10.860
12.560
CH2
Ph
N
CO2Me
Boc
(±)-4a
10
11
12
13
14
Time
[min.]


[V]
1.0
0.8
0.6
0.4
0.2
0.0
Voltage
AC-12-18A-P2 27Apr R1 (Ver2)
10.620
12.410
CH2
CO2Me
N
Ph
Boc
(R)-4a
(er 73:27)
10
11
12
13
14
Time
[min.]


[V]
AC-12-93-P2 2892021 R2
10.897
12.693
1.0
0.5
0.0
Voltage
11
12
13
14
Time
[min.]
CH2
CO2Me
N
Ph
Boc
(R)-4a
(er 72:28)

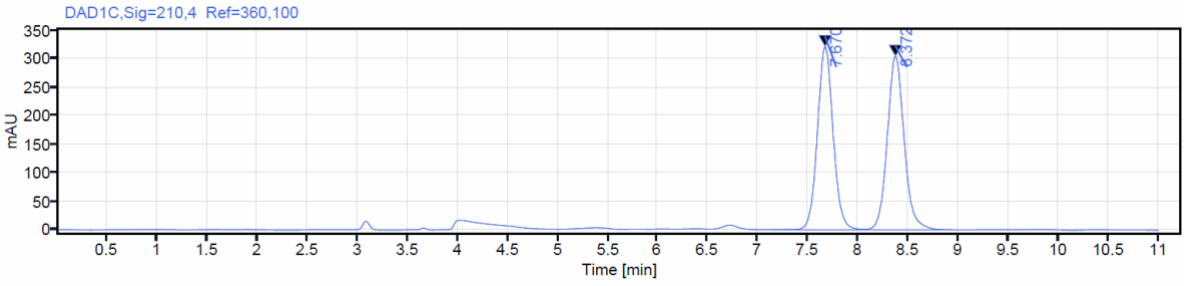

[mV]
AC-12-74-P2 1192021 R1
10.577
12.180
800
600
400
200
0
Voltage
10
11
12
13
14
Time
[min.]
CH2
CO2Me
N
Ph
Boc
(S)-4a
(er 81:19)

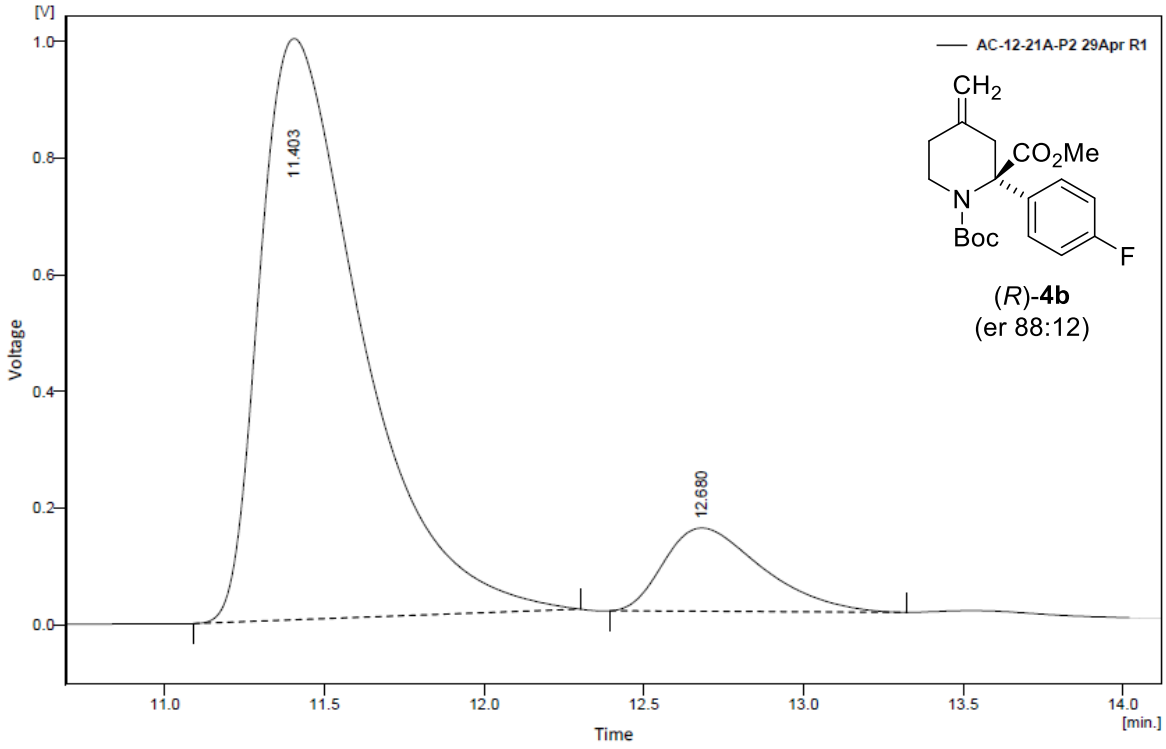

[mV]
600
500
400
300
200
100
0
Voltage
AC-12-96-P1 2992021 R1
12.530
10.767
CH2
CO2Me
Ph
N
Boc
(S)-4a
(er 99:1)
10
11
12
13
14
Time
[min.]




HPLC of (±)-**4b** from Agilent system fitted with a Chiral Art Cellulose-C column:

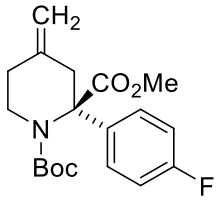
| Chiral Art Cellulose-C Column | | | |
|---|---|---|---|
| | | | |
| | $R_f$/min | Area/mAU.s | Area/% |
| 1 | 7.670 | 3502.22 | 49.52 |
| 2 | 8.372 | 3570.49 | 50.48 |
| | Total | 7072.71 | 100.00 |



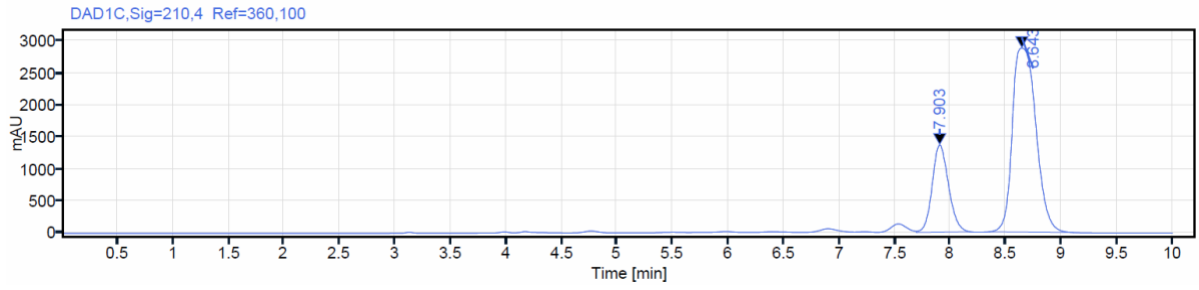


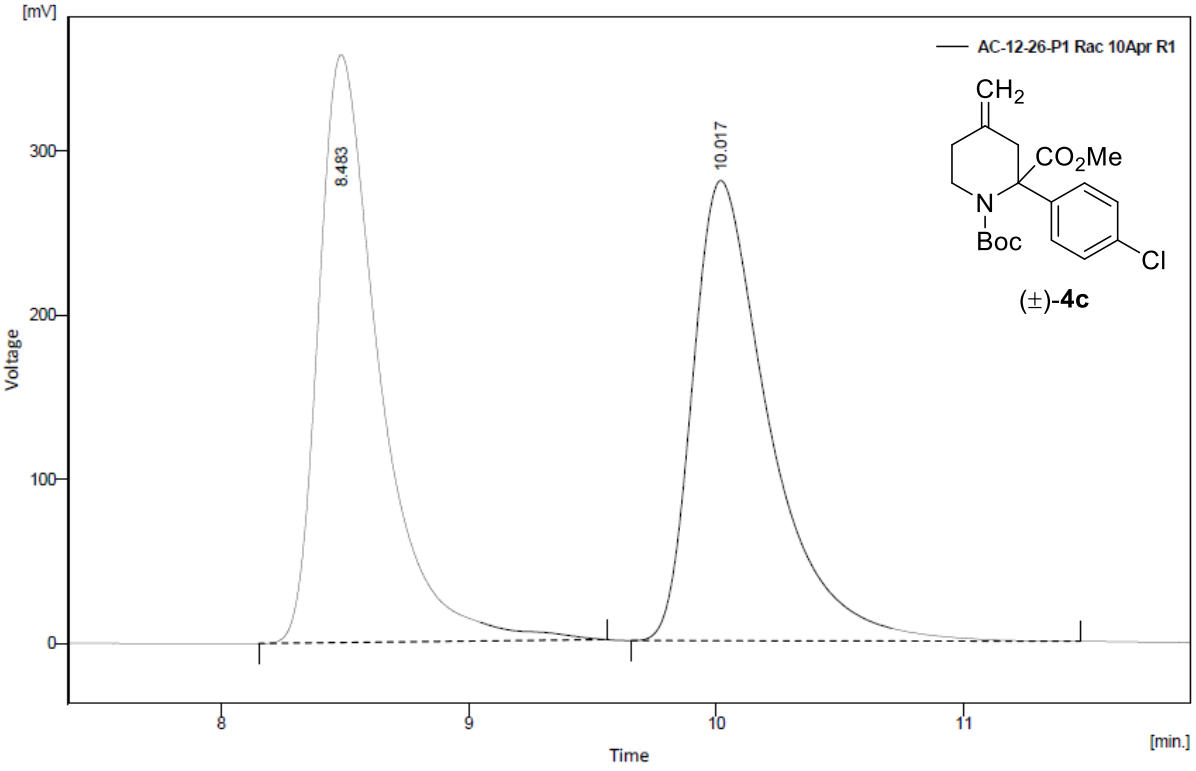

HPLC of (*R*)-**4b** from Agilent system fitted with a Chiral Art Cellulose-C column:

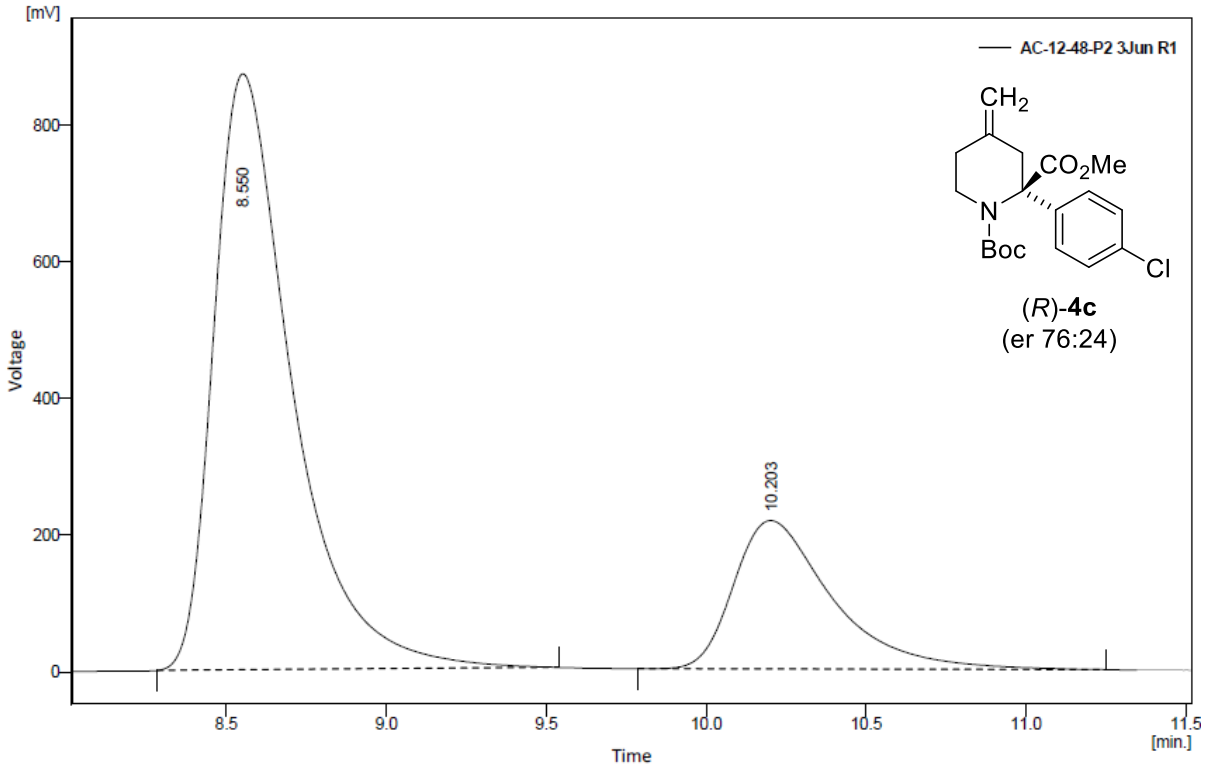
| Chiral Art Cellulose-C Column | | | |
|---|---|---|---|
| | | | |
| | $R_f$/min | Area/mAU.s | Area/% |
| 1 | 7.903 | 13930.66 | 24.72 |
| 2 | 8.643 | 42424.82 | 75.28 |
| | Total | 56355.48 | 100.00 |

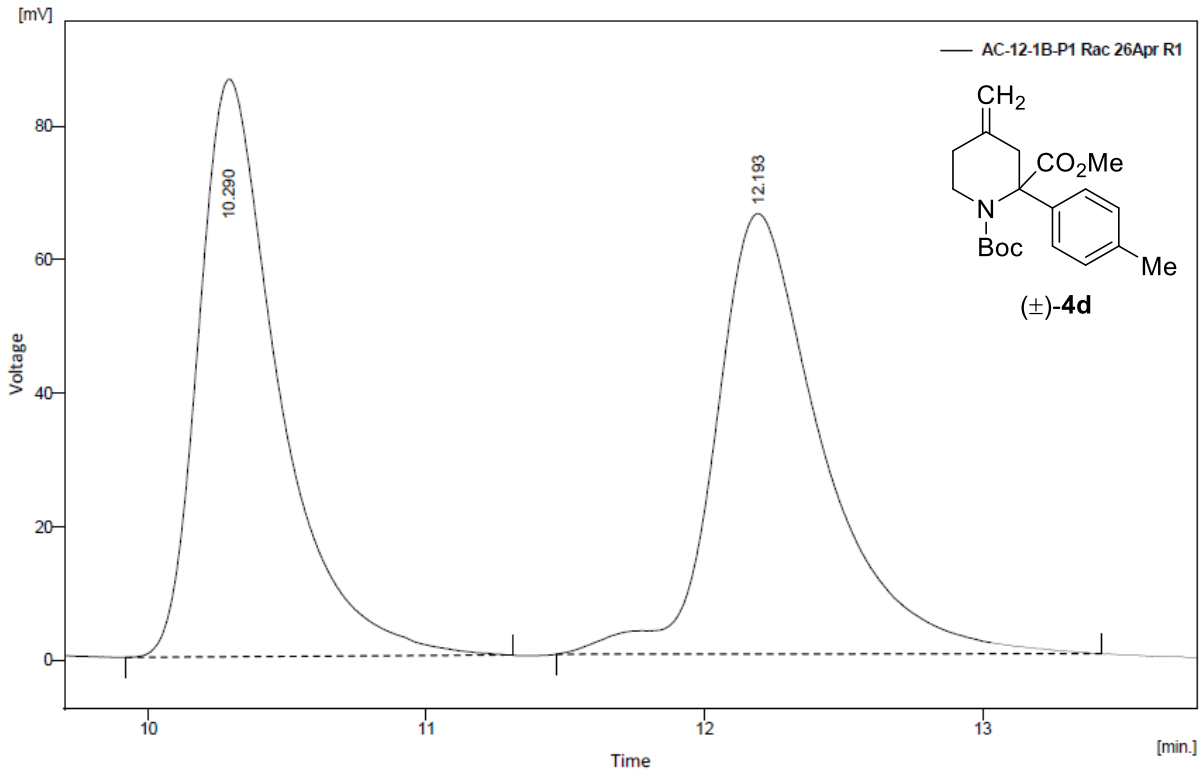


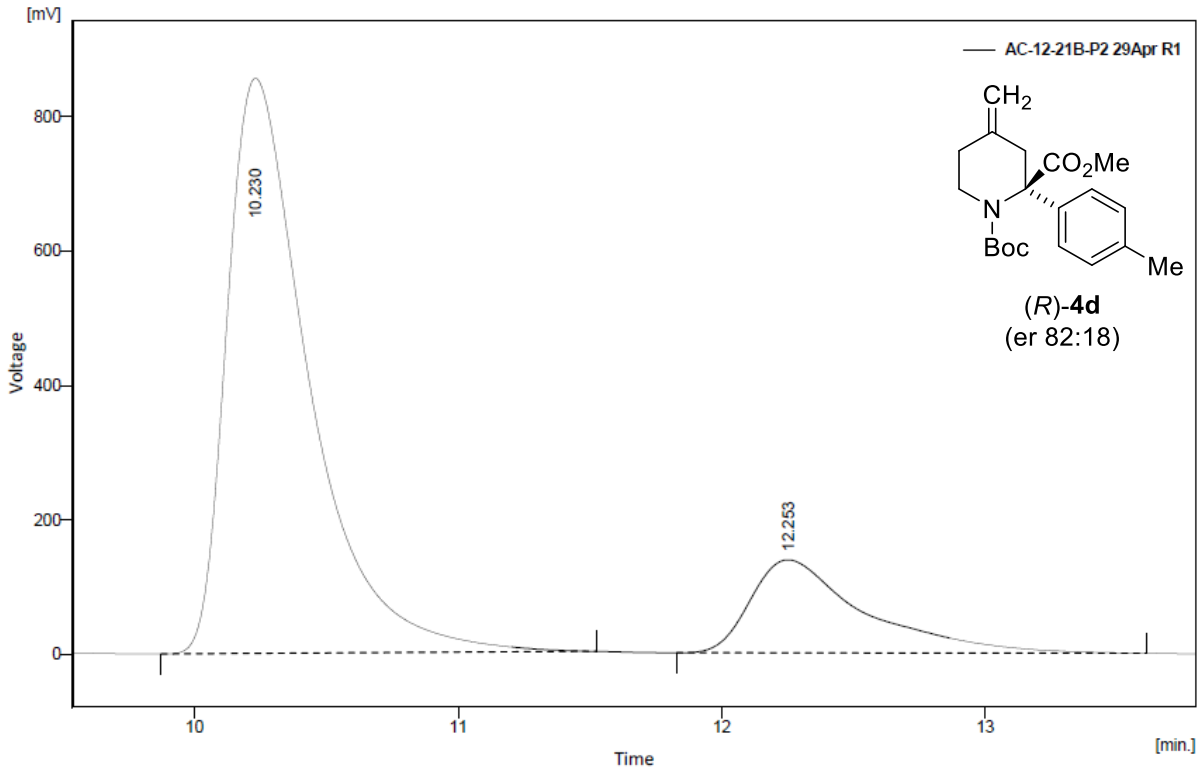

(*R*)-**4b**
(er 75:25)

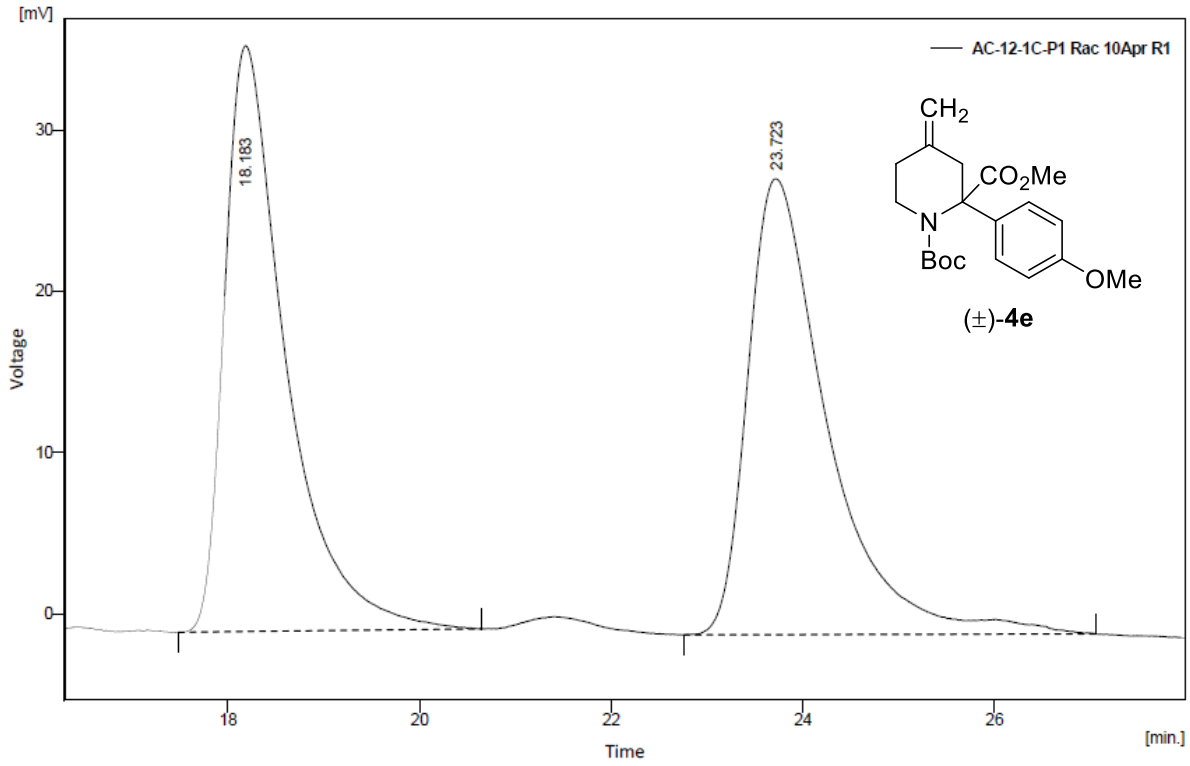


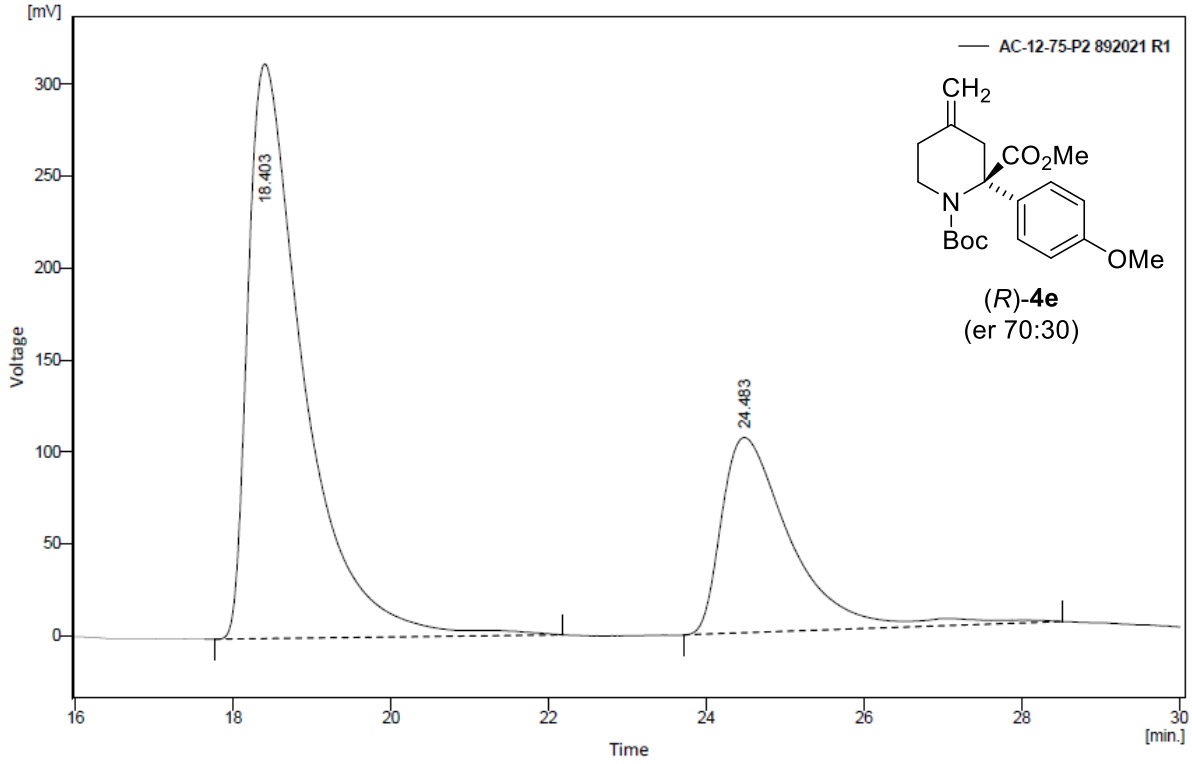

[mV]
AC-12-26-P1 Rac 10Apr R1
8.483
10.017
CH2
CO2Me
N
Boc
Cl
(±)-4c
Voltage
300
200
100
0
8
9
10
11
Time
[min.]

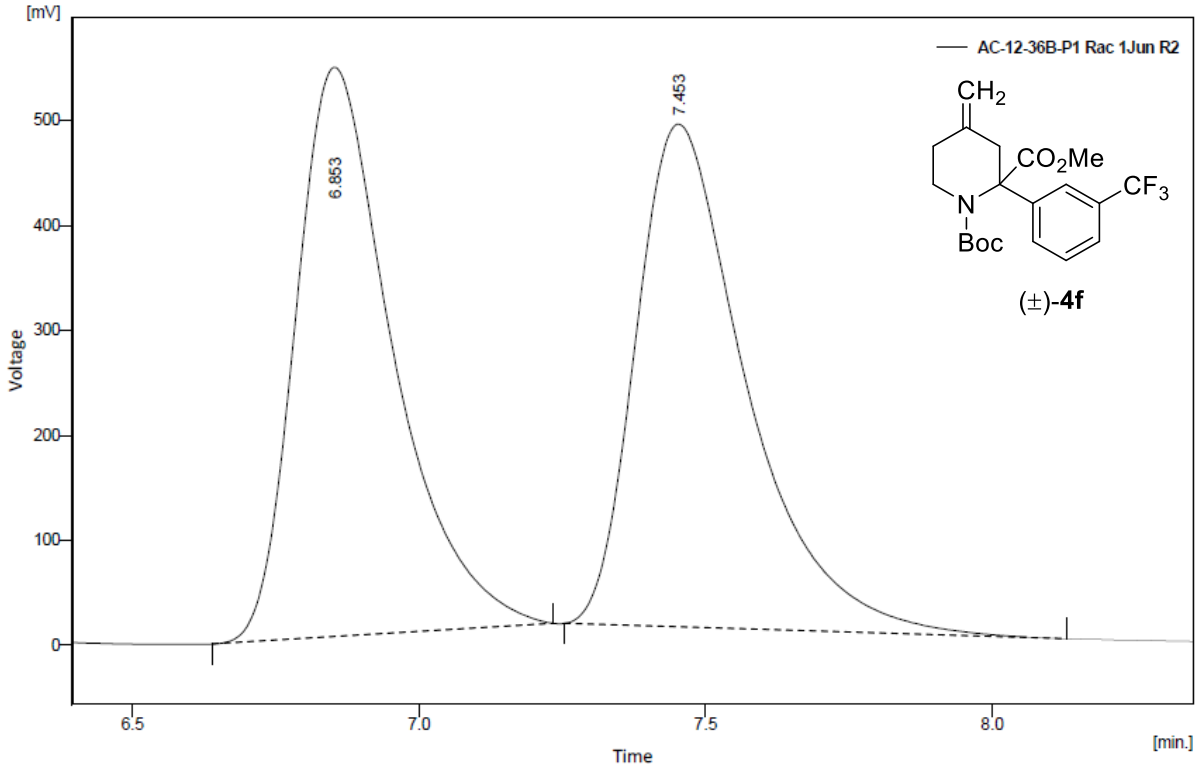

[mV]
AC-12-48-P2 3Jun R1
8.550
10.203
CH2
CO2Me
N
Boc
Cl
(R)-4c
(er 76:24)
Voltage
800
600
400
200
0
8.5
9.0
9.5
10.0
10.5
11.0
11.5
Time
[min.]

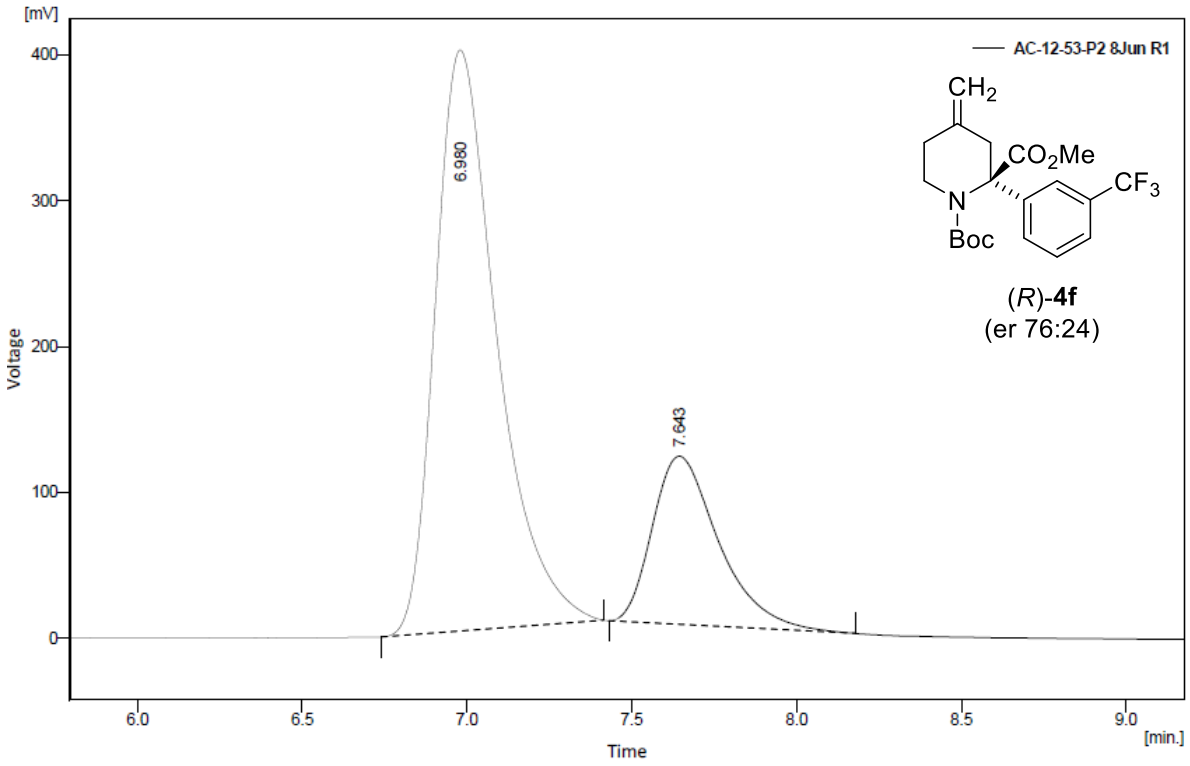

[mV]
AC-12-1B-P1 Rac 26Apr R1
10.290
12.193
Voltage
Time
[min.]
(±)-4d

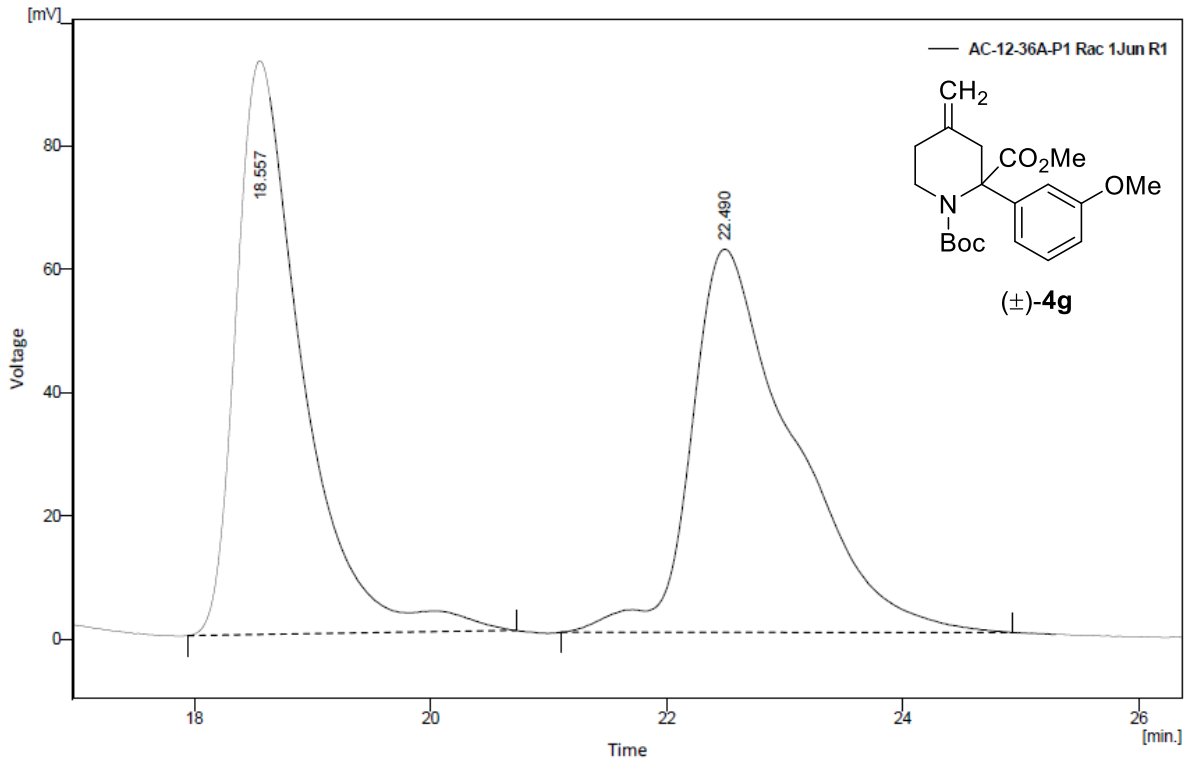

[mV]
AC-12-21B-P2 29Apr R1
10.230
12.253
Voltage
Time
[min.]
(R)-4d
(er 82:18)

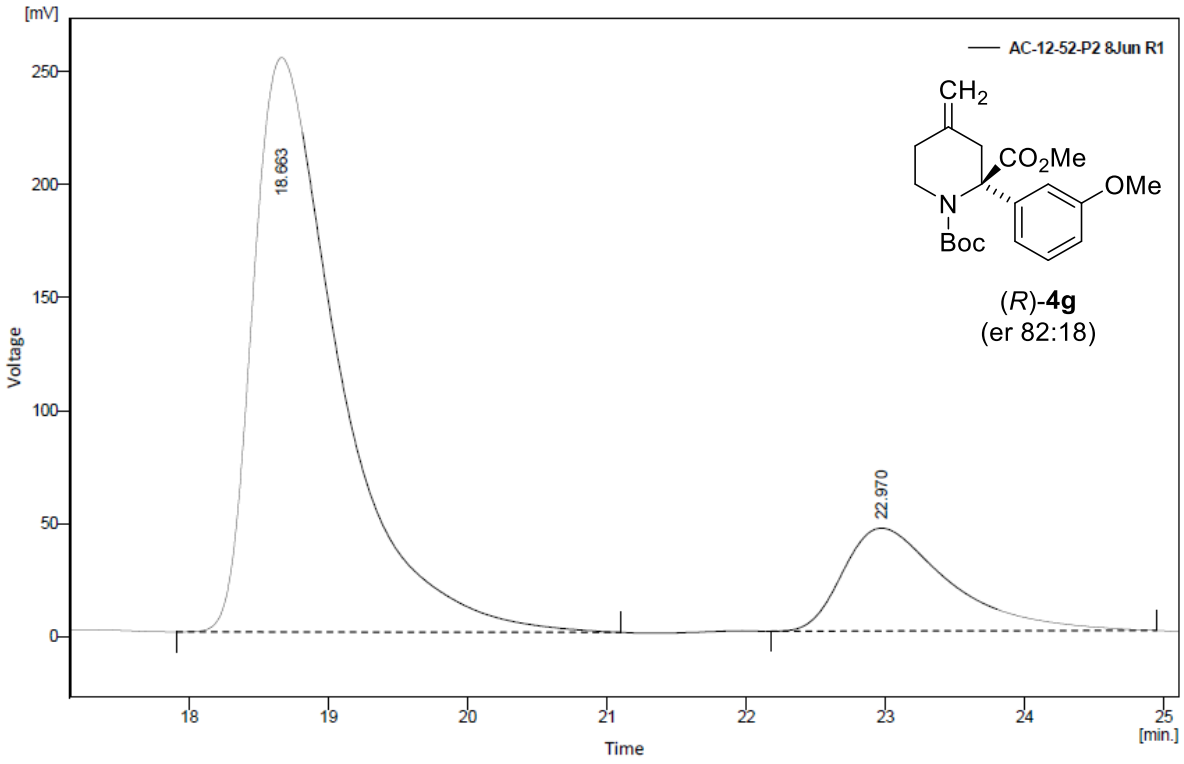

[mV]
AC-12-1C-P1 Rac 10Apr R1
18.183
23.723
CH2
CO2Me
N
Boc
OMe
(±)-4e
Voltage
Time
[min.]

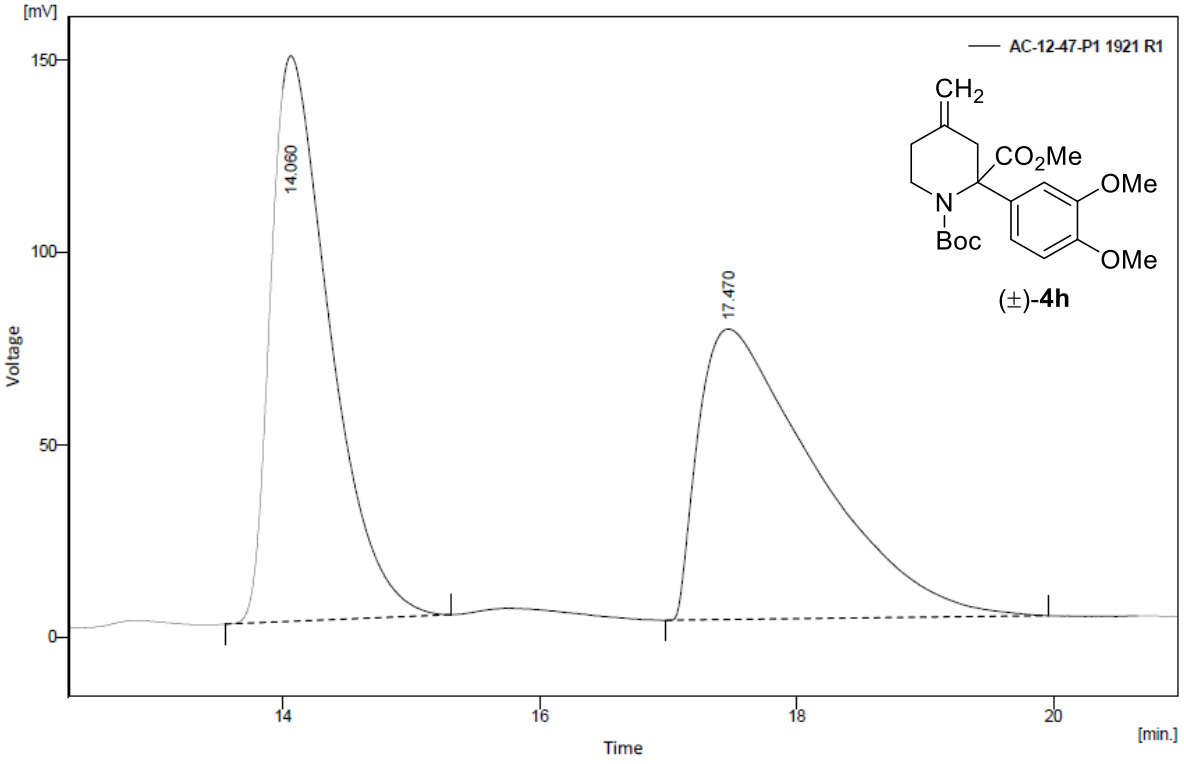

[mV]
AC-12-75-P2 892021 R1
18.403
24.483
CH2
CO2Me
N
Boc
OMe
(R)-4e
(er 70:30)
Voltage
Time
[min.]

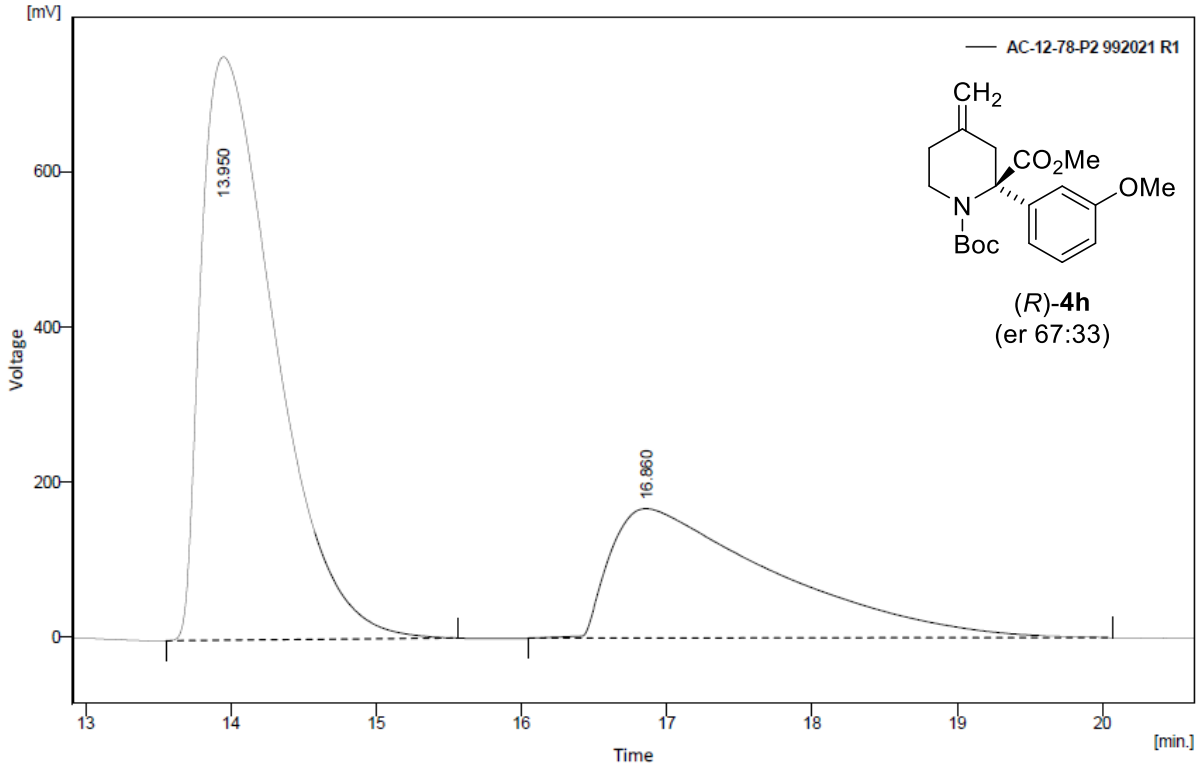

[mV]
AC-12-36B-P1 Rac 1Jun R2
6.853
7.453
CH2
CO2Me
CF3
N
Boc
(±)-4f
Voltage
500
400
300
200
100
0
6.5
7.0
7.5
8.0
Time
[min.]

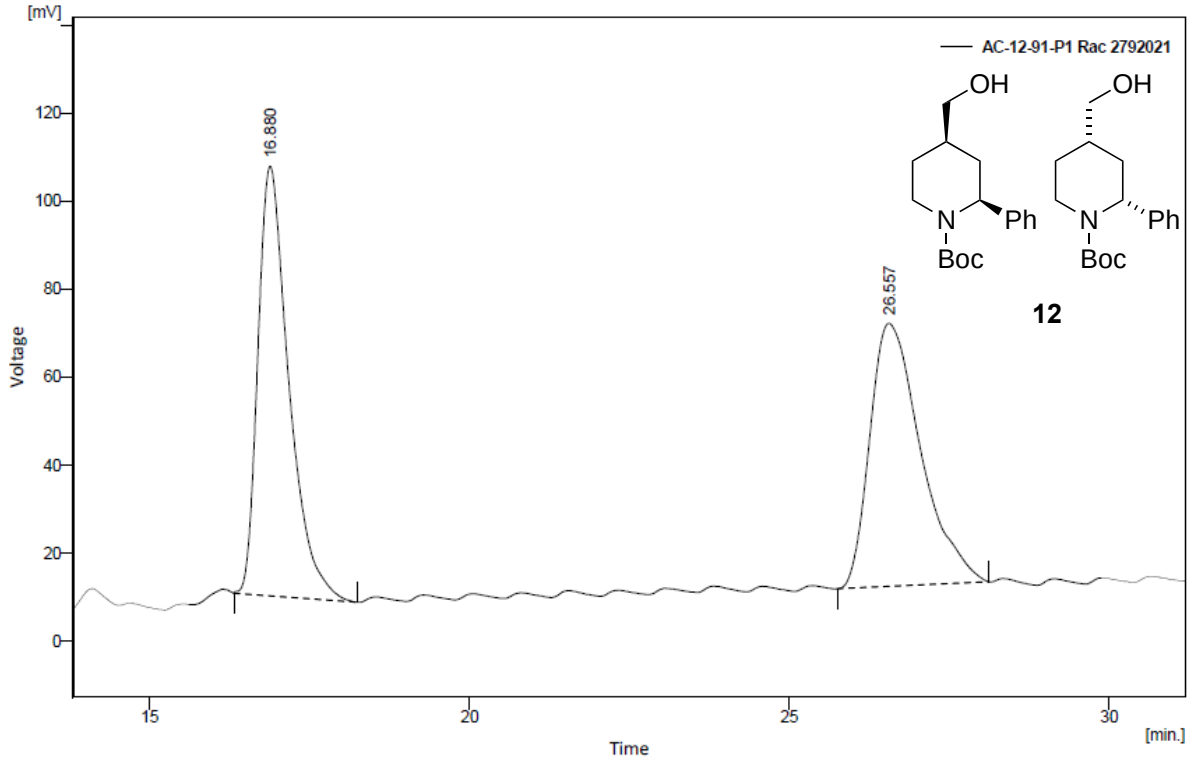

[mV]
AC-12-53-P2 8Jun R1
6.980
7.643
CH2
CO2Me
CF3
N
Boc
(R)-4f
(er 76:24)
Voltage
400
300
200
100
0
6.0
6.5
7.0
7.5
8.0
8.5
9.0
Time
[min.]

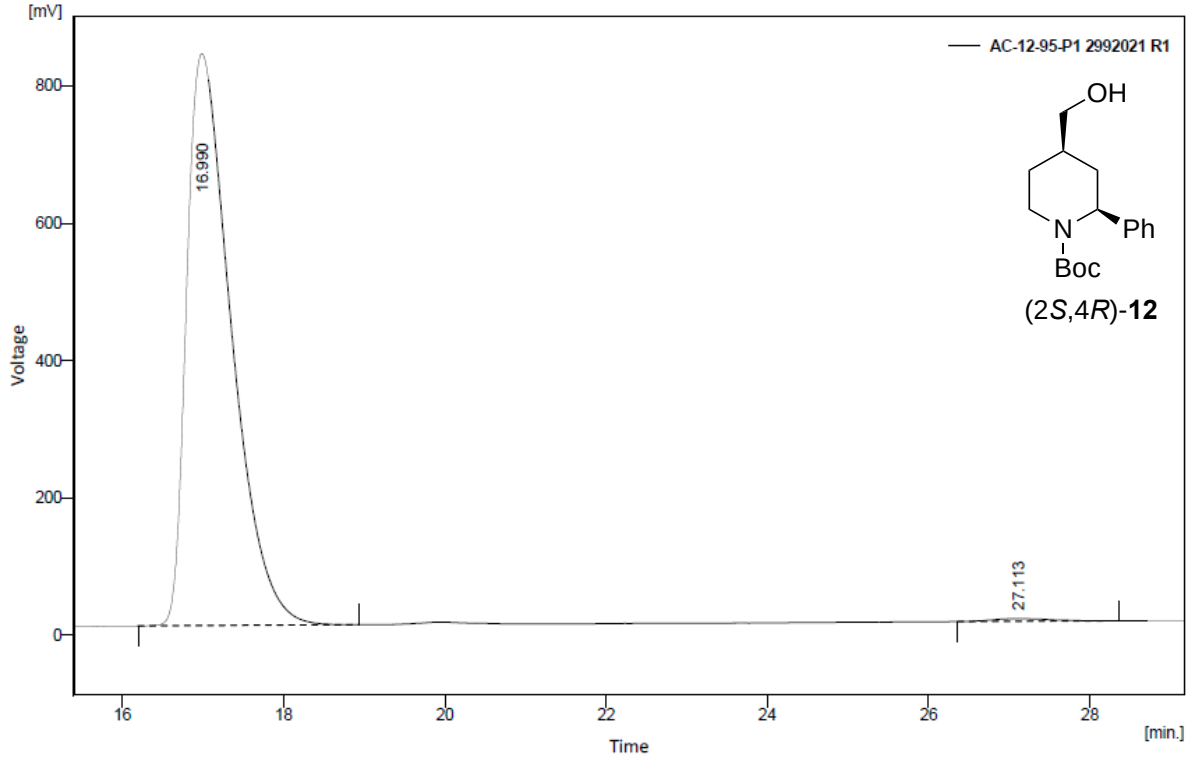

[mV]
AC-12-36A-P1 Rac 1Jun R1
18.557
22.490
Voltage
Time
[min.]
(±)-4g

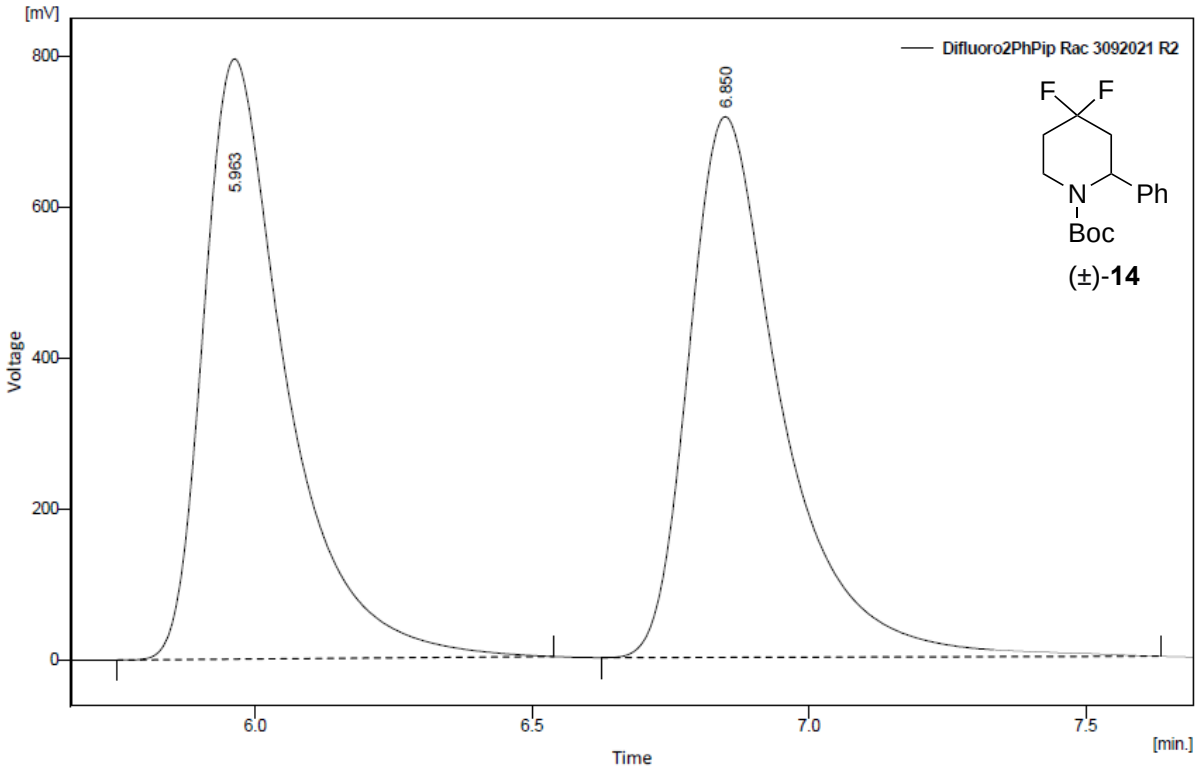

[mV]
AC-12-52-P2 8Jun R1
18.663
22.970
Voltage
Time
[min.]
(R)-4g
(er 82:18)

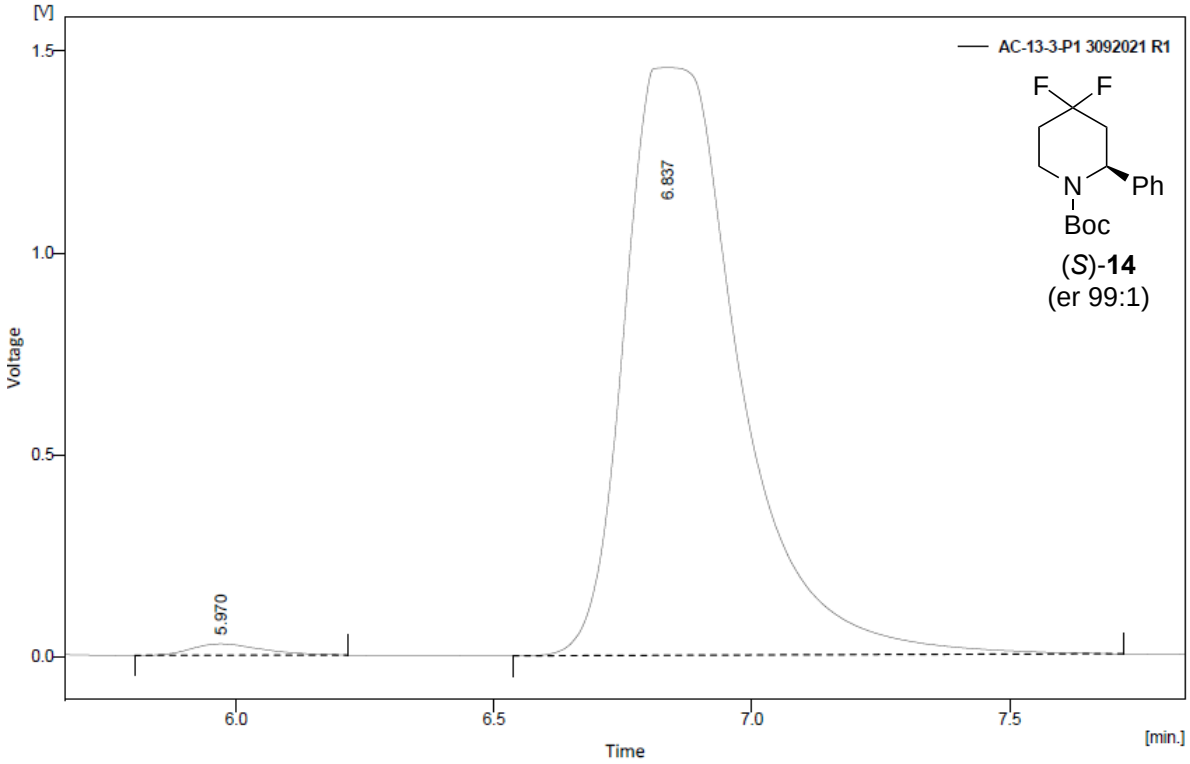

[mV]
150
100
50
0
Voltage
AC-12-47-P1 1921 R1
14.060
17.470
CH2
CO2Me
OMe
N
Boc
OMe
(±)-4h
14
16
18
20
Time
[min.]

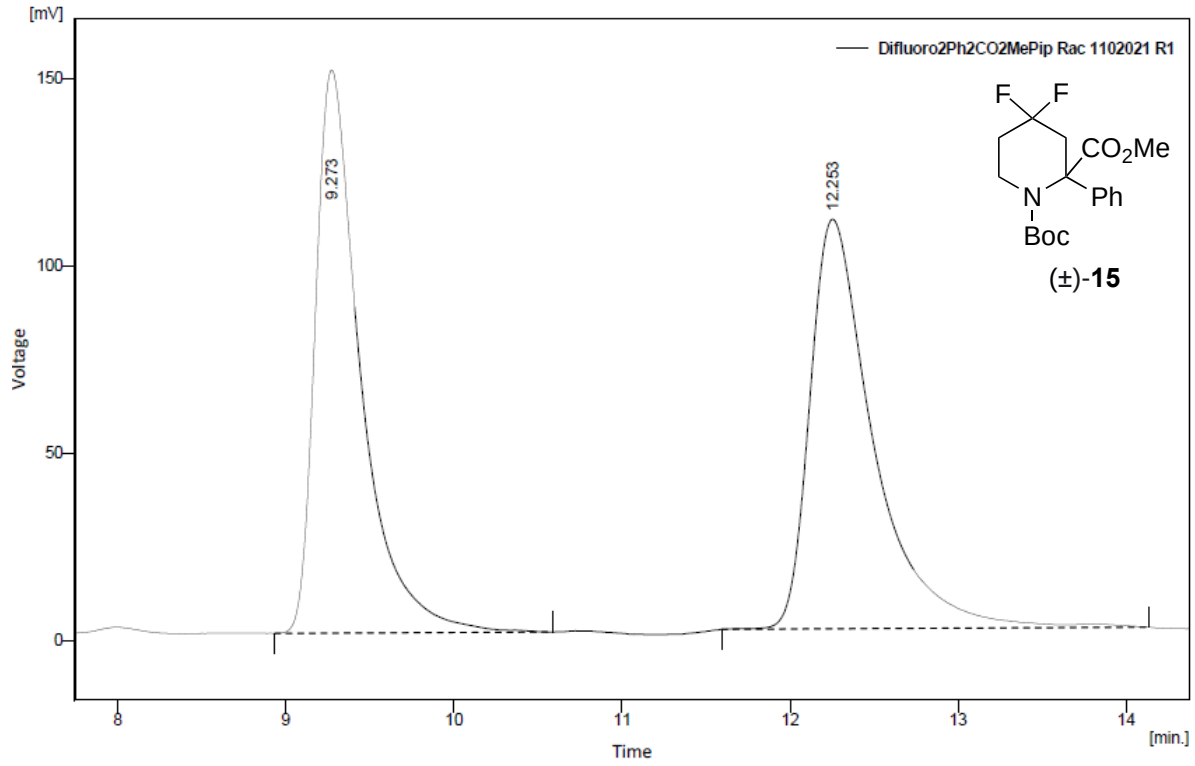

[mV]
600
400
200
0
Voltage
AC-12-78-P2 992021 R1
13.950
16.860
CH2
CO2Me
OMe
N
Boc
(R)-4h
(er 67:33)
13
14
15
16
17
18
19
20
Time
[min.]

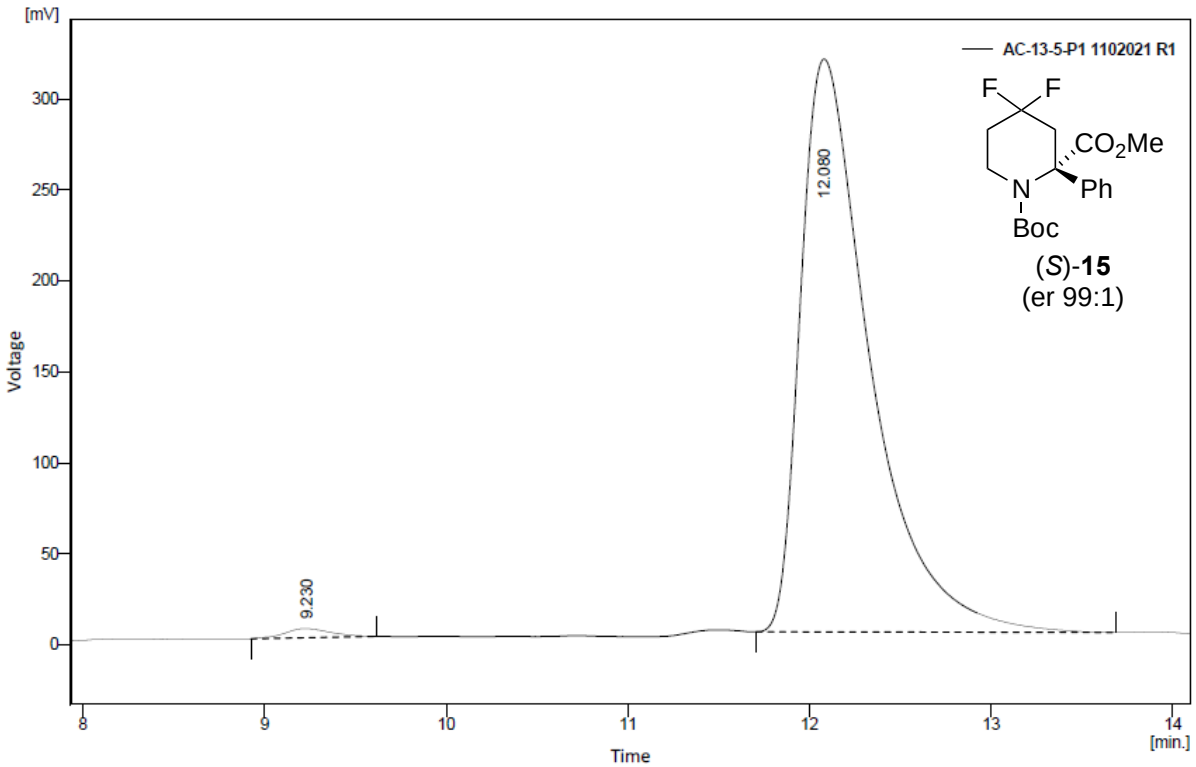

[mV]
AC-12-91-P1 Rac 2792021
16.880
26.557
OH
N
Ph
Boc
12
Voltage
Time
[min.]


[mV]
AC-12-95-P1 2992021 R1
16.990
27.113
OH
N
Ph
Boc
(2S,4R)-12
Voltage
Time
[min.]

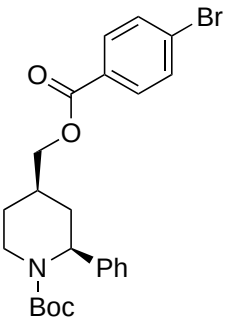

[mV]
800
600
400
200
0
Voltage
Difluoro2PhPip Rac 3092021 R2
5.963
6.850
F
F
N
Ph
Boc
(±)-14
6.0
6.5
7.0
7.5
Time
[min.]


[V]
1.5
1.0
0.5
0.0
Voltage
AC-13-3-P1 3092021 R1
5.970
6.837
F
F
N
Ph
Boc
(S)-14
(er 99:1)
6.0
6.5
7.0
7.5
Time
[min.]

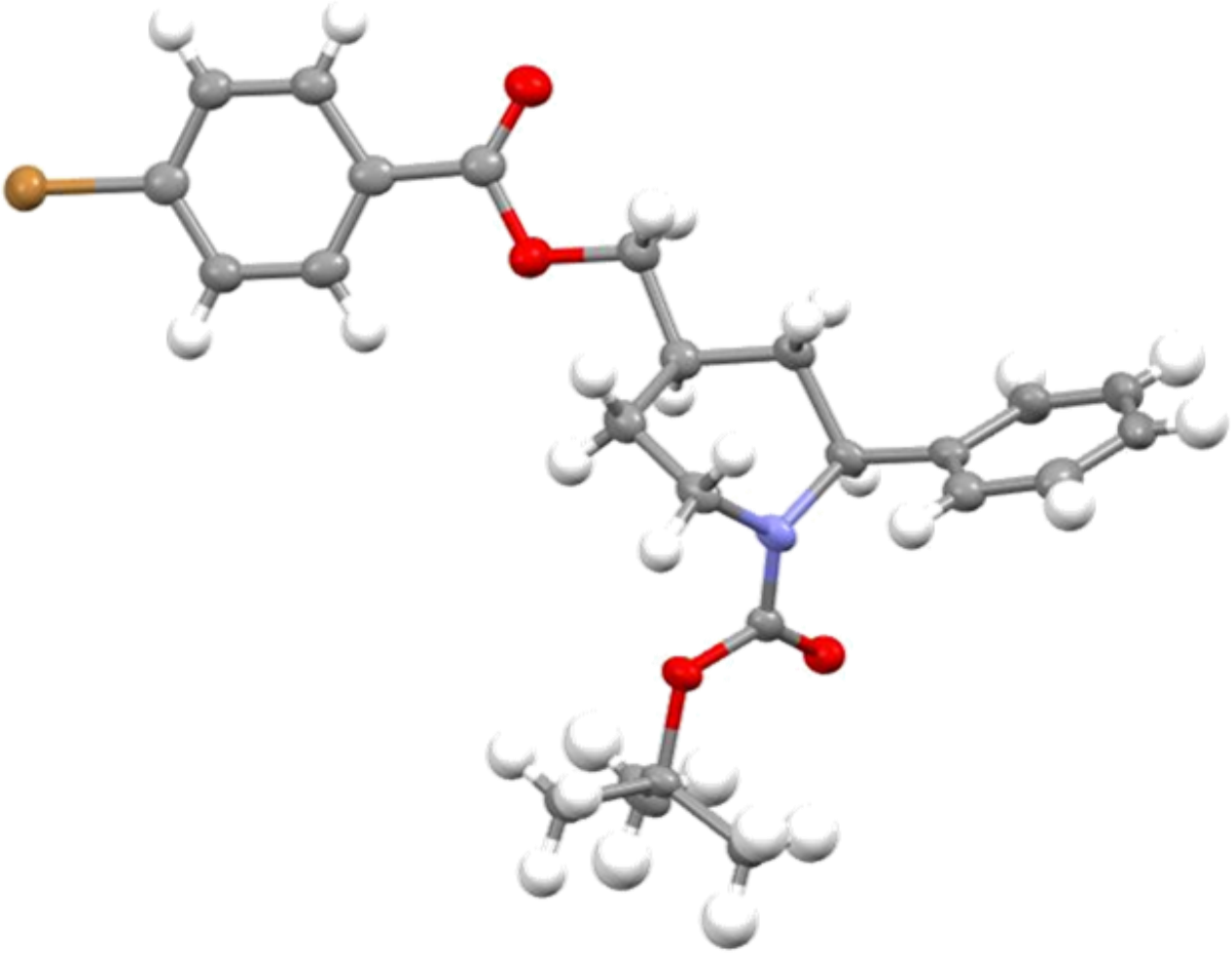

[mV]
Difluoro2Ph2CO2MePip Rac 1102021 R1
150
100
50
0
Voltage
9.273
12.253
F
F
CO2Me
N
Ph
Boc
(±)-15
8
9
10
11
12
13
14
[min.]
Time


[mV]
AC-13-5-P1 1102021 R1
300
250
200
150
100
50
0
Voltage
9.230
12.080
F
F
CO2Me
N
Ph
Boc
(S)-15
(er 99:1)
8
9
10
11
12
13
14
[min.]
Time

## 6. X-ray data for ester (2*S*,4*R*)-13




(2*S*,4*R*)-**13**



Thermal ellipsoid plot displayed at 50% probability level

CCDC 2155914

Compound (2*S*,4*R*)-**13** was prepared by recrystallization by slow evaporation in the solvent system $CH_2Cl_2$–hexane

**Table S2 Crystal data and structure refinement for OIC323v_0m.**

| | |
|---|---|
| Identification code | OIC323v_0m |
| Empirical formula | $C_{24}H_{28}BrNO_4$ |
| Formula weight | 474.38 |
| Temperature/K | 99.99 |
| Crystal system | monoclinic |
| Space group | C2 |
| a/Å | 17.0948(12) |
| b/Å | 10.5262(7) |
| c/Å | 13.2389(9) |
| α/° | 90 |
| β/° | 106.728(3) |
| γ/° | 90 |
| Volume/Å$^3$ | 2281.4(3) |
| Z | 4 |
| $\rho_{calc}$g/cm$^3$ | 1.381 |
| μ/mm$^{-1}$ | 2.694 |
| F(000) | 984.0 |
| Crystal size/mm$^3$ | 0.2 × 0.19 × 0.14 |
| Radiation | CuKα (λ = 1.54178) |
| 2Θ range for data collection/° | 6.972 to 133.964 |
| Index ranges | $-20 \leq h \leq 20$, $-12 \leq k \leq 12$, $-15 \leq l \leq 15$ |
| Reflections collected | 41440 |
| Independent reflections | 4016 [$R_{int}$ = 0.0517, $R_{sigma}$ = 0.0256] |
| Data/restraints/parameters | 4016/1/274 |
| Goodness-of-fit on F$^2$ | 1.031 |
| Final R indexes [I>=2σ (I)] | $R_1$ = 0.0246, $wR_2$ = 0.0581 |
| Final R indexes [all data] | $R_1$ = 0.0258, $wR_2$ = 0.0588 |
| Largest diff. peak/hole / e Å$^{-3}$ | 0.28/-0.27 |
| Flack parameter | 0.091(7) |

**Table S3 Fractional Atomic Coordinates (×$10^4$) and Equivalent Isotropic Displacement Parameters (Å$^2$×$10^3$) for OIC323v_0m. $U_{eq}$ is defined as 1/3 of of the trace of the orthogonalised $U_{IJ}$ tensor.**

| Atom | *x* | *y* | *z* | U(eq) |
|---|---|---|---|---|
| Br1 | 3663.9(2) | -1713.9(4) | 9528.9(2) | 37.47(11) |
| O1 | 4410.2(15) | 4379(2) | 8341.0(19) | 35.1(6) |
| O2 | 3544.1(15) | 4802(3) | 9289(2) | 38.1(6) |
| O3 | 6231.4(13) | 6765(2) | 5112.1(17) | 30.9(5) |
| O4 | 7000.0(13) | 5363(2) | 6306.5(16) | 28.6(5) |
| N1 | 6307.0(16) | 6864(3) | 6854(2) | 26.6(6) |
| C1 | 5615(2) | 7752(3) | 6661(3) | 27.8(7) |
| C2 | 5103.1(19) | 7412(3) | 7411(2) | 28.2(7) |
| C3 | 5043.2(19) | 5981(3) | 7542(2) | 29.9(7) |
| C4 | 5894(2) | 5427(4) | 8077(3) | 34.2(7) |
| C5 | 6560.2(19) | 6290(3) | 7906(2) | 30.3(7) |
| C6 | 5864(2) | 9138(4) | 6779(2) | 28.8(7) |
| C7 | 6646(2) | 9537(4) | 7330(3) | 33.3(8) |
| C8 | 6825(2) | 10828(4) | 7470(3) | 40.3(8) |
| C9 | 6231(3) | 11714(4) | 7057(3) | 43.4(9) |
| C10 | 5451(3) | 11328(4) | 6501(3) | 47.1(10) |
| C11 | 5270(2) | 10058(4) | 6367(3) | 39.3(8) |
| C12 | 4448(2) | 5727(3) | 8170(3) | 35.4(8) |
| C13 | 3924(2) | 4036(4) | 8941(3) | 31.2(9) |
| C14 | 3911(2) | 2643(4) | 9098(3) | 29.6(8) |
| C15 | 3458(2) | 2178(4) | 9753(3) | 30.7(7) |
| C16 | 3398.2(19) | 892(3) | 9896(2) | 30.5(7) |
| C17 | 3787(2) | 61(3) | 9386(2) | 31.5(7) |
| C18 | 4255.8(19) | 498(4) | 8760(2) | 30.7(7) |
| C19 | 4312(2) | 1799(4) | 8619(3) | 31.7(8) |
| C20 | 6492.5(17) | 6358(3) | 6010(2) | 25.0(6) |
| C21 | 7401.0(19) | 4756(3) | 5582(2) | 27.7(7) |
| C22 | 6776(2) | 4172(4) | 4650(3) | 43.9(9) |
| C23 | 7943(2) | 5727(4) | 5260(3) | 40.7(8) |
| C24 | 7924.0(19) | 3753(3) | 6281(3) | 29.5(7) |

**Table S4 Anisotropic Displacement Parameters ($Å^2×10^3$) for OIC323v_0m. The Anisotropic displacement factor exponent takes the form: $-2\pi^2[h^2a^{*2}U_{11}+2hka^*b^*U_{12}+\ldots]$.**

| Atom | $U_{11}$ | $U_{22}$ | $U_{33}$ | $U_{23}$ | $U_{13}$ | $U_{12}$ |
|---|---|---|---|---|---|---|
| Br1 | 39.98(18) | 38.69(19) | 33.44(16) | 5.49(18) | 10.07(12) | 2.9(2) |
| O1 | 39.0(13) | 33.2(15) | 36.3(13) | -3.4(11) | 16.2(11) | -4.0(11) |
| O2 | 39.5(14) | 41.5(15) | 34.6(13) | -3.6(11) | 13.0(11) | 3.5(11) |
| O3 | 29.4(11) | 37.5(14) | 25.9(11) | 6.7(10) | 8.0(9) | 8.9(10) |
| O4 | 27.1(11) | 33.9(13) | 25.3(10) | 3.4(9) | 8.4(9) | 10.5(9) |
| N1 | 19.4(13) | 32.7(16) | 24.6(13) | -0.9(11) | 1.3(10) | 7.5(11) |
| C1 | 20.9(16) | 35.1(18) | 24.6(16) | 0.2(13) | 2.1(13) | 8.2(13) |
| C2 | 20.9(15) | 33.9(19) | 27.6(15) | -1.5(13) | 3.4(12) | 4.3(13) |
| C3 | 28.1(16) | 33.4(19) | 25.9(15) | -2.3(13) | 4.0(13) | 1.8(13) |
| C4 | 35.8(18) | 38(2) | 26.7(16) | 4.3(14) | 6.0(13) | 9.4(15) |
| C5 | 24.5(15) | 40(2) | 20.1(14) | -2.0(14) | -2.6(12) | 10.2(14) |
| C6 | 29.6(17) | 35(2) | 24.8(15) | 3.0(14) | 12.1(13) | 9.1(15) |
| C7 | 33.1(18) | 38(2) | 29.0(17) | 0.6(15) | 8.7(14) | 3.9(15) |
| C8 | 47(2) | 41(2) | 37.0(18) | -6.1(16) | 18.5(16) | -7.9(17) |
| C9 | 63(3) | 27.9(19) | 52(2) | 1.7(16) | 38(2) | 6.0(17) |
| C10 | 51(2) | 39(2) | 63(2) | 17.1(19) | 34(2) | 17.8(18) |
| C11 | 30.9(18) | 44(2) | 46(2) | 12.7(16) | 15.3(15) | 11.3(15) |
| C12 | 37.1(18) | 31.5(19) | 39.8(18) | -4.3(15) | 14.5(15) | 0.4(15) |
| C13 | 27.9(18) | 39(2) | 24.1(17) | -4.7(15) | 2.9(14) | -2.4(16) |
| C14 | 22.1(17) | 43(2) | 19.6(16) | -4.5(14) | -0.9(13) | -2.1(14) |
| C15 | 25.5(16) | 40(2) | 24.7(16) | -3.6(14) | 4.7(13) | 0.7(14) |
| C16 | 26.2(16) | 40(2) | 22.6(15) | 1.2(13) | 3.2(12) | -0.2(14) |
| C17 | 25.1(16) | 42(2) | 21.8(15) | -0.4(13) | -1.7(12) | -0.5(14) |
| C18 | 27.0(16) | 38(2) | 26.1(16) | -1.1(13) | 5.5(13) | 3.1(14) |
| C19 | 23.4(16) | 47(2) | 23.1(16) | -2.4(15) | 3.8(13) | -3.5(15) |
| C20 | 18.5(14) | 27.4(17) | 28.4(16) | -0.6(13) | 5.5(12) | 0.9(12) |
| C21 | 25.8(15) | 32.5(17) | 25.0(15) | -1.6(13) | 7.7(12) | 7.9(13) |
| C22 | 37.6(19) | 47(2) | 36.6(18) | -9.5(17) | -5.7(15) | 13.4(18) |
| C23 | 37.6(19) | 39(2) | 52(2) | 12.0(17) | 22.6(17) | 10.9(16) |
| C24 | 26.2(16) | 32.4(17) | 27.8(15) | 0.6(12) | 4.2(13) | 7.7(12) |

**Table S5 Bond Lengths for OIC323v_0m.**

| Atom | Atom | Length/Å | Atom | Atom | Length/Å |
|---|---|---|---|---|---|
| Br1 | C17 | 1.896(4) | C6 | C7 | 1.392(5) |
| O1 | C12 | 1.442(5) | C6 | C11 | 1.395(5) |
| O1 | C13 | 1.353(5) | C7 | C8 | 1.393(5) |
| O2 | C13 | 1.207(5) | C8 | C9 | 1.372(6) |
| O3 | C20 | 1.221(4) | C9 | C10 | 1.386(6) |
| O4 | C20 | 1.345(4) | C10 | C11 | 1.372(6) |
| O4 | C21 | 1.475(4) | C13 | C14 | 1.482(5) |
| N1 | C1 | 1.472(4) | C14 | C15 | 1.406(5) |
| N1 | C5 | 1.464(4) | C14 | C19 | 1.383(5) |
| N1 | C20 | 1.355(4) | C15 | C16 | 1.374(5) |
| C1 | C2 | 1.542(5) | C16 | C17 | 1.387(5) |
| C1 | C6 | 1.515(5) | C17 | C18 | 1.385(5) |
| C2 | C3 | 1.523(5) | C18 | C19 | 1.390(5) |
| C3 | C4 | 1.537(4) | C21 | C22 | 1.511(5) |
| C3 | C12 | 1.512(5) | C21 | C23 | 1.522(5) |
| C4 | C5 | 1.525(5) | C21 | C24 | 1.514(4) |

**Table S6 Bond Angles for OIC323v_0m.**

| Atom | Atom | Atom | Angle/° | Atom | Atom | Atom | Angle/° |
|---|---|---|---|---|---|---|---|
| C13 | O1 | C12 | 114.6(3) | O1 | C13 | C14 | 112.5(4) |
| C20 | O4 | C21 | 122.0(2) | O2 | C13 | O1 | 122.4(4) |
| C5 | N1 | C1 | 115.5(3) | O2 | C13 | C14 | 125.1(4) |
| C20 | N1 | C1 | 118.3(3) | C15 | C14 | C13 | 117.7(4) |
| C20 | N1 | C5 | 123.2(3) | C19 | C14 | C13 | 122.8(4) |
| N1 | C1 | C2 | 108.5(3) | C19 | C14 | C15 | 119.5(4) |
| N1 | C1 | C6 | 114.0(3) | C16 | C15 | C14 | 120.3(3) |
| C6 | C1 | C2 | 110.6(3) | C15 | C16 | C17 | 119.3(3) |
| C3 | C2 | C1 | 111.8(3) | C16 | C17 | Br1 | 119.4(3) |
| C2 | C3 | C4 | 110.0(3) | C18 | C17 | Br1 | 119.1(3) |
| C12 | C3 | C2 | 108.4(3) | C18 | C17 | C16 | 121.5(3) |
| C12 | C3 | C4 | 112.1(3) | C17 | C18 | C19 | 118.8(3) |
| C5 | C4 | C3 | 110.7(3) | C14 | C19 | C18 | 120.6(3) |
| N1 | C5 | C4 | 111.0(2) | O3 | C20 | O4 | 125.6(3) |
| C7 | C6 | C1 | 122.9(3) | O3 | C20 | N1 | 123.9(3) |
| C7 | C6 | C11 | 118.5(4) | O4 | C20 | N1 | 110.5(3) |
| C11 | C6 | C1 | 118.5(3) | O4 | C21 | C22 | 110.8(3) |
| C6 | C7 | C8 | 120.3(3) | O4 | C21 | C23 | 109.0(3) |
| C9 | C8 | C7 | 120.1(4) | O4 | C21 | C24 | 102.0(2) |
| C8 | C9 | C10 | 120.1(4) | C22 | C21 | C23 | 112.9(3) |
| C11 | C10 | C9 | 120.1(3) | C22 | C21 | C24 | 111.7(3) |
| C10 | C11 | C6 | 121.0(4) | C24 | C21 | C23 | 109.9(3) |
| O1 | C12 | C3 | 109.1(3) | | | | |

**Table S7 Torsion Angles for OIC323v_0m.**

| A | B | C | D | Angle/° | A | B | C | D | Angle/° |
|---|---|---|---|---|---|---|---|---|---|
| Br1 | C17 | C18 | C19 | 177.0(2) | C7 | C6 | C11 | C10 | -0.1(5) |
| O1 | C13 | C14 | C15 | 176.9(3) | C7 | C8 | C9 | C10 | 0.0(5) |
| O1 | C13 | C14 | C19 | -4.0(5) | C8 | C9 | C10 | C11 | 0.5(6) |
| O2 | C13 | C14 | C15 | -3.8(6) | C9 | C10 | C11 | C6 | -0.4(6) |
| O2 | C13 | C14 | C19 | 175.2(3) | C11 | C6 | C7 | C8 | 0.5(5) |
| N1 | C1 | C2 | C3 | -38.4(4) | C12 | O1 | C13 | O2 | 1.1(5) |
| N1 | C1 | C6 | C7 | -19.4(5) | C12 | O1 | C13 | C14 | -179.6(3) |
| N1 | C1 | C6 | C11 | 164.3(3) | C12 | C3 | C4 | C5 | -144.4(3) |
| C1 | N1 | C5 | C4 | 65.7(4) | C13 | O1 | C12 | C3 | 177.0(3) |
| C1 | N1 | C20 | O3 | 14.6(5) | C13 | C14 | C15 | C16 | 177.5(3) |
| C1 | N1 | C20 | O4 | -165.6(3) | C13 | C14 | C19 | C18 | -177.6(4) |
| C1 | C2 | C3 | C4 | 64.2(3) | C14 | C15 | C16 | C17 | -0.1(5) |
| C1 | C2 | C3 | C12 | -172.9(3) | C15 | C14 | C19 | C18 | 1.5(5) |
| C1 | C6 | C7 | C8 | -175.8(3) | C15 | C16 | C17 | Br1 | -177.1(2) |
| C1 | C6 | C11 | C10 | 176.4(3) | C15 | C16 | C17 | C18 | 2.0(5) |
| C2 | C1 | C6 | C7 | 103.2(3) | C16 | C17 | C18 | C19 | -2.1(5) |
| C2 | C1 | C6 | C11 | -73.1(4) | C17 | C18 | C19 | C14 | 0.3(5) |
| C2 | C3 | C4 | C5 | -23.7(4) | C19 | C14 | C15 | C16 | -1.5(5) |
| C2 | C3 | C12 | O1 | -177.5(3) | C20 | O4 | C21 | C22 | -63.5(4) |
| C3 | C4 | C5 | N1 | -36.4(4) | C20 | O4 | C21 | C23 | 61.4(4) |
| C4 | C3 | C12 | O1 | -55.9(4) | C20 | O4 | C21 | C24 | 177.5(3) |
| C5 | N1 | C1 | C2 | -24.8(4) | C20 | N1 | C1 | C2 | 135.9(3) |
| C5 | N1 | C1 | C6 | 98.9(4) | C20 | N1 | C1 | C6 | -100.4(4) |
| C5 | N1 | C20 | O3 | 173.8(3) | C20 | N1 | C5 | C4 | -94.1(4) |
| C5 | N1 | C20 | O4 | -6.4(4) | C21 | O4 | C20 | O3 | 9.4(5) |
| C6 | C1 | C2 | C3 | -164.2(3) | C21 | O4 | C20 | N1 | -170.4(3) |
| C6 | C7 | C8 | C9 | -0.5(5) | | | | | |

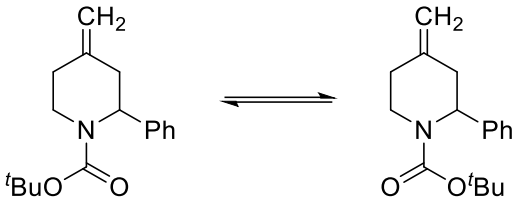
**Table S8 Hydrogen Atom Coordinates (Å×10$^4$) and Isotropic Displacement Parameters (Å$^2$×10$^3$) for OIC323v_0m.**

| Atom | *x* | *y* | *z* | U(eq) |
|---|---|---|---|---|
| H1 | 5264.26 | 7619.31 | 5921.71 | 33 |
| H2A | 5355.13 | 7802.75 | 8109.5 | 34 |
| H2B | 4547 | 7769.29 | 7128.51 | 34 |
| H3 | 4826.76 | 5587.04 | 6828.66 | 36 |
| H4A | 5966.3 | 5331.59 | 8842.88 | 41 |
| H4B | 5939.45 | 4574.98 | 7782.93 | 41 |
| H5A | 6681.6 | 6969.41 | 8446.08 | 36 |
| H5B | 7065.29 | 5790.89 | 7987.42 | 36 |
| H7 | 7060.92 | 8926.7 | 7611.82 | 40 |
| H8 | 7359.41 | 11095.23 | 7851.6 | 48 |
| H9 | 6353.67 | 12594.01 | 7153.66 | 52 |
| H10 | 5041.06 | 11943.28 | 6210.96 | 56 |
| H11 | 4732.97 | 9801.27 | 5988.24 | 47 |
| H12A | 4628.33 | 6173.84 | 8856.64 | 43 |
| H12B | 3899.62 | 6048.77 | 7781.26 | 43 |
| H15 | 3192.43 | 2754.69 | 10097.66 | 37 |
| H16 | 3093.45 | 576.65 | 10339.07 | 37 |
| H18 | 4533.52 | -82.28 | 8434.33 | 37 |
| H19 | 4629.29 | 2111.21 | 8188.97 | 38 |
| H22A | 6412.9 | 3615.13 | 4902.92 | 66 |
| H22B | 7055.29 | 3676 | 4231.82 | 66 |
| H22C | 6454.24 | 4847.3 | 4212.02 | 66 |
| H23A | 7601.71 | 6372.53 | 4806.86 | 61 |
| H23B | 8278.71 | 5300.73 | 4873.74 | 61 |
| H23C | 8299.18 | 6134.83 | 5891.68 | 61 |
| H24A | 8317.06 | 4164.2 | 6880.03 | 44 |
| H24B | 8218.59 | 3268.42 | 5874.34 | 44 |
| H24C | 7574.77 | 3178.06 | 6541.82 | 44 |

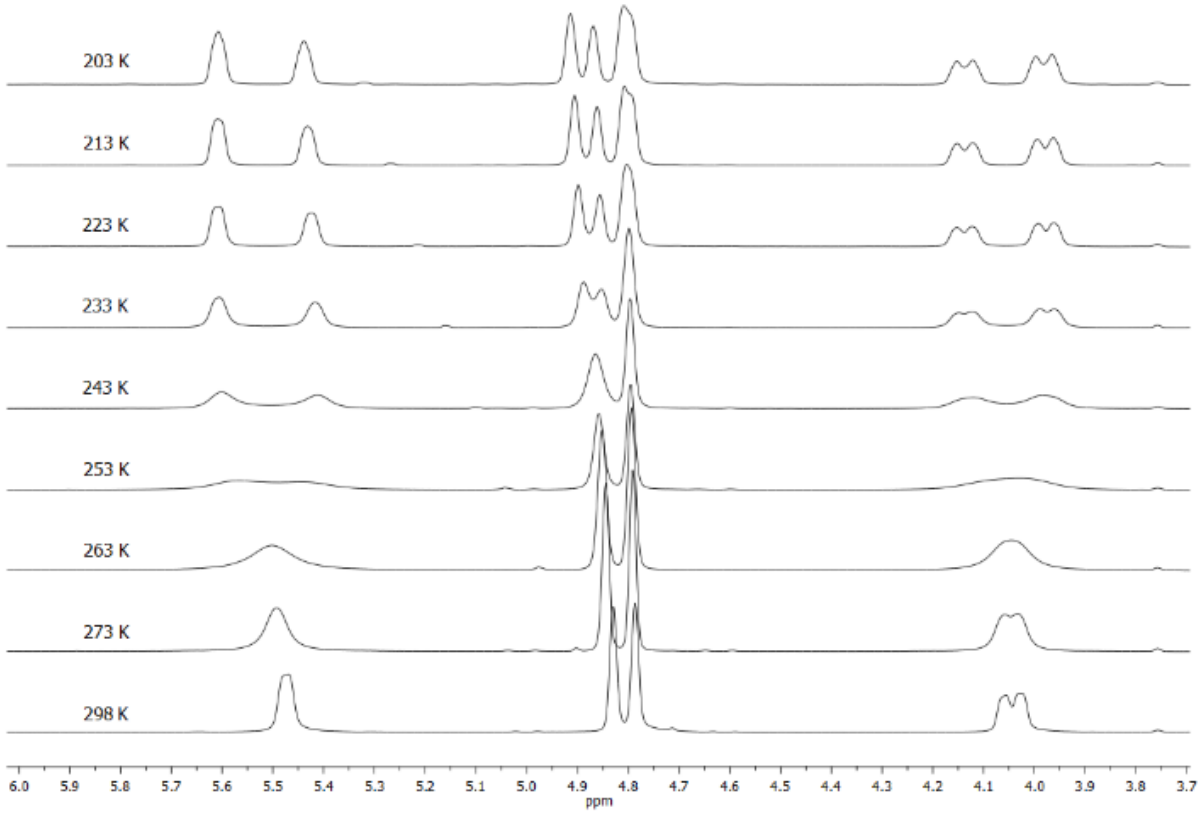
**Crystal structure determination of OIC323v_0m**

**Crystal Data** for $C_{24}H_{28}BrNO_4$ ($M$ =474.38 g/mol): monoclinic, space group C2 (no. 5), $a$ = 17.0948(12) Å, $b$ = 10.5262(7) Å, $c$ = 13.2389(9) Å, $\beta$ = 106.728(3)°, $V$ = 2281.4(3) Å$^3$, $Z$ = 4, $T$ = 99.99 K, μ(CuKα) = 2.694 mm$^{-1}$, *Dcalc* = 1.381 g/cm$^3$, 41440 reflections measured (6.972° ≤ 2Θ ≤ 133.964°), 4016 unique ($R_{int}$ = 0.0517, $R_{sigma}$ = 0.0256) which were used in all calculations. The final $R_1$ was 0.0246 (I > 2σ(I)) and $wR_2$ was 0.0588 (all data).

## 7. Variable temperature $^1$H NMR spectra for alkene 3a




Coalescence of signals in the $^1$H NMR spectrum of alkene **3a** in $D_8$-THF was followed by taking spectra at various temperatures. The $^1$H NMR spectra in the region 6.0–3.7 ppm are shown below:



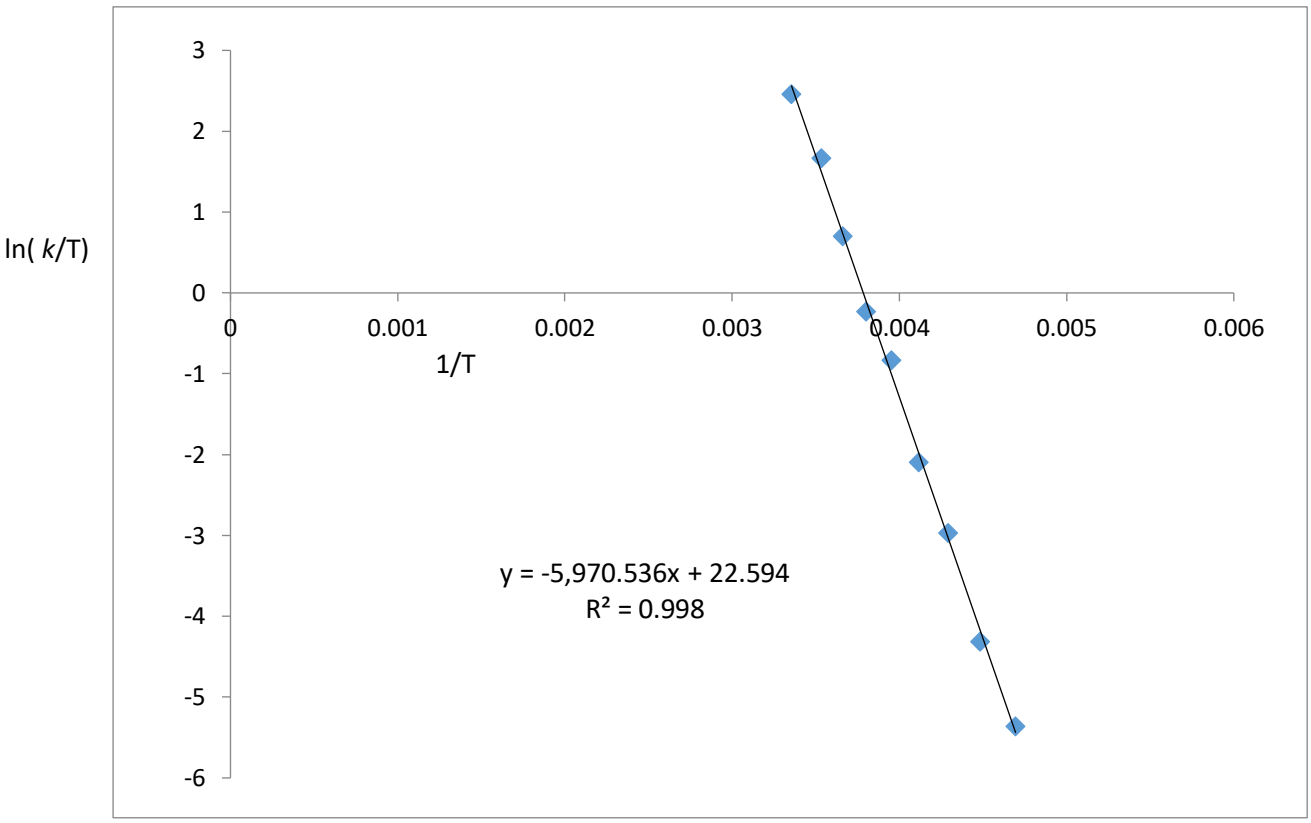

The ratio of rotamers is ~1.2 : 1.

Assuming an approximately equal rate and using line shape analysis (DNMR with the software iNMR), the following rate data can be estimated:

**Table S-9**. Estimated rate constants from VT-NMR spectroscopy of carbamate **3a**.

| T/K | 1/T | *k* | ln(*k*/T) |
|---|---|---|---|
| 203 | 0.004926 | 0.1 | -7.61579107 |
| 213 | 0.004695 | 1 | -5.36129217 |
| 223 | 0.004484 | 3 | -4.30855948 |
| 233 | 0.004292 | 12 | -2.9661318 |
| 243 | 0.004115 | 30 | -2.09186406 |
| 253 | 0.003953 | 110 | -0.83290912 |
| 263 | 0.003802 | 210 | -0.2250465 |
| 273 | 0.003663 | 550 | 0.700446483 |
| 283 | 0.003534 | 1500 | 1.667773489 |
| 298 | 0.003356 | 3500 | 2.463424761 |

Eyring plot:



By using the Eyring equation, this gave the following data:

slope –5970.54, intercept 22.59

Approximate activation parameters for Boc rotation in THF:

$\Delta H^{\ddagger} \approx 49.6$ kJ/mol

$\Delta S^{\ddagger} \approx -9.7$ J/K·mol.

Hence the barrier to rotation $\Delta G^{\ddagger} \approx 51.5$ kJ/mol at –78 °C.

The half-life for rotation is about 11 sec at –78 °C.

## 8. DFT Data

DFT calculations on the rotamers of piperidine **3a** were carried out using the methods described in the general information. Two conformations of piperidine **3a** were considered where the phenyl group could be axial or equatorial. The minimal energy structures for the rotamers of piperidine **3a** with an axial phenyl group are shown in Figure 1a,c. Of these two structures the rotamer in which the carbonyl group of the Boc group is pointing towards the benzylic position (C-2) was lower in thermal energy by 170 $Jmol^{-1}$. From these structures the lowest energy transition state for rotation of the Boc group was obtained (Figure 1b) where the Gibbs energy of activation was calculated to be ~77 $kJmol^{-1}$ at –78 °C.

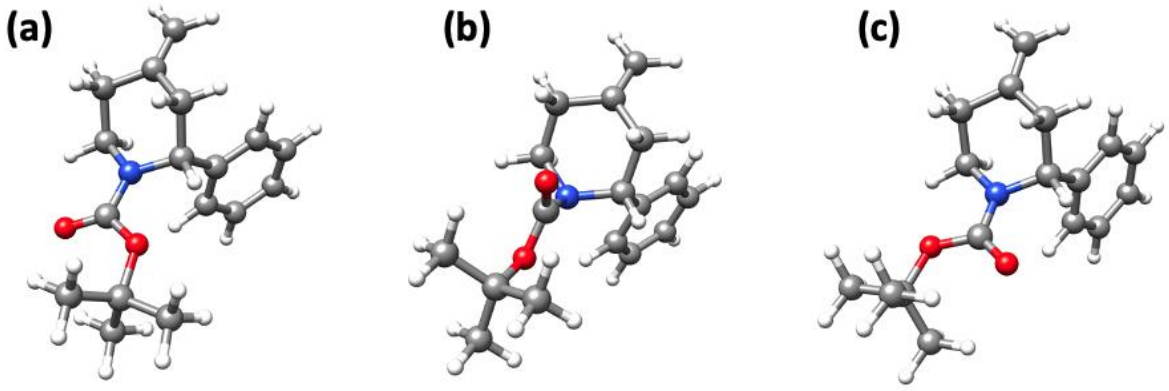



*Figure 1*

In contrast, the minimal energy structures for the rotamers of piperidine **3a** with an equatorial phenyl group are shown in Figure 2a,c. As expected, based on $A_{1,3}$ strain considerations these structures were higher in energy then their corresponding axial rotamers, however the rotamer in which the carbonyl group of the Boc group is pointing towards the benzylic position (C-2) was now higher in thermal energy by 6.3 $kJmol^{-1}$. The Gibbs energy of activation for rotation of the Boc group through the lowest energy transition state (Figure 2b) was calculated to be ~34 $kJmol^{-1}$ at –78 °C. Although further optimization of the rotamers in Figure 2a,c gave lower energy structures, the lowest energy transition state obtained for rotation of the Boc group from these structures was much higher in energy when compared to the other transition states calculated. Therefore, these structures were not considered any further.

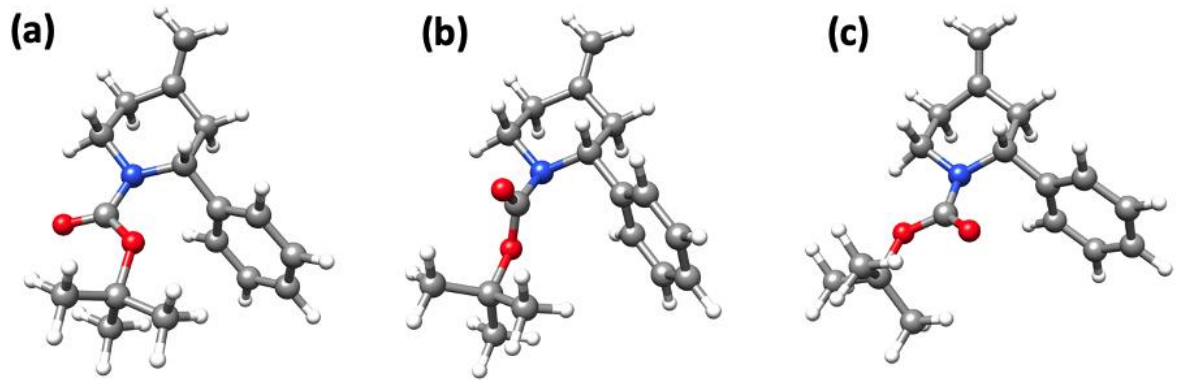
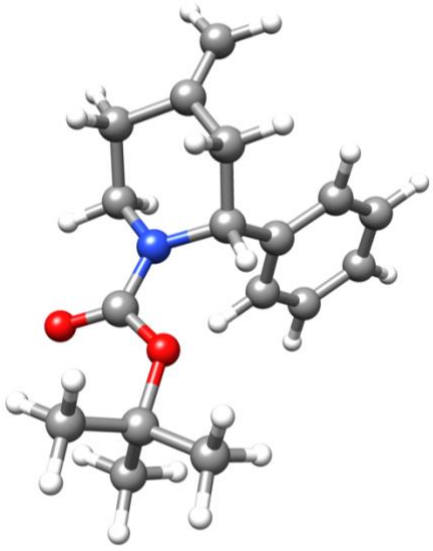



*Figure 2*

With the phenyl group axial in piperidine **3a** we found when comparing this to the lowest energy equatorial transition state for rotation of the Boc group the Gibbs energy of activation was calculated to be ~55 $kJmol^{-1}$ at –78 °C (with $\Delta H \approx 43$ $kJmol^{-1}$ and $\Delta S \approx -63$ $JK^{-1}mol^{-1}$). This value matched well with the results obtained from VT-NMR and indicated that the rate of ring flipping between the axial and equatorial positions of the phenyl group was fast along with the rotation of the Boc group under the reaction conditions.

Below are summaries for optimised structures and transition states obtained from the calculations performed. Thermochemistry data at 298 K, 223 K and 195 K has also been provided as well.

Left Rotamer Axial



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.6574 Debye

Energy : -867.300243526 a.u.

Gibbs Energy : -866.979530 a.u.

Number of imaginary frequencies : 0

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -1.41379400 | -1.48908400 | 1.39336000 |
| C | -0.64103300 | -0.33635800 | 0.71920700 |
| C | -0.64043300 | -1.61694300 | -1.40517300 |
| C | -1.42477200 | -2.76659000 | -0.76582800 |
| H | 0.07834400 | 0.04029900 | 1.44046200 |
| H | -0.66022700 | -2.14732100 | 1.83644400 |
| H | -2.02984700 | -1.11639700 | 2.20891000 |
| H | -1.33666300 | -0.92697700 | -1.89147400 |
| H | 0.05359000 | -1.98355700 | -2.15380300 |
| H | -2.06760000 | -3.23185000 | -1.51396400 |
| H | -0.70914400 | -3.52084300 | -0.42095200 |
| C | -2.22815300 | -2.27127500 | 0.40337600 |
| C | -3.53518400 | -2.47520300 | 0.53201400 |
| H | -4.08764600 | -2.08981900 | 1.38040800 |
| H | -4.09436900 | -3.03763500 | -0.20609400 |
| N | 0.12622500 | -0.89038000 | -0.39924400 |

| | | | |
|---|---|---|---|
| C | 1.46011600 | -0.68835500 | -0.58630300 |
| O | 2.08870400 | -1.12864600 | -1.53596800 |
| O | 1.98784600 | 0.05600000 | 0.40436800 |
| C | 3.40317300 | 0.45464200 | 0.40959200 |
| C | 4.29797600 | -0.77654600 | 0.49413500 |
| H | 4.23784500 | -1.37079000 | -0.41346500 |
| H | 5.33172900 | -0.45977600 | 0.64053400 |
| H | 4.00809800 | -1.39535600 | 1.34477300 |
| C | 3.70726000 | 1.31568200 | -0.81116700 |
| H | 4.71556700 | 1.72258500 | -0.72194900 |
| H | 3.64273800 | 0.73672500 | -1.72840600 |
| H | 3.00670400 | 2.15039000 | -0.86663100 |
| C | 3.50575500 | 1.28083200 | 1.68585500 |
| H | 3.24637200 | 0.67627200 | 2.55560000 |
| H | 4.52525000 | 1.64658700 | 1.80927200 |
| H | 2.83200700 | 2.13709900 | 1.64260800 |
| C | -1.49911400 | 0.84544000 | 0.27335000 |
| C | -1.05462200 | 1.67357100 | -0.75863900 |
| C | -2.69588100 | 1.17320200 | 0.90936700 |
| C | -1.78234300 | 2.79118500 | -1.14659700 |
| H | -0.13103400 | 1.44075100 | -1.27060300 |
| C | -3.42752600 | 2.29198100 | 0.52474100 |
| H | -3.07455100 | 0.55773200 | 1.71192700 |
| C | -2.97553700 | 3.10604600 | -0.50599500 |
| H | -1.41600800 | 3.41567900 | -1.95144400 |
| H | -4.35587600 | 2.52235700 | 1.03176100 |
| H | -3.54656600 | 3.97431500 | -0.80817700 |

Frequencies

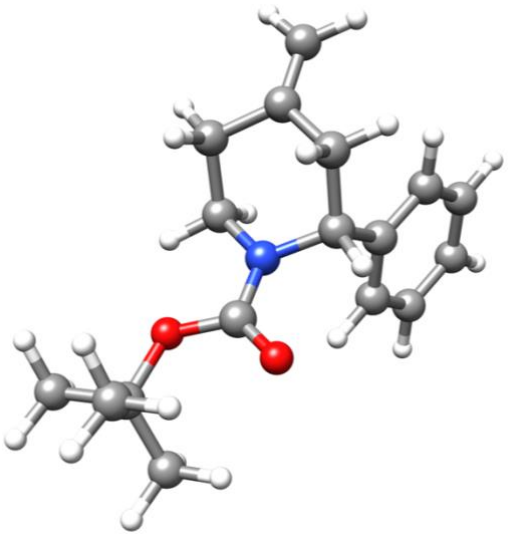
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | 14.16070000 | 0.02060000 | 0.00000000 |
| 2 | 19.09830000 | 0.17990000 | 0.00000000 |
| 3 | 34.18630000 | 0.01750000 | 0.00000000 |
| 4 | 59.89320000 | 4.61870000 | 0.00000000 |
| 5 | 68.74770000 | 0.27250000 | 0.00000000 |
| 6 | 100.20840000 | 0.47870000 | 0.00000000 |
| 7 | 107.13920000 | 0.23520000 | 0.00000000 |
| 8 | 124.02560000 | 1.12160000 | 0.00000000 |
| 9 | 160.17790000 | 0.17590000 | 0.00000000 |
| 10 | 199.02450000 | 1.17170000 | 0.00000000 |
| 11 | 204.41360000 | 0.22210000 | 0.00000000 |
| 12 | 219.00280000 | 8.03990000 | 0.00000000 |
| 13 | 241.93030000 | 0.04140000 | 0.00000000 |
| 14 | 271.52830000 | 0.06880000 | 0.00000000 |
| 15 | 275.83610000 | 3.09010000 | 0.00000000 |
| 16 | 306.93210000 | 0.37410000 | 0.00000000 |
| 17 | 330.05430000 | 3.81040000 | 0.00000000 |
| 18 | 340.62590000 | 12.67090000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 19 | 351.09040000 | 1.95050000 | 0.00000000 |
| 20 | 384.15790000 | 10.95380000 | 0.00000000 |
| 21 | 410.14060000 | 1.13510000 | 0.00000000 |
| 22 | 413.73130000 | 3.57770000 | 0.00000000 |
| 23 | 415.40020000 | 0.07740000 | 0.00000000 |
| 24 | 436.04500000 | 1.64770000 | 0.00000000 |
| 25 | 459.74400000 | 3.71200000 | 0.00000000 |
| 26 | 469.28450000 | 15.86460000 | 0.00000000 |
| 27 | 483.41550000 | 1.45780000 | 0.00000000 |
| 28 | 511.69800000 | 0.80150000 | 0.00000000 |
| 29 | 542.05550000 | 9.22950000 | 0.00000000 |
| 30 | 623.94120000 | 7.78990000 | 0.00000000 |
| 31 | 638.25710000 | 1.03310000 | 0.00000000 |
| 32 | 664.64230000 | 21.36010000 | 0.00000000 |
| 33 | 712.81940000 | 54.31570000 | 0.00000000 |
| 34 | 723.29660000 | 18.21150000 | 0.00000000 |
| 35 | 743.44520000 | 12.23450000 | 0.00000000 |
| 36 | 766.15980000 | 7.17110000 | 0.00000000 |
| 37 | 771.72180000 | 17.59310000 | 0.00000000 |
| 38 | 776.37560000 | 26.19100000 | 0.00000000 |
| 39 | 786.15690000 | 12.90970000 | 0.00000000 |
| 40 | 812.77920000 | 16.82260000 | 0.00000000 |
| 41 | 840.54860000 | 5.75630000 | 0.00000000 |
| 42 | 857.51940000 | 0.67370000 | 0.00000000 |
| 43 | 867.35760000 | 47.70610000 | 0.00000000 |
| 44 | 917.36150000 | 27.17080000 | 0.00000000 |
| 45 | 928.21160000 | 39.30960000 | 0.00000000 |
| 46 | 929.49550000 | 3.79850000 | 0.00000000 |
| 47 | 930.79810000 | 0.14670000 | 0.00000000 |
| 48 | 939.92590000 | 13.87540000 | 0.00000000 |
| 49 | 963.59740000 | 20.37220000 | 0.00000000 |
| 50 | 972.60480000 | 0.10580000 | 0.00000000 |
| 51 | 979.39580000 | 0.37410000 | 0.00000000 |
| 52 | 994.50530000 | 1.08140000 | 0.00000000 |
| 53 | 1007.37460000 | 21.82210000 | 0.00000000 |
| 54 | 1014.22440000 | 79.32760000 | 0.00000000 |
| 55 | 1025.10860000 | 4.61930000 | 0.00000000 |
| 56 | 1029.52630000 | 60.32650000 | 0.00000000 |
| 57 | 1052.70300000 | 0.67880000 | 0.00000000 |
| 58 | 1055.51190000 | 9.62660000 | 0.00000000 |
| 59 | 1059.16300000 | 0.95600000 | 0.00000000 |
| 60 | 1070.39220000 | 10.22900000 | 0.00000000 |
| 61 | 1115.02270000 | 21.65620000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 62 | 1126.69820000 | 183.51340000 | 0.00000000 |
| 63 | 1169.18920000 | 70.52510000 | 0.00000000 |
| 64 | 1181.97660000 | 6.71480000 | 0.00000000 |
| 65 | 1185.39030000 | 416.03820000 | 0.00000000 |
| 66 | 1198.72450000 | 56.29080000 | 0.00000000 |
| 67 | 1211.07760000 | 5.65180000 | 0.00000000 |
| 68 | 1223.71120000 | 17.14680000 | 0.00000000 |
| 69 | 1248.58540000 | 4.27730000 | 0.00000000 |
| 70 | 1269.20150000 | 96.09440000 | 0.00000000 |
| 71 | 1269.83470000 | 86.09100000 | 0.00000000 |
| 72 | 1284.04360000 | 36.02090000 | 0.00000000 |
| 73 | 1292.64790000 | 97.78100000 | 0.00000000 |
| 74 | 1305.65780000 | 12.79180000 | 0.00000000 |
| 75 | 1325.22680000 | 20.97300000 | 0.00000000 |
| 76 | 1347.77640000 | 160.69840000 | 0.00000000 |
| 77 | 1354.84960000 | 7.78100000 | 0.00000000 |
| 78 | 1364.27420000 | 0.18930000 | 0.00000000 |
| 79 | 1378.87620000 | 16.93550000 | 0.00000000 |
| 80 | 1396.25500000 | 31.37290000 | 0.00000000 |
| 81 | 1396.87640000 | 28.31070000 | 0.00000000 |
| 82 | 1401.19940000 | 16.17020000 | 0.00000000 |
| 83 | 1423.04640000 | 18.01430000 | 0.00000000 |
| 84 | 1444.24550000 | 393.77190000 | 0.00000000 |
| 85 | 1456.82030000 | 25.68590000 | 0.00000000 |
| 86 | 1466.68250000 | 0.20610000 | 0.00000000 |
| 87 | 1473.28380000 | 4.81720000 | 0.00000000 |
| 88 | 1482.76110000 | 11.02400000 | 0.00000000 |
| 89 | 1484.26350000 | 1.61930000 | 0.00000000 |
| 90 | 1484.35710000 | 1.59170000 | 0.00000000 |
| 91 | 1486.94800000 | 25.93270000 | 0.00000000 |
| 92 | 1492.10110000 | 29.79960000 | 0.00000000 |
| 93 | 1497.60620000 | 2.46160000 | 0.00000000 |
| 94 | 1499.56730000 | 19.29340000 | 0.00000000 |
| 95 | 1517.34740000 | 32.81390000 | 0.00000000 |
| 96 | 1535.33650000 | 19.18150000 | 0.00000000 |
| 97 | 1625.44980000 | 0.39220000 | 0.00000000 |
| 98 | 1646.23830000 | 11.23140000 | 0.00000000 |
| 99 | 1701.82210000 | 797.65440000 | 0.00000000 |
| 100 | 1717.00020000 | 17.29430000 | 0.00000000 |
| 101 | 3011.92360000 | 20.09000000 | 0.00000000 |
| 102 | 3026.63370000 | 28.21360000 | 0.00000000 |
| 103 | 3029.12930000 | 76.73210000 | 0.00000000 |
| 104 | 3041.44740000 | 15.45400000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 105 | 3043.10580000 | 39.69190000 | 0.00000000 |
| 106 | 3049.98520000 | 20.64360000 | 0.00000000 |
| 107 | 3086.55710000 | 44.81620000 | 0.00000000 |
| 108 | 3102.06480000 | 8.04560000 | 0.00000000 |
| 109 | 3104.19370000 | 30.62440000 | 0.00000000 |
| 110 | 3109.71890000 | 25.64920000 | 0.00000000 |
| 111 | 3111.08380000 | 45.13500000 | 0.00000000 |
| 112 | 3117.60990000 | 64.10510000 | 0.00000000 |
| 113 | 3120.69660000 | 8.14510000 | 0.00000000 |
| 114 | 3131.75470000 | 14.54570000 | 0.00000000 |
| 115 | 3144.88970000 | 0.65150000 | 0.00000000 |
| 116 | 3147.99200000 | 24.36750000 | 0.00000000 |
| 117 | 3152.11910000 | 6.65550000 | 0.00000000 |
| 118 | 3169.80960000 | 0.56760000 | 0.00000000 |
| 119 | 3177.90180000 | 11.67750000 | 0.00000000 |
| 120 | 3190.57040000 | 32.40370000 | 0.00000000 |
| 121 | 3198.42780000 | 21.89150000 | 0.00000000 |
| 122 | 3210.45420000 | 8.79120000 | 0.00000000 |
| 123 | 3211.23580000 | 26.50140000 | 0.00000000 |

Right Rotamer Axial



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.7968 Debye

Energy : -867.300166083 a.u.

Gibbs Energy : -866.983065 a.u.

Number of imaginary frequencies : 0

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -1.42919500 | -1.73875000 | 1.22136800 |
| C | -0.97148400 | -0.29229000 | 0.94757600 |
| C | -0.01570300 | -1.00933700 | -1.21443600 |
| C | -0.45123400 | -2.46108100 | -0.98477300 |
| H | -0.61807700 | 0.13212800 | 1.88510700 |
| H | -0.63129600 | -2.20655900 | 1.80643300 |
| H | -2.32517600 | -1.75190300 | 1.83972300 |
| H | -0.79692400 | -0.47575500 | -1.76281400 |
| H | 0.89675500 | -0.96334300 | -1.79584200 |
| H | -0.69064500 | -2.93122000 | -1.93943700 |
| H | 0.39287400 | -3.00406200 | -0.54533000 |
| C | -1.62615500 | -2.52125600 | -0.04786400 |
| C | -2.74194100 | -3.18733600 | -0.32735200 |
| H | -3.57875700 | -3.20563200 | 0.36050000 |

| | | | |
|---|---|---|---|
| H | -2.85300700 | -3.74048700 | -1.25225500 |
| N | 0.19345100 | -0.33402400 | 0.06151300 |
| C | 1.39189700 | 0.12881600 | 0.51006900 |
| O | 1.54994100 | 0.66046700 | 1.59884800 |
| O | 2.36740100 | -0.06550700 | -0.39718200 |
| C | 3.74644400 | 0.38828000 | -0.16084500 |
| C | 3.78107200 | 1.90425400 | -0.00283400 |
| H | 3.28543300 | 2.21736600 | 0.91203500 |
| H | 4.81921600 | 2.23843400 | 0.02692200 |
| H | 3.29386100 | 2.38296800 | -0.85377000 |
| C | 4.33967300 | -0.33763400 | 1.04131800 |
| H | 5.40093500 | -0.09677900 | 1.11858100 |
| H | 3.84470000 | -0.04375600 | 1.96278000 |
| H | 4.24410400 | -1.41714300 | 0.91431600 |
| C | 4.45505600 | -0.03220700 | -1.44265400 |
| H | 4.00414000 | 0.45514500 | -2.30769500 |
| H | 5.50673300 | 0.25084100 | -1.39392500 |
| H | 4.39240100 | -1.11239500 | -1.57849800 |
| C | -2.03735700 | 0.64445800 | 0.39114200 |
| C | -1.63956100 | 1.86550100 | -0.15840700 |
| C | -3.39964100 | 0.36027300 | 0.44997800 |
| C | -2.57314800 | 2.77429900 | -0.63647000 |
| H | -0.58549300 | 2.10354700 | -0.21396600 |
| C | -4.33953500 | 1.26900400 | -0.02859900 |
| H | -3.74489900 | -0.57577400 | 0.86200700 |
| C | -3.93158300 | 2.47844100 | -0.57473100 |
| H | -2.24046600 | 3.71467300 | -1.05727500 |
| H | -5.39277900 | 1.02405400 | 0.02311600 |
| H | -4.66215900 | 3.18353000 | -0.94955000 |

Frequencies

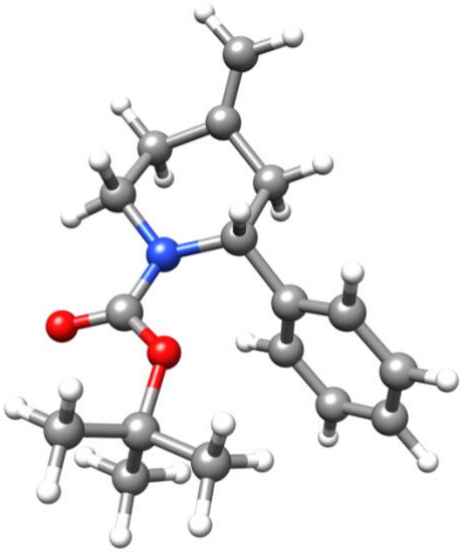
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | 2.45010000 | 0.07770000 | 0.00000000 |
| 2 | 4.31770000 | 0.05220000 | 0.00000000 |
| 3 | 26.95830000 | 0.06870000 | 0.00000000 |
| 4 | 53.99790000 | 5.22180000 | 0.00000000 |
| 5 | 73.90260000 | 0.66050000 | 0.00000000 |
| 6 | 98.47940000 | 0.52890000 | 0.00000000 |
| 7 | 103.36100000 | 0.49950000 | 0.00000000 |
| 8 | 122.69100000 | 0.67640000 | 0.00000000 |
| 9 | 157.64960000 | 0.79010000 | 0.00000000 |
| 10 | 199.43650000 | 0.32700000 | 0.00000000 |
| 11 | 203.57420000 | 0.15290000 | 0.00000000 |
| 12 | 236.83350000 | 0.94040000 | 0.00000000 |
| 13 | 243.56010000 | 12.01890000 | 0.00000000 |
| 14 | 250.64830000 | 1.38880000 | 0.00000000 |
| 15 | 268.76940000 | 0.06440000 | 0.00000000 |
| 16 | 288.92720000 | 0.56290000 | 0.00000000 |
| 17 | 331.96410000 | 18.47730000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 18 | 337.81910000 | 6.86540000 | 0.00000000 |
| 19 | 349.67860000 | 1.18140000 | 0.00000000 |
| 20 | 380.21470000 | 3.05640000 | 0.00000000 |
| 21 | 407.79230000 | 1.55030000 | 0.00000000 |
| 22 | 414.28380000 | 0.31150000 | 0.00000000 |
| 23 | 418.26190000 | 1.31320000 | 0.00000000 |
| 24 | 452.47170000 | 5.63920000 | 0.00000000 |
| 25 | 459.53920000 | 2.92150000 | 0.00000000 |
| 26 | 474.37770000 | 13.05360000 | 0.00000000 |
| 27 | 486.88570000 | 1.12660000 | 0.00000000 |
| 28 | 512.08290000 | 0.38750000 | 0.00000000 |
| 29 | 562.59240000 | 11.62690000 | 0.00000000 |
| 30 | 621.37590000 | 15.77720000 | 0.00000000 |
| 31 | 637.50680000 | 0.78950000 | 0.00000000 |
| 32 | 652.22480000 | 16.04450000 | 0.00000000 |
| 33 | 712.09610000 | 61.92540000 | 0.00000000 |
| 34 | 720.48630000 | 8.98440000 | 0.00000000 |
| 35 | 737.42060000 | 20.79820000 | 0.00000000 |
| 36 | 755.92130000 | 5.29830000 | 0.00000000 |
| 37 | 774.52910000 | 33.13490000 | 0.00000000 |
| 38 | 781.99990000 | 14.18240000 | 0.00000000 |
| 39 | 782.51300000 | 4.49550000 | 0.00000000 |
| 40 | 812.43830000 | 14.82340000 | 0.00000000 |
| 41 | 839.78000000 | 4.26130000 | 0.00000000 |
| 42 | 856.20450000 | 0.27180000 | 0.00000000 |
| 43 | 870.43770000 | 63.66860000 | 0.00000000 |
| 44 | 916.96660000 | 28.57370000 | 0.00000000 |
| 45 | 927.49790000 | 34.75110000 | 0.00000000 |
| 46 | 929.11700000 | 3.70030000 | 0.00000000 |
| 47 | 929.61990000 | 0.27020000 | 0.00000000 |
| 48 | 934.04640000 | 10.78130000 | 0.00000000 |
| 49 | 963.14540000 | 9.97930000 | 0.00000000 |
| 50 | 971.41980000 | 0.10420000 | 0.00000000 |
| 51 | 977.05430000 | 0.19100000 | 0.00000000 |
| 52 | 992.55190000 | 0.65020000 | 0.00000000 |
| 53 | 1003.39320000 | 19.11090000 | 0.00000000 |
| 54 | 1013.07010000 | 60.33330000 | 0.00000000 |
| 55 | 1023.33920000 | 83.27710000 | 0.00000000 |
| 56 | 1026.77890000 | 50.37930000 | 0.00000000 |
| 57 | 1052.09840000 | 1.18770000 | 0.00000000 |
| 58 | 1053.76880000 | 9.23390000 | 0.00000000 |
| 59 | 1058.26650000 | 2.11370000 | 0.00000000 |
| 60 | 1066.97280000 | 1.01460000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 61 | 1110.95620000 | 29.30920000 | 0.00000000 |
| 62 | 1131.09720000 | 182.01100000 | 0.00000000 |
| 63 | 1167.27670000 | 29.86450000 | 0.00000000 |
| 64 | 1180.89360000 | 10.63670000 | 0.00000000 |
| 65 | 1183.79790000 | 546.75020000 | 0.00000000 |
| 66 | 1206.41480000 | 14.33350000 | 0.00000000 |
| 67 | 1209.89080000 | 1.83440000 | 0.00000000 |
| 68 | 1222.95910000 | 21.70410000 | 0.00000000 |
| 69 | 1247.87770000 | 12.23390000 | 0.00000000 |
| 70 | 1265.99330000 | 179.91710000 | 0.00000000 |
| 71 | 1268.80260000 | 22.79600000 | 0.00000000 |
| 72 | 1284.58240000 | 42.07890000 | 0.00000000 |
| 73 | 1287.88590000 | 54.44890000 | 0.00000000 |
| 74 | 1304.88460000 | 10.82540000 | 0.00000000 |
| 75 | 1331.01430000 | 10.30370000 | 0.00000000 |
| 76 | 1348.34690000 | 151.03810000 | 0.00000000 |
| 77 | 1354.74240000 | 3.42020000 | 0.00000000 |
| 78 | 1364.77030000 | 1.78950000 | 0.00000000 |
| 79 | 1379.64700000 | 14.17490000 | 0.00000000 |
| 80 | 1395.82840000 | 28.40310000 | 0.00000000 |
| 81 | 1396.54330000 | 44.12880000 | 0.00000000 |
| 82 | 1400.73470000 | 13.64270000 | 0.00000000 |
| 83 | 1421.46170000 | 19.49900000 | 0.00000000 |
| 84 | 1447.57240000 | 417.17350000 | 0.00000000 |
| 85 | 1456.00790000 | 35.17910000 | 0.00000000 |
| 86 | 1465.84070000 | 0.15340000 | 0.00000000 |
| 87 | 1471.82940000 | 8.96120000 | 0.00000000 |
| 88 | 1483.18840000 | 11.06640000 | 0.00000000 |
| 89 | 1483.81090000 | 2.04970000 | 0.00000000 |
| 90 | 1483.90290000 | 0.21040000 | 0.00000000 |
| 91 | 1485.98480000 | 22.98670000 | 0.00000000 |
| 92 | 1490.06320000 | 26.06210000 | 0.00000000 |
| 93 | 1496.67560000 | 2.24090000 | 0.00000000 |
| 94 | 1501.85860000 | 21.90430000 | 0.00000000 |
| 95 | 1516.36830000 | 42.17840000 | 0.00000000 |
| 96 | 1535.33810000 | 17.56570000 | 0.00000000 |
| 97 | 1626.21340000 | 1.69160000 | 0.00000000 |
| 98 | 1646.81110000 | 8.02510000 | 0.00000000 |
| 99 | 1696.53820000 | 732.21270000 | 0.00000000 |
| 100 | 1715.10180000 | 21.48700000 | 0.00000000 |
| 101 | 3010.87800000 | 22.43100000 | 0.00000000 |
| 102 | 3026.86340000 | 33.27280000 | 0.00000000 |
| 103 | 3034.47150000 | 59.24340000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 104 | 3040.86340000 | 16.23940000 | 0.00000000 |
| 105 | 3043.25430000 | 40.90710000 | 0.00000000 |
| 106 | 3049.84740000 | 22.12720000 | 0.00000000 |
| 107 | 3084.59440000 | 45.71090000 | 0.00000000 |
| 108 | 3100.16260000 | 5.36240000 | 0.00000000 |
| 109 | 3102.25590000 | 6.58280000 | 0.00000000 |
| 110 | 3102.87160000 | 43.41560000 | 0.00000000 |
| 111 | 3103.63150000 | 27.14860000 | 0.00000000 |
| 112 | 3110.68590000 | 46.57890000 | 0.00000000 |
| 113 | 3117.08330000 | 61.35300000 | 0.00000000 |
| 114 | 3131.29930000 | 14.58860000 | 0.00000000 |
| 115 | 3144.86150000 | 2.56480000 | 0.00000000 |
| 116 | 3148.03850000 | 24.01270000 | 0.00000000 |
| 117 | 3169.12410000 | 0.72100000 | 0.00000000 |
| 118 | 3171.33050000 | 6.95070000 | 0.00000000 |
| 119 | 3177.04790000 | 9.38000000 | 0.00000000 |
| 120 | 3187.88440000 | 31.52680000 | 0.00000000 |
| 121 | 3195.71500000 | 26.22850000 | 0.00000000 |
| 122 | 3210.00930000 | 20.13710000 | 0.00000000 |
| 123 | 3216.75610000 | 13.57740000 | 0.00000000 |

Left Rotamer Equatorial



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.5409 Debye

Energy : -867.295403418 a.u.

Gibbs Energy : -866.973483 a.u.

Number of imaginary frequencies : 0

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -3.48872700 | -1.12642600 | -0.70406700 |
| C | -2.21300100 | -1.82479900 | -0.25297200 |
| C | -1.20184600 | 0.37630100 | 0.45404900 |
| C | -2.55702100 | 1.02659800 | 0.07748100 |
| H | -2.37627500 | -2.24226400 | 0.74907100 |
| H | -1.96921600 | -2.64631500 | -0.91789200 |
| H | -3.38330600 | -0.82964300 | -1.75290600 |
| H | -4.31940300 | -1.82927200 | -0.63355700 |
| H | -1.19082200 | 0.22463900 | 1.53929200 |
| H | -2.70022300 | 1.88941800 | 0.72736800 |
| H | -2.46712300 | 1.40022900 | -0.94727300 |
| C | -3.71674100 | 0.08624100 | 0.14153200 |
| C | -4.79553100 | 0.28776500 | 0.89105500 |
| H | -5.61404100 | -0.42198500 | 0.90465200 |
| H | -4.89726700 | 1.17200900 | 1.50880200 |
| N | -1.04378500 | -0.92912700 | -0.21792600 |

| | | | |
|---|---|---|---|
| C | 0.16123200 | -1.60270300 | -0.21045300 |
| O | 0.31523600 | -2.69921000 | -0.72139800 |
| O | 1.11600100 | -0.92159500 | 0.43025100 |
| C | 2.54168700 | -1.27502000 | 0.31660400 |
| C | 2.80194100 | -2.60426600 | 1.01455800 |
| H | 2.31071200 | -3.42283800 | 0.49547700 |
| H | 3.87629100 | -2.79365400 | 1.03898300 |
| H | 2.43918400 | -2.56703100 | 2.04294200 |
| C | 2.96054400 | -1.29115900 | -1.14881900 |
| H | 4.04180000 | -1.42259900 | -1.20863700 |
| H | 2.48108900 | -2.10242300 | -1.69043900 |
| H | 2.70423200 | -0.34306800 | -1.62259400 |
| C | 3.22675700 | -0.13153200 | 1.05333400 |
| H | 2.88111000 | -0.08059400 | 2.08627100 |
| H | 4.30548900 | -0.29056800 | 1.05559100 |
| H | 3.01075100 | 0.81990600 | 0.56950200 |
| C | -0.13038700 | 1.38542100 | 0.09725000 |
| C | 0.29184400 | 1.55838500 | -1.21931600 |
| C | 0.37490500 | 2.22786000 | 1.08116100 |
| C | 1.22354000 | 2.53647300 | -1.53885200 |
| H | -0.09501500 | 0.90787800 | -1.99327800 |
| C | 1.29904600 | 3.21740800 | 0.76369700 |
| H | 0.05529600 | 2.09910100 | 2.10832800 |
| C | 1.73192600 | 3.37151900 | -0.54762900 |
| H | 1.55448700 | 2.64838300 | -2.56360100 |
| H | 1.68863800 | 3.85930000 | 1.54352100 |
| H | 2.45920200 | 4.13333600 | -0.79663800 |

Frequencies

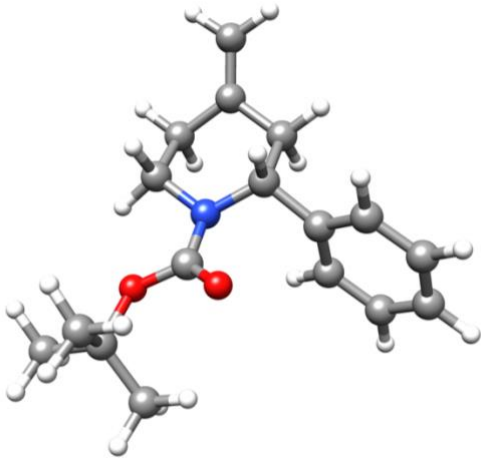
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | 22.03290000 | 0.49000000 | 0.00000000 |
| 2 | 40.45610000 | 0.35270000 | 0.00000000 |
| 3 | 60.34950000 | 4.19230000 | 0.00000000 |
| 4 | 67.42860000 | 0.04790000 | 0.00000000 |
| 5 | 75.24240000 | 0.02880000 | 0.00000000 |
| 6 | 91.43500000 | 2.34870000 | 0.00000000 |
| 7 | 105.79890000 | 1.29440000 | 0.00000000 |
| 8 | 140.09510000 | 0.13080000 | 0.00000000 |
| 9 | 171.77960000 | 0.22190000 | 0.00000000 |
| 10 | 182.85150000 | 4.51620000 | 0.00000000 |
| 11 | 209.75920000 | 0.66660000 | 0.00000000 |
| 12 | 220.32100000 | 4.68400000 | 0.00000000 |
| 13 | 242.00230000 | 0.48270000 | 0.00000000 |
| 14 | 250.10050000 | 0.49620000 | 0.00000000 |
| 15 | 274.24460000 | 2.82900000 | 0.00000000 |
| 16 | 278.34080000 | 2.58680000 | 0.00000000 |
| 17 | 285.78990000 | 4.94000000 | 0.00000000 |
| 18 | 324.31710000 | 4.34990000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 19 | 355.29400000 | 1.26240000 | 0.00000000 |
| 20 | 363.42850000 | 15.26280000 | 0.00000000 |
| 21 | 383.48180000 | 8.23190000 | 0.00000000 |
| 22 | 417.77920000 | 0.13190000 | 0.00000000 |
| 23 | 419.33730000 | 0.94310000 | 0.00000000 |
| 24 | 430.35130000 | 5.60970000 | 0.00000000 |
| 25 | 464.78630000 | 2.25110000 | 0.00000000 |
| 26 | 467.36990000 | 3.01530000 | 0.00000000 |
| 27 | 468.12900000 | 2.65560000 | 0.00000000 |
| 28 | 532.31110000 | 1.15100000 | 0.00000000 |
| 29 | 556.61320000 | 12.24140000 | 0.00000000 |
| 30 | 610.52550000 | 30.36150000 | 0.00000000 |
| 31 | 635.96070000 | 0.05190000 | 0.00000000 |
| 32 | 669.28950000 | 14.98480000 | 0.00000000 |
| 33 | 696.67420000 | 8.89860000 | 0.00000000 |
| 34 | 718.08190000 | 68.61840000 | 0.00000000 |
| 35 | 737.25580000 | 2.17330000 | 0.00000000 |
| 36 | 761.86530000 | 12.81390000 | 0.00000000 |
| 37 | 776.55150000 | 26.42290000 | 0.00000000 |
| 38 | 790.94940000 | 53.49620000 | 0.00000000 |
| 39 | 809.08940000 | 14.24560000 | 0.00000000 |
| 40 | 838.47520000 | 3.18560000 | 0.00000000 |
| 41 | 854.60230000 | 9.64790000 | 0.00000000 |
| 42 | 861.27550000 | 38.69870000 | 0.00000000 |
| 43 | 862.27150000 | 4.26100000 | 0.00000000 |
| 44 | 918.72080000 | 8.18220000 | 0.00000000 |
| 45 | 927.67090000 | 21.97020000 | 0.00000000 |
| 46 | 930.26610000 | 41.29340000 | 0.00000000 |
| 47 | 931.57400000 | 0.30360000 | 0.00000000 |
| 48 | 931.92810000 | 0.61000000 | 0.00000000 |
| 49 | 974.20350000 | 0.21100000 | 0.00000000 |
| 50 | 978.59230000 | 9.65010000 | 0.00000000 |
| 51 | 985.23920000 | 0.53180000 | 0.00000000 |
| 52 | 1000.82130000 | 1.53800000 | 0.00000000 |
| 53 | 1014.62050000 | 20.69160000 | 0.00000000 |
| 54 | 1022.29350000 | 34.67290000 | 0.00000000 |
| 55 | 1025.47420000 | 2.34010000 | 0.00000000 |
| 56 | 1031.78840000 | 14.50270000 | 0.00000000 |
| 57 | 1053.34540000 | 10.27100000 | 0.00000000 |
| 58 | 1054.47130000 | 1.65170000 | 0.00000000 |
| 59 | 1063.09100000 | 1.76090000 | 0.00000000 |
| 60 | 1077.26260000 | 13.52930000 | 0.00000000 |
| 61 | 1104.62530000 | 13.24600000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 62 | 1140.60920000 | 58.77210000 | 0.00000000 |
| 63 | 1157.04250000 | 74.94480000 | 0.00000000 |
| 64 | 1178.42140000 | 3.56200000 | 0.00000000 |
| 65 | 1183.80470000 | 521.78070000 | 0.00000000 |
| 66 | 1200.04040000 | 3.28940000 | 0.00000000 |
| 67 | 1212.99860000 | 4.80630000 | 0.00000000 |
| 68 | 1228.47050000 | 23.15160000 | 0.00000000 |
| 69 | 1253.98090000 | 12.77100000 | 0.00000000 |
| 70 | 1270.69200000 | 29.04240000 | 0.00000000 |
| 71 | 1276.87350000 | 192.76640000 | 0.00000000 |
| 72 | 1283.58290000 | 22.50890000 | 0.00000000 |
| 73 | 1291.21070000 | 137.40570000 | 0.00000000 |
| 74 | 1309.59700000 | 1.26230000 | 0.00000000 |
| 75 | 1326.49350000 | 82.02740000 | 0.00000000 |
| 76 | 1345.78170000 | 118.00340000 | 0.00000000 |
| 77 | 1357.19860000 | 13.63800000 | 0.00000000 |
| 78 | 1359.34030000 | 45.87040000 | 0.00000000 |
| 79 | 1368.71930000 | 51.34900000 | 0.00000000 |
| 80 | 1396.88200000 | 25.97130000 | 0.00000000 |
| 81 | 1398.39860000 | 58.45590000 | 0.00000000 |
| 82 | 1400.89160000 | 34.90900000 | 0.00000000 |
| 83 | 1423.33380000 | 56.91950000 | 0.00000000 |
| 84 | 1425.50890000 | 97.32290000 | 0.00000000 |
| 85 | 1455.12610000 | 5.25360000 | 0.00000000 |
| 86 | 1467.88220000 | 0.35040000 | 0.00000000 |
| 87 | 1468.89350000 | 5.69880000 | 0.00000000 |
| 88 | 1484.21540000 | 9.74030000 | 0.00000000 |
| 89 | 1484.72180000 | 3.13500000 | 0.00000000 |
| 90 | 1485.98300000 | 2.50370000 | 0.00000000 |
| 91 | 1488.75970000 | 24.51830000 | 0.00000000 |
| 92 | 1491.77480000 | 9.38220000 | 0.00000000 |
| 93 | 1498.32810000 | 2.64370000 | 0.00000000 |
| 94 | 1508.22840000 | 10.80060000 | 0.00000000 |
| 95 | 1517.58540000 | 22.63130000 | 0.00000000 |
| 96 | 1532.75530000 | 19.40900000 | 0.00000000 |
| 97 | 1629.03240000 | 1.17970000 | 0.00000000 |
| 98 | 1647.55880000 | 17.81460000 | 0.00000000 |
| 99 | 1701.25430000 | 687.48360000 | 0.00000000 |
| 100 | 1720.61590000 | 36.47150000 | 0.00000000 |
| 101 | 2980.70690000 | 63.78030000 | 0.00000000 |
| 102 | 2997.90540000 | 40.47240000 | 0.00000000 |
| 103 | 3019.11770000 | 21.95580000 | 0.00000000 |
| 104 | 3026.58810000 | 55.49470000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 105 | 3042.55910000 | 17.28790000 | 0.00000000 |
| 106 | 3045.05090000 | 32.60710000 | 0.00000000 |
| 107 | 3052.07840000 | 26.89620000 | 0.00000000 |
| 108 | 3089.03990000 | 44.64920000 | 0.00000000 |
| 109 | 3097.63280000 | 23.93710000 | 0.00000000 |
| 110 | 3101.62980000 | 15.20980000 | 0.00000000 |
| 111 | 3108.32090000 | 14.45010000 | 0.00000000 |
| 112 | 3113.61750000 | 64.72460000 | 0.00000000 |
| 113 | 3127.15570000 | 25.90220000 | 0.00000000 |
| 114 | 3131.09830000 | 16.62430000 | 0.00000000 |
| 115 | 3143.06140000 | 2.17170000 | 0.00000000 |
| 116 | 3145.32450000 | 10.00950000 | 0.00000000 |
| 117 | 3146.45510000 | 24.56730000 | 0.00000000 |
| 118 | 3163.19280000 | 8.92470000 | 0.00000000 |
| 119 | 3169.18020000 | 0.04220000 | 0.00000000 |
| 120 | 3178.12170000 | 15.35040000 | 0.00000000 |
| 121 | 3185.15890000 | 37.21380000 | 0.00000000 |
| 122 | 3195.23570000 | 21.47190000 | 0.00000000 |
| 123 | 3210.88940000 | 19.60330000 | 0.00000000 |

Right Rotamer Equatorial



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.9888 Debye

Energy : -867.292815979 a.u.

Gibbs Energy : -866.972580 a.u.

Number of imaginary frequencies : 0

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | 0.69356000 | -3.12724700 | 0.82557000 |
| C | -0.38893300 | -2.28343000 | 0.16357100 |
| C | 1.31705100 | -0.53271400 | -0.46519200 |
| C | 2.39173300 | -1.46824800 | 0.13656000 |
| H | -0.57884900 | -2.68122800 | -0.84156100 |
| H | -1.31163300 | -2.35356900 | 0.72745600 |
| H | 0.78393000 | -2.83075200 | 1.87597600 |
| H | 0.38930200 | -4.17395800 | 0.79572400 |
| H | 1.31650200 | -0.67042800 | -1.55249600 |
| H | 3.32020100 | -1.29871200 | -0.40805100 |
| H | 2.55828200 | -1.15619400 | 1.17229700 |
| C | 1.99935900 | -2.91035400 | 0.12938100 |
| C | 2.70512600 | -3.87044200 | -0.45903100 |
| H | 2.38045300 | -4.90392500 | -0.43772500 |
| H | 3.63324300 | -3.65429600 | -0.97448600 |
| N | -0.02290200 | -0.85747700 | 0.06168500 |
| C | -1.03217400 | 0.02194900 | -0.27927000 |
| O | -0.86568400 | 1.03798600 | -0.92472200 |

| | | | |
|---|---|---|---|
| O | -2.21460200 | -0.38196900 | 0.21799200 |
| C | -3.45268400 | 0.37928200 | -0.01347400 |
| C | -3.34573400 | 1.75787300 | 0.62865700 |
| H | -2.60592800 | 2.37241500 | 0.12320300 |
| H | -4.31494400 | 2.25588500 | 0.57360800 |
| H | -3.07069500 | 1.66332600 | 1.68023200 |
| C | -3.75728500 | 0.45217800 | -1.50565000 |
| H | -4.74820500 | 0.88593700 | -1.64757400 |
| H | -3.02924100 | 1.06479000 | -2.03011100 |
| H | -3.75920200 | -0.54903200 | -1.93943900 |
| C | -4.49743400 | -0.46664700 | 0.70396400 |
| H | -4.25573600 | -0.55680500 | 1.76344300 |
| H | -5.47852000 | -0.00066700 | 0.61034100 |
| H | -4.54526200 | -1.46614600 | 0.27046900 |
| C | 1.74491100 | 0.88688300 | -0.15881000 |
| C | 1.57269400 | 1.43081000 | 1.11254900 |
| C | 2.41717400 | 1.63060600 | -1.12264300 |
| C | 2.04444800 | 2.70330800 | 1.40617300 |
| H | 1.05081400 | 0.85983000 | 1.86997600 |
| C | 2.89874300 | 2.90205400 | -0.83059200 |
| H | 2.55331300 | 1.21731100 | -2.11485400 |
| C | 2.71099700 | 3.44502000 | 0.43516300 |
| H | 1.89269300 | 3.11764700 | 2.39494700 |
| H | 3.41426900 | 3.47035600 | -1.59440900 |
| H | 3.07850700 | 4.43713200 | 0.66352200 |

Frequencies

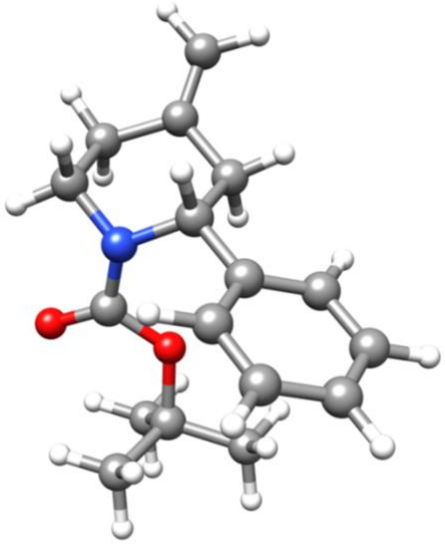
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | 24.69350000 | 0.10800000 | 0.00000000 |
| 2 | 26.31540000 | 0.55800000 | 0.00000000 |
| 3 | 40.91610000 | 2.70950000 | 0.00000000 |
| 4 | 47.35990000 | 0.19540000 | 0.00000000 |
| 5 | 67.71640000 | 0.71750000 | 0.00000000 |
| 6 | 87.87200000 | 0.67590000 | 0.00000000 |
| 7 | 111.06730000 | 0.76730000 | 0.00000000 |
| 8 | 119.97730000 | 1.90210000 | 0.00000000 |
| 9 | 167.22320000 | 1.38040000 | 0.00000000 |
| 10 | 186.44590000 | 4.95200000 | 0.00000000 |
| 11 | 205.49770000 | 0.22030000 | 0.00000000 |
| 12 | 223.87930000 | 2.17900000 | 0.00000000 |
| 13 | 237.21130000 | 3.30500000 | 0.00000000 |
| 14 | 245.56130000 | 1.21050000 | 0.00000000 |
| 15 | 270.96990000 | 3.02940000 | 0.00000000 |
| 16 | 276.67470000 | 9.89850000 | 0.00000000 |
| 17 | 284.50800000 | 1.54640000 | 0.00000000 |
| 18 | 318.90600000 | 0.24690000 | 0.00000000 |
| 19 | 341.94190000 | 31.04130000 | 0.00000000 |
| 20 | 352.76330000 | 2.03610000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 21 | 396.36240000 | 0.75060000 | 0.00000000 |
| 22 | 416.53490000 | 0.34250000 | 0.00000000 |
| 23 | 420.56820000 | 0.13120000 | 0.00000000 |
| 24 | 430.68880000 | 5.98750000 | 0.00000000 |
| 25 | 460.72750000 | 1.46960000 | 0.00000000 |
| 26 | 467.31630000 | 5.87210000 | 0.00000000 |
| 27 | 470.21020000 | 0.35600000 | 0.00000000 |
| 28 | 530.60720000 | 17.14970000 | 0.00000000 |
| 29 | 562.32420000 | 2.84640000 | 0.00000000 |
| 30 | 612.39060000 | 28.56850000 | 0.00000000 |
| 31 | 636.92230000 | 0.12210000 | 0.00000000 |
| 32 | 650.33180000 | 4.92440000 | 0.00000000 |
| 33 | 697.91400000 | 14.86230000 | 0.00000000 |
| 34 | 714.97420000 | 58.91570000 | 0.00000000 |
| 35 | 736.89210000 | 0.57690000 | 0.00000000 |
| 36 | 766.89960000 | 25.43960000 | 0.00000000 |
| 37 | 774.85390000 | 24.21280000 | 0.00000000 |
| 38 | 797.90750000 | 32.73050000 | 0.00000000 |
| 39 | 808.71450000 | 20.01440000 | 0.00000000 |
| 40 | 837.83760000 | 0.14980000 | 0.00000000 |
| 41 | 849.41790000 | 13.28300000 | 0.00000000 |
| 42 | 858.28190000 | 0.15660000 | 0.00000000 |
| 43 | 871.92140000 | 36.78450000 | 0.00000000 |
| 44 | 918.78150000 | 13.56530000 | 0.00000000 |
| 45 | 925.35860000 | 12.41350000 | 0.00000000 |
| 46 | 928.59880000 | 40.56900000 | 0.00000000 |
| 47 | 930.43060000 | 0.63160000 | 0.00000000 |
| 48 | 932.23090000 | 7.73380000 | 0.00000000 |
| 49 | 971.86720000 | 0.09570000 | 0.00000000 |
| 50 | 975.09020000 | 0.64380000 | 0.00000000 |
| 51 | 977.79900000 | 4.68880000 | 0.00000000 |
| 52 | 990.10390000 | 1.42600000 | 0.00000000 |
| 53 | 1014.37660000 | 24.49070000 | 0.00000000 |
| 54 | 1024.47490000 | 0.07730000 | 0.00000000 |
| 55 | 1026.45450000 | 78.56160000 | 0.00000000 |
| 56 | 1032.44980000 | 3.43130000 | 0.00000000 |
| 57 | 1052.70280000 | 5.52420000 | 0.00000000 |
| 58 | 1052.75120000 | 6.82180000 | 0.00000000 |
| 59 | 1061.08100000 | 4.90780000 | 0.00000000 |
| 60 | 1077.74770000 | 22.65070000 | 0.00000000 |
| 61 | 1103.55630000 | 5.36740000 | 0.00000000 |
| 62 | 1135.28950000 | 166.84240000 | 0.00000000 |
| 63 | 1155.67910000 | 56.74680000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 64 | 1178.24010000 | 8.60050000 | 0.00000000 |
| 65 | 1183.38440000 | 620.40370000 | 0.00000000 |
| 66 | 1198.97590000 | 4.27780000 | 0.00000000 |
| 67 | 1215.09890000 | 6.69930000 | 0.00000000 |
| 68 | 1233.48060000 | 17.65410000 | 0.00000000 |
| 69 | 1256.07470000 | 177.29880000 | 0.00000000 |
| 70 | 1261.09690000 | 108.54890000 | 0.00000000 |
| 71 | 1269.10750000 | 21.52440000 | 0.00000000 |
| 72 | 1282.91490000 | 33.21200000 | 0.00000000 |
| 73 | 1288.50690000 | 51.31480000 | 0.00000000 |
| 74 | 1310.36990000 | 5.79970000 | 0.00000000 |
| 75 | 1327.58190000 | 89.12910000 | 0.00000000 |
| 76 | 1345.45610000 | 148.09720000 | 0.00000000 |
| 77 | 1356.31530000 | 12.78570000 | 0.00000000 |
| 78 | 1363.26810000 | 78.76170000 | 0.00000000 |
| 79 | 1368.88900000 | 36.09440000 | 0.00000000 |
| 80 | 1396.96380000 | 25.65920000 | 0.00000000 |
| 81 | 1399.18350000 | 42.10230000 | 0.00000000 |
| 82 | 1402.21040000 | 47.98790000 | 0.00000000 |
| 83 | 1413.62820000 | 54.69410000 | 0.00000000 |
| 84 | 1423.25140000 | 34.17920000 | 0.00000000 |
| 85 | 1455.70760000 | 2.87750000 | 0.00000000 |
| 86 | 1466.96780000 | 0.17000000 | 0.00000000 |
| 87 | 1468.72570000 | 6.83170000 | 0.00000000 |
| 88 | 1483.84510000 | 0.94980000 | 0.00000000 |
| 89 | 1484.24420000 | 1.69830000 | 0.00000000 |
| 90 | 1485.12210000 | 10.27140000 | 0.00000000 |
| 91 | 1487.79990000 | 17.28970000 | 0.00000000 |
| 92 | 1490.83210000 | 9.69190000 | 0.00000000 |
| 93 | 1497.71830000 | 2.16780000 | 0.00000000 |
| 94 | 1508.45160000 | 4.25300000 | 0.00000000 |
| 95 | 1516.52380000 | 22.63140000 | 0.00000000 |
| 96 | 1532.32320000 | 17.66470000 | 0.00000000 |
| 97 | 1628.98830000 | 1.63260000 | 0.00000000 |
| 98 | 1647.39650000 | 14.55970000 | 0.00000000 |
| 99 | 1720.15480000 | 204.23450000 | 0.00000000 |
| 100 | 1723.67770000 | 393.41920000 | 0.00000000 |
| 101 | 2982.18940000 | 61.65630000 | 0.00000000 |
| 102 | 2997.20510000 | 42.27880000 | 0.00000000 |
| 103 | 3018.44020000 | 22.65970000 | 0.00000000 |
| 104 | 3026.73750000 | 53.87360000 | 0.00000000 |
| 105 | 3040.94880000 | 16.47740000 | 0.00000000 |
| 106 | 3043.38130000 | 38.73260000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 107 | 3050.16950000 | 22.30400000 | 0.00000000 |
| 108 | 3088.88740000 | 44.80140000 | 0.00000000 |
| 109 | 3097.26630000 | 24.35050000 | 0.00000000 |
| 110 | 3102.22170000 | 7.57100000 | 0.00000000 |
| 111 | 3103.59850000 | 25.57260000 | 0.00000000 |
| 112 | 3110.93270000 | 46.31660000 | 0.00000000 |
| 113 | 3116.99510000 | 62.99780000 | 0.00000000 |
| 114 | 3131.07570000 | 16.43210000 | 0.00000000 |
| 115 | 3145.82610000 | 1.70870000 | 0.00000000 |
| 116 | 3148.63810000 | 25.17380000 | 0.00000000 |
| 117 | 3154.61640000 | 12.32440000 | 0.00000000 |
| 118 | 3162.51830000 | 9.47720000 | 0.00000000 |
| 119 | 3167.91860000 | 0.06890000 | 0.00000000 |
| 120 | 3176.95450000 | 16.57950000 | 0.00000000 |
| 121 | 3183.96230000 | 42.61260000 | 0.00000000 |
| 122 | 3194.17770000 | 22.40660000 | 0.00000000 |
| 123 | 3210.83250000 | 19.41290000 | 0.00000000 |

Left Rotamer Equatorial Re-Optimized



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.5348 Debye

Energy : -867.296096363 a.u.

Gibbs Energy : -866.973549 a.u.

Number of imaginary frequencies : 0

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -3.42792700 | 0.76307600 | -0.13179500 |
| C | -2.50772000 | 0.71741200 | -1.36170600 |
| C | -1.10390400 | -0.98441500 | -0.34106000 |
| C | -1.92485700 | -0.98128300 | 0.95867600 |
| H | -2.85530800 | -0.03633100 | -2.07026200 |
| H | -2.47878800 | 1.67844000 | -1.86418500 |
| H | -3.10952100 | 1.60888400 | 0.48775800 |
| H | -4.45917100 | 0.94767400 | -0.43563800 |
| H | -1.65861800 | -1.60513300 | -1.05280800 |
| H | -1.95643000 | -1.97925200 | 1.39492200 |
| H | -1.43732400 | -0.31335700 | 1.67577100 |
| C | -3.32848800 | -0.51090400 | 0.66533200 |
| C | -4.39886000 | -1.20642800 | 1.03967000 |
| H | -5.40170000 | -0.87049000 | 0.80464300 |
| H | -4.30648800 | -2.12956400 | 1.59933900 |

| | | | |
|---|---|---|---|
| N | -1.15215500 | 0.36095500 | -0.94429700 |
| C | -0.33327600 | 1.40274400 | -0.58195100 |
| O | -0.47619100 | 2.53952600 | -1.00160100 |
| O | 0.62323500 | 1.01362800 | 0.26886400 |
| C | 1.80121000 | 1.84771600 | 0.55608900 |
| C | 2.53104300 | 2.17678700 | -0.74086400 |
| H | 1.93595900 | 2.82749900 | -1.37669900 |
| H | 3.46941300 | 2.68114600 | -0.50613700 |
| H | 2.76204100 | 1.25942200 | -1.28392900 |
| C | 1.38280800 | 3.09482500 | 1.32579700 |
| H | 2.27458100 | 3.63120800 | 1.65409500 |
| H | 0.78089700 | 3.75558100 | 0.70800600 |
| H | 0.80885400 | 2.81550500 | 2.21077900 |
| C | 2.65061700 | 0.93327900 | 1.42909400 |
| H | 2.91260400 | 0.02369100 | 0.89057400 |
| H | 3.56629400 | 1.44926800 | 1.71941300 |
| H | 2.10752300 | 0.65438500 | 2.33250900 |
| C | 0.28140200 | -1.59314400 | -0.27587900 |
| C | 0.77840100 | -2.19852000 | 0.87263100 |
| C | 1.06662700 | -1.60242300 | -1.42981600 |
| C | 2.03842700 | -2.79025600 | 0.87502100 |
| H | 0.19725500 | -2.19956800 | 1.78365700 |
| C | 2.32642800 | -2.18191000 | -1.42896000 |
| H | 0.69012800 | -1.13193200 | -2.32944400 |
| C | 2.81951100 | -2.78075900 | -0.27230100 |
| H | 2.41096500 | -3.24996600 | 1.78157700 |
| H | 2.92472800 | -2.16955200 | -2.33115300 |
| H | 3.80218600 | -3.23426000 | -0.26868300 |

Frequencies

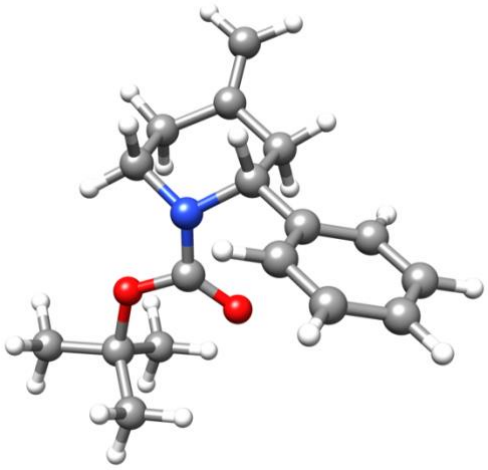
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | 28.92760000 | 1.68780000 | 0.00000000 |
| 2 | 33.66180000 | 0.26290000 | 0.00000000 |
| 3 | 52.39400000 | 0.01620000 | 0.00000000 |
| 4 | 73.37800000 | 0.12730000 | 0.00000000 |
| 5 | 81.27800000 | 3.82970000 | 0.00000000 |
| 6 | 100.63980000 | 1.01760000 | 0.00000000 |
| 7 | 117.69270000 | 0.82780000 | 0.00000000 |
| 8 | 130.76300000 | 0.30520000 | 0.00000000 |
| 9 | 135.65300000 | 0.55860000 | 0.00000000 |
| 10 | 187.00340000 | 1.84500000 | 0.00000000 |
| 11 | 205.64790000 | 0.25920000 | 0.00000000 |
| 12 | 216.46970000 | 6.31200000 | 0.00000000 |
| 13 | 244.46510000 | 0.27350000 | 0.00000000 |
| 14 | 272.47360000 | 1.67510000 | 0.00000000 |
| 15 | 276.08270000 | 0.28010000 | 0.00000000 |
| 16 | 311.79050000 | 2.17420000 | 0.00000000 |
| 17 | 324.07560000 | 5.32540000 | 0.00000000 |
| 18 | 344.66560000 | 5.68850000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 19 | 359.04860000 | 2.33070000 | 0.00000000 |
| 20 | 382.48320000 | 4.23330000 | 0.00000000 |
| 21 | 399.23730000 | 18.80210000 | 0.00000000 |
| 22 | 414.63120000 | 0.30070000 | 0.00000000 |
| 23 | 423.07500000 | 1.93150000 | 0.00000000 |
| 24 | 436.69290000 | 2.32410000 | 0.00000000 |
| 25 | 462.29210000 | 2.97740000 | 0.00000000 |
| 26 | 479.78690000 | 7.34260000 | 0.00000000 |
| 27 | 490.28310000 | 0.34870000 | 0.00000000 |
| 28 | 515.42550000 | 1.71190000 | 0.00000000 |
| 29 | 546.97880000 | 2.60960000 | 0.00000000 |
| 30 | 625.07830000 | 12.26560000 | 0.00000000 |
| 31 | 639.21050000 | 2.19330000 | 0.00000000 |
| 32 | 647.22560000 | 41.77350000 | 0.00000000 |
| 33 | 681.29580000 | 9.74250000 | 0.00000000 |
| 34 | 714.00020000 | 60.06290000 | 0.00000000 |
| 35 | 733.12650000 | 1.53520000 | 0.00000000 |
| 36 | 766.24960000 | 9.73520000 | 0.00000000 |
| 37 | 767.72950000 | 35.79680000 | 0.00000000 |
| 38 | 785.12650000 | 43.02070000 | 0.00000000 |
| 39 | 797.24860000 | 8.07860000 | 0.00000000 |
| 40 | 830.39170000 | 5.46250000 | 0.00000000 |
| 41 | 859.06850000 | 0.88910000 | 0.00000000 |
| 42 | 862.97590000 | 29.93470000 | 0.00000000 |
| 43 | 869.18240000 | 23.18460000 | 0.00000000 |
| 44 | 917.93730000 | 20.19720000 | 0.00000000 |
| 45 | 927.42040000 | 48.56600000 | 0.00000000 |
| 46 | 931.24170000 | 0.74710000 | 0.00000000 |
| 47 | 931.52860000 | 0.32190000 | 0.00000000 |
| 48 | 943.84080000 | 17.10030000 | 0.00000000 |
| 49 | 959.83050000 | 8.52640000 | 0.00000000 |
| 50 | 972.90110000 | 0.25900000 | 0.00000000 |
| 51 | 982.71660000 | 0.51040000 | 0.00000000 |
| 52 | 998.51860000 | 50.00810000 | 0.00000000 |
| 53 | 999.80300000 | 1.31620000 | 0.00000000 |
| 54 | 1014.44060000 | 36.50940000 | 0.00000000 |
| 55 | 1024.82300000 | 16.59360000 | 0.00000000 |
| 56 | 1026.51500000 | 4.95270000 | 0.00000000 |
| 57 | 1053.45150000 | 1.12090000 | 0.00000000 |
| 58 | 1056.07420000 | 8.34450000 | 0.00000000 |
| 59 | 1062.43420000 | 1.05710000 | 0.00000000 |
| 60 | 1070.55200000 | 22.97860000 | 0.00000000 |
| 61 | 1115.92820000 | 6.30940000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 62 | 1146.64670000 | 67.03450000 | 0.00000000 |
| 63 | 1165.76320000 | 34.20700000 | 0.00000000 |
| 64 | 1179.84000000 | 8.71060000 | 0.00000000 |
| 65 | 1186.00370000 | 150.44880000 | 0.00000000 |
| 66 | 1187.95800000 | 313.59630000 | 0.00000000 |
| 67 | 1207.18430000 | 1.89560000 | 0.00000000 |
| 68 | 1235.90590000 | 2.35240000 | 0.00000000 |
| 69 | 1252.92010000 | 8.70100000 | 0.00000000 |
| 70 | 1269.98280000 | 29.15830000 | 0.00000000 |
| 71 | 1273.40950000 | 216.20630000 | 0.00000000 |
| 72 | 1286.60070000 | 77.69050000 | 0.00000000 |
| 73 | 1290.07530000 | 14.20440000 | 0.00000000 |
| 74 | 1305.84850000 | 6.55730000 | 0.00000000 |
| 75 | 1323.87380000 | 131.63150000 | 0.00000000 |
| 76 | 1339.68420000 | 18.23590000 | 0.00000000 |
| 77 | 1349.74850000 | 11.16020000 | 0.00000000 |
| 78 | 1361.47370000 | 4.32780000 | 0.00000000 |
| 79 | 1378.98850000 | 10.07320000 | 0.00000000 |
| 80 | 1385.96590000 | 24.98240000 | 0.00000000 |
| 81 | 1396.30010000 | 26.20770000 | 0.00000000 |
| 82 | 1400.88380000 | 30.49720000 | 0.00000000 |
| 83 | 1424.32940000 | 18.14900000 | 0.00000000 |
| 84 | 1450.02680000 | 169.98470000 | 0.00000000 |
| 85 | 1456.02750000 | 87.39860000 | 0.00000000 |
| 86 | 1466.88460000 | 0.26860000 | 0.00000000 |
| 87 | 1472.37730000 | 11.17010000 | 0.00000000 |
| 88 | 1483.97780000 | 2.75310000 | 0.00000000 |
| 89 | 1485.26470000 | 3.54080000 | 0.00000000 |
| 90 | 1485.74810000 | 31.92310000 | 0.00000000 |
| 91 | 1487.28650000 | 14.59100000 | 0.00000000 |
| 92 | 1488.53000000 | 7.19280000 | 0.00000000 |
| 93 | 1496.43380000 | 60.74000000 | 0.00000000 |
| 94 | 1497.36110000 | 3.74290000 | 0.00000000 |
| 95 | 1517.01030000 | 36.46110000 | 0.00000000 |
| 96 | 1536.30970000 | 17.17490000 | 0.00000000 |
| 97 | 1628.06460000 | 2.59340000 | 0.00000000 |
| 98 | 1649.22470000 | 16.25480000 | 0.00000000 |
| 99 | 1698.38340000 | 733.11260000 | 0.00000000 |
| 100 | 1709.47210000 | 35.27680000 | 0.00000000 |
| 101 | 3003.85100000 | 14.34550000 | 0.00000000 |
| 102 | 3013.06260000 | 19.91580000 | 0.00000000 |
| 103 | 3029.01150000 | 29.50320000 | 0.00000000 |
| 104 | 3042.18020000 | 18.95250000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 105 | 3044.06500000 | 29.14180000 | 0.00000000 |
| 106 | 3051.08670000 | 28.35480000 | 0.00000000 |
| 107 | 3056.85940000 | 46.99690000 | 0.00000000 |
| 108 | 3084.32270000 | 60.91580000 | 0.00000000 |
| 109 | 3095.48150000 | 32.96890000 | 0.00000000 |
| 110 | 3100.89770000 | 15.64060000 | 0.00000000 |
| 111 | 3106.35960000 | 17.53710000 | 0.00000000 |
| 112 | 3113.58970000 | 65.95530000 | 0.00000000 |
| 113 | 3126.77850000 | 25.71940000 | 0.00000000 |
| 114 | 3131.10850000 | 16.52930000 | 0.00000000 |
| 115 | 3140.86230000 | 7.58300000 | 0.00000000 |
| 116 | 3146.48660000 | 18.27510000 | 0.00000000 |
| 117 | 3151.20010000 | 10.25770000 | 0.00000000 |
| 118 | 3167.03100000 | 2.30600000 | 0.00000000 |
| 119 | 3173.98620000 | 2.78900000 | 0.00000000 |
| 120 | 3182.79940000 | 29.33180000 | 0.00000000 |
| 121 | 3193.05860000 | 34.53630000 | 0.00000000 |
| 122 | 3203.57790000 | 11.08460000 | 0.00000000 |
| 123 | 3210.43890000 | 20.99850000 | 0.00000000 |

Right Rotamer Equatorial Re-Optimized



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.9756 Debye

Energy : -867.293496677 a.u.

Gibbs Energy : -866.972175 a.u.

Number of imaginary frequencies : 0

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | 0.93684500 | 2.86530400 | -0.29797400 |
| C | 0.81602900 | 1.76876900 | -1.36730000 |
| C | -1.25170500 | 0.93962800 | -0.39911000 |
| C | -1.20229200 | 1.96156500 | 0.74803400 |
| H | 0.22391800 | 2.12797200 | -2.21077200 |
| H | 1.79051600 | 1.47304300 | -1.73773000 |
| H | 1.62114100 | 2.49973800 | 0.47610800 |
| H | 1.37605600 | 3.76716000 | -0.72665600 |
| H | -1.65979500 | 1.46481300 | -1.26840200 |
| H | -2.20890200 | 2.26631400 | 1.03354900 |
| H | -0.73459300 | 1.48469200 | 1.61491000 |
| C | -0.40537600 | 3.16746400 | 0.31563300 |
| C | -0.88112500 | 4.40532800 | 0.42009300 |
| H | -0.30708200 | 5.26159900 | 0.08684000 |
| H | -1.85625300 | 4.60211700 | 0.84938900 |
| N | 0.12683000 | 0.60517800 | -0.80285600 |
| C | 0.82929600 | -0.31495500 | -0.06204300 |

| | | | |
|---|---|---|---|
| O | 0.34274300 | -1.01535100 | 0.80467200 |
| O | 2.11828700 | -0.35760400 | -0.45134600 |
| C | 3.09505400 | -1.23845700 | 0.20686800 |
| C | 3.21863100 | -0.87544000 | 1.68264100 |
| H | 2.31025000 | -1.11764200 | 2.22735400 |
| H | 4.04931900 | -1.43101600 | 2.12021600 |
| H | 3.42663900 | 0.19014600 | 1.79260000 |
| C | 2.71147400 | -2.69870700 | -0.00420900 |
| H | 3.51471900 | -3.33808400 | 0.36522800 |
| H | 1.79468100 | -2.94525000 | 0.52407900 |
| H | 2.57531600 | -2.90267200 | -1.06735400 |
| C | 4.38581300 | -0.91069800 | -0.53354100 |
| H | 4.63938200 | 0.14321100 | -0.41407300 |
| H | 5.20362900 | -1.51163700 | -0.13538700 |
| H | 4.28252500 | -1.12645000 | -1.59741700 |
| C | -2.13920400 | -0.27048800 | -0.19993300 |
| C | -2.89552000 | -0.46762000 | 0.95020000 |
| C | -2.25298100 | -1.19178800 | -1.24193300 |
| C | -3.73780200 | -1.56958900 | 1.06469500 |
| H | -2.82232800 | 0.22615600 | 1.77563000 |
| C | -3.08665300 | -2.29491300 | -1.12953800 |
| H | -1.66889200 | -1.04611800 | -2.14229300 |
| C | -3.83514200 | -2.48883100 | 0.02816300 |
| H | -4.31436700 | -1.70999300 | 1.97024200 |
| H | -3.15621400 | -3.00259800 | -1.94598700 |
| H | -4.48776500 | -3.34753900 | 0.11883000 |

Frequencies

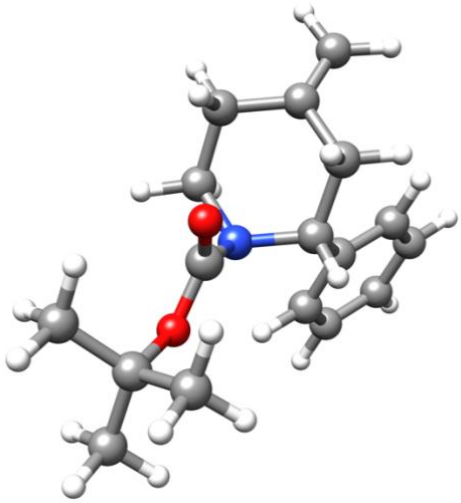
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | 23.52920000 | 0.86060000 | 0.00000000 |
| 2 | 31.55340000 | 0.04650000 | 0.00000000 |
| 3 | 37.25000000 | 0.21230000 | 0.00000000 |
| 4 | 60.17330000 | 0.80580000 | 0.00000000 |
| 5 | 73.59420000 | 3.05600000 | 0.00000000 |
| 6 | 108.10230000 | 0.33190000 | 0.00000000 |
| 7 | 111.05750000 | 0.64480000 | 0.00000000 |
| 8 | 123.61660000 | 0.74090000 | 0.00000000 |
| 9 | 140.54420000 | 1.10310000 | 0.00000000 |
| 10 | 185.30660000 | 5.22700000 | 0.00000000 |
| 11 | 206.13720000 | 0.23730000 | 0.00000000 |
| 12 | 219.08660000 | 4.51060000 | 0.00000000 |
| 13 | 242.66420000 | 0.93550000 | 0.00000000 |
| 14 | 271.37990000 | 4.80190000 | 0.00000000 |
| 15 | 274.94820000 | 1.67040000 | 0.00000000 |
| 16 | 284.78600000 | 0.62620000 | 0.00000000 |
| 17 | 330.75580000 | 22.81410000 | 0.00000000 |
| 18 | 343.11230000 | 1.92000000 | 0.00000000 |
| 19 | 353.82390000 | 2.21580000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 20 | 385.32510000 | 7.97110000 | 0.00000000 |
| 21 | 411.79360000 | 1.80540000 | 0.00000000 |
| 22 | 414.64180000 | 0.26080000 | 0.00000000 |
| 23 | 422.31010000 | 0.82930000 | 0.00000000 |
| 24 | 439.11680000 | 7.98860000 | 0.00000000 |
| 25 | 461.83480000 | 4.17680000 | 0.00000000 |
| 26 | 480.80350000 | 5.65960000 | 0.00000000 |
| 27 | 487.05510000 | 5.08070000 | 0.00000000 |
| 28 | 516.51440000 | 1.76920000 | 0.00000000 |
| 29 | 577.06850000 | 4.96460000 | 0.00000000 |
| 30 | 607.22140000 | 16.47530000 | 0.00000000 |
| 31 | 635.15070000 | 4.36030000 | 0.00000000 |
| 32 | 645.97080000 | 18.95470000 | 0.00000000 |
| 33 | 677.77590000 | 15.28260000 | 0.00000000 |
| 34 | 711.02380000 | 53.15290000 | 0.00000000 |
| 35 | 733.61280000 | 2.53530000 | 0.00000000 |
| 36 | 756.17190000 | 59.25040000 | 0.00000000 |
| 37 | 777.47780000 | 15.72890000 | 0.00000000 |
| 38 | 787.02190000 | 14.56080000 | 0.00000000 |
| 39 | 798.95370000 | 20.25550000 | 0.00000000 |
| 40 | 830.90030000 | 1.85930000 | 0.00000000 |
| 41 | 854.75980000 | 15.49630000 | 0.00000000 |
| 42 | 855.54980000 | 0.17470000 | 0.00000000 |
| 43 | 879.35530000 | 33.51600000 | 0.00000000 |
| 44 | 916.74590000 | 10.40400000 | 0.00000000 |
| 45 | 926.46280000 | 56.96680000 | 0.00000000 |
| 46 | 929.85120000 | 0.25050000 | 0.00000000 |
| 47 | 930.84380000 | 0.07860000 | 0.00000000 |
| 48 | 942.26360000 | 2.43720000 | 0.00000000 |
| 49 | 959.51390000 | 3.16650000 | 0.00000000 |
| 50 | 972.51400000 | 0.02710000 | 0.00000000 |
| 51 | 972.52580000 | 0.45110000 | 0.00000000 |
| 52 | 988.25100000 | 1.75980000 | 0.00000000 |
| 53 | 997.12620000 | 65.90640000 | 0.00000000 |
| 54 | 1012.75200000 | 77.29580000 | 0.00000000 |
| 55 | 1024.50400000 | 12.40710000 | 0.00000000 |
| 56 | 1026.45330000 | 3.18130000 | 0.00000000 |
| 57 | 1053.59530000 | 1.84050000 | 0.00000000 |
| 58 | 1055.34780000 | 11.37710000 | 0.00000000 |
| 59 | 1060.35430000 | 3.40630000 | 0.00000000 |
| 60 | 1069.60270000 | 13.73580000 | 0.00000000 |
| 61 | 1114.64110000 | 7.91520000 | 0.00000000 |
| 62 | 1137.86690000 | 121.45220000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 63 | 1171.15400000 | 260.14910000 | 0.00000000 |
| 64 | 1179.00560000 | 334.78710000 | 0.00000000 |
| 65 | 1179.81250000 | 1.80020000 | 0.00000000 |
| 66 | 1189.30290000 | 141.34050000 | 0.00000000 |
| 67 | 1205.96970000 | 1.20690000 | 0.00000000 |
| 68 | 1234.58850000 | 24.64630000 | 0.00000000 |
| 69 | 1249.55960000 | 170.38020000 | 0.00000000 |
| 70 | 1254.34400000 | 8.47540000 | 0.00000000 |
| 71 | 1269.15080000 | 22.67220000 | 0.00000000 |
| 72 | 1282.57170000 | 20.05520000 | 0.00000000 |
| 73 | 1287.81270000 | 2.39920000 | 0.00000000 |
| 74 | 1304.58890000 | 3.68430000 | 0.00000000 |
| 75 | 1332.88260000 | 147.68440000 | 0.00000000 |
| 76 | 1340.57410000 | 86.60810000 | 0.00000000 |
| 77 | 1349.75960000 | 27.69000000 | 0.00000000 |
| 78 | 1360.77760000 | 13.84420000 | 0.00000000 |
| 79 | 1378.58430000 | 11.40640000 | 0.00000000 |
| 80 | 1388.07240000 | 44.03590000 | 0.00000000 |
| 81 | 1397.16380000 | 25.88730000 | 0.00000000 |
| 82 | 1399.74230000 | 23.27340000 | 0.00000000 |
| 83 | 1422.72260000 | 14.20020000 | 0.00000000 |
| 84 | 1437.57990000 | 177.90540000 | 0.00000000 |
| 85 | 1453.67010000 | 2.54020000 | 0.00000000 |
| 86 | 1467.14920000 | 0.30860000 | 0.00000000 |
| 87 | 1471.97050000 | 9.88210000 | 0.00000000 |
| 88 | 1483.76800000 | 1.77690000 | 0.00000000 |
| 89 | 1484.11350000 | 0.08590000 | 0.00000000 |
| 90 | 1486.49260000 | 20.09070000 | 0.00000000 |
| 91 | 1487.22960000 | 17.61690000 | 0.00000000 |
| 92 | 1487.52550000 | 6.93800000 | 0.00000000 |
| 93 | 1497.68180000 | 2.15860000 | 0.00000000 |
| 94 | 1503.00940000 | 40.47690000 | 0.00000000 |
| 95 | 1516.68140000 | 33.86080000 | 0.00000000 |
| 96 | 1536.02380000 | 15.97230000 | 0.00000000 |
| 97 | 1628.15060000 | 2.19580000 | 0.00000000 |
| 98 | 1649.04180000 | 11.04700000 | 0.00000000 |
| 99 | 1708.98980000 | 93.98130000 | 0.00000000 |
| 100 | 1721.51060000 | 522.20050000 | 0.00000000 |
| 101 | 3010.03340000 | 31.23760000 | 0.00000000 |
| 102 | 3012.95550000 | 1.51420000 | 0.00000000 |
| 103 | 3031.85190000 | 24.62170000 | 0.00000000 |
| 104 | 3041.11590000 | 16.75480000 | 0.00000000 |
| 105 | 3042.93640000 | 38.75630000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 106 | 3049.80900000 | 22.89250000 | 0.00000000 |
| 107 | 3056.72830000 | 50.14370000 | 0.00000000 |
| 108 | 3083.42390000 | 59.95990000 | 0.00000000 |
| 109 | 3094.06990000 | 32.25330000 | 0.00000000 |
| 110 | 3101.74440000 | 7.83900000 | 0.00000000 |
| 111 | 3103.76870000 | 28.79600000 | 0.00000000 |
| 112 | 3110.68470000 | 46.28800000 | 0.00000000 |
| 113 | 3117.17590000 | 59.89480000 | 0.00000000 |
| 114 | 3130.94940000 | 16.70940000 | 0.00000000 |
| 115 | 3145.25100000 | 3.32390000 | 0.00000000 |
| 116 | 3148.68050000 | 23.76070000 | 0.00000000 |
| 117 | 3161.71780000 | 13.81560000 | 0.00000000 |
| 118 | 3165.42600000 | 3.61030000 | 0.00000000 |
| 119 | 3172.37410000 | 1.91930000 | 0.00000000 |
| 120 | 3181.23130000 | 32.79490000 | 0.00000000 |
| 121 | 3192.15740000 | 37.40260000 | 0.00000000 |
| 122 | 3202.48040000 | 11.94490000 | 0.00000000 |
| 123 | 3210.25360000 | 21.35260000 | 0.00000000 |

Axial Clockwise Transition State



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.1747 Debye

Energy : -867.274004513 a.u.

Gibbs Energy : -866.951473 a.u.

Number of imaginary frequencies : -1

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -1.19655600 | -1.61359700 | 1.16879700 |
| C | -0.78851000 | -0.18746200 | 0.73389000 |
| C | -0.25695000 | -1.03369400 | -1.51850700 |
| C | -0.66570500 | -2.46433100 | -1.13608200 |
| H | -0.27078400 | 0.27795600 | 1.57751900 |
| H | -0.30401600 | -2.07299400 | 1.59930700 |
| H | -1.95220300 | -1.58163800 | 1.95219900 |
| H | -1.10964700 | -0.52275100 | -1.97127900 |
| H | 0.54419200 | -1.04447000 | -2.25831700 |
| H | -1.08617100 | -2.97131100 | -2.00634700 |
| H | 0.22956600 | -3.01039100 | -0.82578500 |
| C | -1.65060400 | -2.44042700 | -0.00095800 |
| C | -2.81989100 | -3.07298800 | -0.03977300 |
| H | -3.51591800 | -3.02983700 | 0.78944800 |
| H | -3.11611600 | -3.65986700 | -0.90109600 |
| N | 0.17774500 | -0.21530700 | -0.38021400 |

| | | | |
|---|---|---|---|
| C | 1.51857100 | -0.45113700 | 0.02554300 |
| O | 1.93271100 | -1.47441800 | 0.52292200 |
| O | 2.25272700 | 0.63031700 | -0.22577800 |
| C | 3.69992800 | 0.68860300 | 0.08909900 |
| C | 3.90790800 | 0.53558100 | 1.59050400 |
| H | 3.65072600 | -0.46452000 | 1.92909400 |
| H | 4.95627200 | 0.72432700 | 1.82534800 |
| H | 3.30202800 | 1.26323500 | 2.13238600 |
| C | 4.44686300 | -0.36479800 | -0.71917000 |
| H | 5.51988100 | -0.21711400 | -0.59030300 |
| H | 4.19331400 | -1.37062400 | -0.39495200 |
| H | 4.21501100 | -0.26215300 | -1.78026400 |
| C | 4.07837800 | 2.09045400 | -0.36871800 |
| H | 3.50509800 | 2.84004700 | 0.17739400 |
| H | 5.13908700 | 2.26374600 | -0.18643200 |
| H | 3.88469900 | 2.21129700 | -1.43485300 |
| C | -1.94946100 | 0.73367800 | 0.36772200 |
| C | -1.68784500 | 1.90469500 | -0.34732300 |
| C | -3.26119200 | 0.48389700 | 0.76598500 |
| C | -2.70485400 | 2.79758500 | -0.65609900 |
| H | -0.67446900 | 2.10037300 | -0.66936800 |
| C | -4.28386300 | 1.37651000 | 0.45744000 |
| H | -3.50498600 | -0.41264000 | 1.31518200 |
| C | -4.01162400 | 2.53647400 | -0.25530100 |
| H | -2.47739400 | 3.69867600 | -1.21174600 |
| H | -5.29604900 | 1.15755300 | 0.77312200 |
| H | -4.80741600 | 3.22879600 | -0.49821400 |

Frequencies

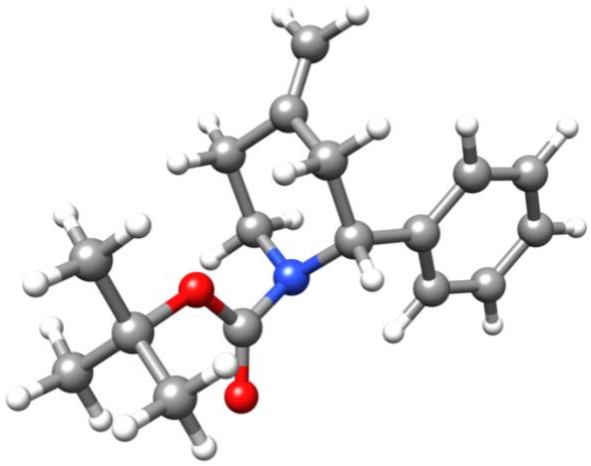
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | -60.63770000 | 2.12340000 | 0.00000000 |
| 2 | 20.26300000 | 0.01600000 | 0.00000000 |
| 3 | 37.57220000 | 0.18260000 | 0.00000000 |
| 4 | 46.92130000 | 0.52900000 | 0.00000000 |
| 5 | 80.77690000 | 0.23990000 | 0.00000000 |
| 6 | 101.02050000 | 0.23940000 | 0.00000000 |
| 7 | 108.70150000 | 0.34940000 | 0.00000000 |
| 8 | 149.70330000 | 0.91520000 | 0.00000000 |
| 9 | 170.19180000 | 4.65830000 | 0.00000000 |
| 10 | 193.00880000 | 2.06390000 | 0.00000000 |
| 11 | 203.49200000 | 0.14140000 | 0.00000000 |
| 12 | 214.71160000 | 1.54780000 | 0.00000000 |
| 13 | 239.97710000 | 0.65410000 | 0.00000000 |
| 14 | 261.53020000 | 5.69670000 | 0.00000000 |
| 15 | 271.77060000 | 0.12340000 | 0.00000000 |
| 16 | 278.85050000 | 0.35730000 | 0.00000000 |
| 17 | 314.55500000 | 7.39690000 | 0.00000000 |
| 18 | 326.33330000 | 13.62230000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 19 | 357.27500000 | 2.57300000 | 0.00000000 |
| 20 | 392.74480000 | 5.69340000 | 0.00000000 |
| 21 | 405.16460000 | 1.07890000 | 0.00000000 |
| 22 | 415.16680000 | 0.58310000 | 0.00000000 |
| 23 | 417.86920000 | 0.48450000 | 0.00000000 |
| 24 | 440.78590000 | 4.42390000 | 0.00000000 |
| 25 | 464.51230000 | 0.70170000 | 0.00000000 |
| 26 | 469.51190000 | 2.80250000 | 0.00000000 |
| 27 | 477.65710000 | 9.55120000 | 0.00000000 |
| 28 | 505.91760000 | 9.33570000 | 0.00000000 |
| 29 | 575.29780000 | 4.91380000 | 0.00000000 |
| 30 | 600.56420000 | 9.52330000 | 0.00000000 |
| 31 | 637.85100000 | 0.00530000 | 0.00000000 |
| 32 | 710.88630000 | 2.12150000 | 0.00000000 |
| 33 | 713.15460000 | 61.30680000 | 0.00000000 |
| 34 | 718.52250000 | 40.77520000 | 0.00000000 |
| 35 | 734.94650000 | 21.01950000 | 0.00000000 |
| 36 | 748.92040000 | 9.57910000 | 0.00000000 |
| 37 | 773.42190000 | 7.34520000 | 0.00000000 |
| 38 | 784.35050000 | 25.28430000 | 0.00000000 |
| 39 | 804.00280000 | 20.57000000 | 0.00000000 |
| 40 | 827.04180000 | 4.38230000 | 0.00000000 |
| 41 | 849.66770000 | 33.64300000 | 0.00000000 |
| 42 | 860.62880000 | 15.85320000 | 0.00000000 |
| 43 | 861.46140000 | 10.00070000 | 0.00000000 |
| 44 | 913.76690000 | 41.35750000 | 0.00000000 |
| 45 | 915.89450000 | 27.51390000 | 0.00000000 |
| 46 | 928.53370000 | 5.82950000 | 0.00000000 |
| 47 | 932.86870000 | 0.26370000 | 0.00000000 |
| 48 | 933.52650000 | 0.05850000 | 0.00000000 |
| 49 | 967.11210000 | 13.92840000 | 0.00000000 |
| 50 | 973.73310000 | 0.05980000 | 0.00000000 |
| 51 | 983.95220000 | 0.20110000 | 0.00000000 |
| 52 | 986.77430000 | 37.00620000 | 0.00000000 |
| 53 | 998.11610000 | 1.90470000 | 0.00000000 |
| 54 | 1006.42800000 | 24.54190000 | 0.00000000 |
| 55 | 1018.00640000 | 110.97990000 | 0.00000000 |
| 56 | 1025.30400000 | 2.26210000 | 0.00000000 |
| 57 | 1035.69340000 | 4.87300000 | 0.00000000 |
| 58 | 1052.62120000 | 1.42290000 | 0.00000000 |
| 59 | 1056.51370000 | 8.29570000 | 0.00000000 |
| 60 | 1063.54580000 | 6.43210000 | 0.00000000 |
| 61 | 1107.45320000 | 4.43170000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 62 | 1115.47710000 | 8.03460000 | 0.00000000 |
| 63 | 1141.70900000 | 54.94870000 | 0.00000000 |
| 64 | 1171.16760000 | 794.05400000 | 0.00000000 |
| 65 | 1178.98830000 | 1.62680000 | 0.00000000 |
| 66 | 1189.96740000 | 32.07480000 | 0.00000000 |
| 67 | 1205.22120000 | 5.57420000 | 0.00000000 |
| 68 | 1223.01140000 | 17.64620000 | 0.00000000 |
| 69 | 1241.78100000 | 18.22370000 | 0.00000000 |
| 70 | 1257.75030000 | 358.18980000 | 0.00000000 |
| 71 | 1265.67380000 | 38.00510000 | 0.00000000 |
| 72 | 1272.74730000 | 14.08290000 | 0.00000000 |
| 73 | 1283.27890000 | 23.90660000 | 0.00000000 |
| 74 | 1300.01630000 | 3.36060000 | 0.00000000 |
| 75 | 1315.75380000 | 173.52700000 | 0.00000000 |
| 76 | 1331.22240000 | 12.25510000 | 0.00000000 |
| 77 | 1356.06010000 | 6.34880000 | 0.00000000 |
| 78 | 1359.88720000 | 0.61050000 | 0.00000000 |
| 79 | 1373.65650000 | 14.40330000 | 0.00000000 |
| 80 | 1388.63100000 | 22.40930000 | 0.00000000 |
| 81 | 1398.77680000 | 25.24190000 | 0.00000000 |
| 82 | 1400.79580000 | 82.60940000 | 0.00000000 |
| 83 | 1402.10280000 | 16.24410000 | 0.00000000 |
| 84 | 1424.35760000 | 20.27530000 | 0.00000000 |
| 85 | 1454.88940000 | 6.84020000 | 0.00000000 |
| 86 | 1468.10210000 | 0.16970000 | 0.00000000 |
| 87 | 1471.34600000 | 9.54530000 | 0.00000000 |
| 88 | 1482.33100000 | 6.62360000 | 0.00000000 |
| 89 | 1483.94320000 | 0.13160000 | 0.00000000 |
| 90 | 1484.40340000 | 1.79140000 | 0.00000000 |
| 91 | 1488.74420000 | 14.54780000 | 0.00000000 |
| 92 | 1490.39090000 | 13.76500000 | 0.00000000 |
| 93 | 1493.08770000 | 42.64310000 | 0.00000000 |
| 94 | 1497.75260000 | 2.49610000 | 0.00000000 |
| 95 | 1516.35680000 | 22.25900000 | 0.00000000 |
| 96 | 1532.66880000 | 19.31640000 | 0.00000000 |
| 97 | 1624.83580000 | 0.98610000 | 0.00000000 |
| 98 | 1645.52740000 | 7.56640000 | 0.00000000 |
| 99 | 1711.07940000 | 46.90890000 | 0.00000000 |
| 100 | 1725.90830000 | 409.89140000 | 0.00000000 |
| 101 | 3026.63730000 | 21.59110000 | 0.00000000 |
| 102 | 3030.35170000 | 26.56590000 | 0.00000000 |
| 103 | 3039.69360000 | 34.44730000 | 0.00000000 |
| 104 | 3043.16920000 | 15.98070000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 105 | 3045.34700000 | 35.36230000 | 0.00000000 |
| 106 | 3051.87130000 | 17.79040000 | 0.00000000 |
| 107 | 3052.31350000 | 25.43060000 | 0.00000000 |
| 108 | 3079.47610000 | 46.23520000 | 0.00000000 |
| 109 | 3089.99010000 | 41.61060000 | 0.00000000 |
| 110 | 3101.11850000 | 31.14560000 | 0.00000000 |
| 111 | 3104.92520000 | 7.95730000 | 0.00000000 |
| 112 | 3106.69580000 | 21.79160000 | 0.00000000 |
| 113 | 3113.64150000 | 42.38280000 | 0.00000000 |
| 114 | 3119.15650000 | 56.48330000 | 0.00000000 |
| 115 | 3129.27860000 | 15.05490000 | 0.00000000 |
| 116 | 3143.05000000 | 0.33170000 | 0.00000000 |
| 117 | 3145.98600000 | 27.38600000 | 0.00000000 |
| 118 | 3167.81770000 | 0.52460000 | 0.00000000 |
| 119 | 3176.53650000 | 18.33070000 | 0.00000000 |
| 120 | 3190.25080000 | 31.82520000 | 0.00000000 |
| 121 | 3199.90810000 | 15.64520000 | 0.00000000 |
| 122 | 3207.64620000 | 22.43350000 | 0.00000000 |
| 123 | 3218.12170000 | 13.62020000 | 0.00000000 |

## Axial Anticlockwise Transition State



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 3.5670 Debye

Energy : -867.273949768 a.u.

Gibbs Energy : -866.951141 a.u.

Number of imaginary frequencies : -1

### Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -0.44218200 | 1.37968600 | -0.98042400 |
| C | -0.71349300 | -0.09447100 | -0.59845300 |
| C | -0.12107200 | 0.41386800 | 1.74459700 |
| C | 0.13910800 | 1.89141700 | 1.41094500 |
| H | -0.34356100 | -0.72047700 | -1.41540600 |
| H | 0.60031500 | 1.43413600 | -1.29916100 |
| H | -1.05301900 | 1.68157600 | -1.82925300 |
| H | -1.14765600 | 0.30430000 | 2.10253500 |
| H | 0.53698400 | 0.07551700 | 2.54542400 |
| H | -0.12752100 | 2.51168300 | 2.26842000 |
| H | 1.20667100 | 2.02435700 | 1.21622600 |
| C | -0.64265900 | 2.29635100 | 0.19275900 |
| C | -1.45632600 | 3.34805900 | 0.16687500 |
| H | -2.01880800 | 3.60772400 | -0.72191100 |
| H | -1.58238800 | 3.98614000 | 1.03350600 |
| N | 0.03728600 | -0.49399900 | 0.60386700 |
| C | 1.35212600 | -0.97376500 | 0.38000400 |

| | | | |
|---|---|---|---|
| O | 1.67258900 | -2.12073000 | 0.57786400 |
| O | 2.17234700 | -0.01595400 | -0.06321100 |
| C | 3.59903300 | -0.26325100 | -0.37764200 |
| C | 4.33293100 | -0.70634700 | 0.88111500 |
| H | 4.00254900 | -1.68814600 | 1.20990800 |
| H | 5.40283900 | -0.74969400 | 0.67320400 |
| H | 4.17206900 | 0.01258200 | 1.68575300 |
| C | 3.70620400 | -1.27629000 | -1.50966300 |
| H | 4.74826100 | -1.35214600 | -1.82312200 |
| H | 3.36517400 | -2.25983600 | -1.19719900 |
| H | 3.11638600 | -0.94952800 | -2.36728700 |
| C | 4.07706100 | 1.10965000 | -0.82985000 |
| H | 3.95091900 | 1.84184200 | -0.03188300 |
| H | 5.13343300 | 1.06376900 | -1.09505100 |
| H | 3.51462100 | 1.44401700 | -1.70202100 |
| C | -2.19018900 | -0.44150100 | -0.41020500 |
| C | -2.53774000 | -1.58342500 | 0.31451100 |
| C | -3.21424000 | 0.30963400 | -0.98507100 |
| C | -3.86539200 | -1.96245100 | 0.46173200 |
| H | -1.75103400 | -2.16725500 | 0.77156000 |
| C | -4.54606800 | -0.06689300 | -0.83945300 |
| H | -2.98919200 | 1.20132300 | -1.55015600 |
| C | -4.87886200 | -1.20362100 | -0.11467500 |
| H | -4.10895300 | -2.85201000 | 1.02898400 |
| H | -5.32310000 | 0.53623600 | -1.29178500 |
| H | -5.91491100 | -1.49453100 | 0.00180000 |

Frequencies

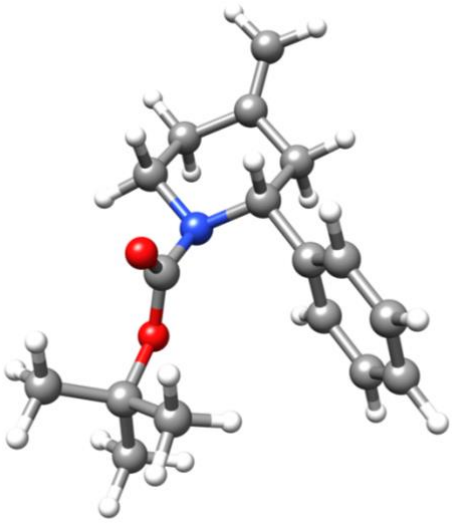
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | -59.18510000 | 1.44730000 | 0.00000000 |
| 2 | 25.91400000 | 0.01060000 | 0.00000000 |
| 3 | 39.50930000 | 0.59840000 | 0.00000000 |
| 4 | 51.24310000 | 0.69810000 | 0.00000000 |
| 5 | 75.25580000 | 0.28450000 | 0.00000000 |
| 6 | 88.58310000 | 0.34500000 | 0.00000000 |
| 7 | 111.80080000 | 0.86990000 | 0.00000000 |
| 8 | 145.41630000 | 1.30550000 | 0.00000000 |
| 9 | 164.76570000 | 2.71210000 | 0.00000000 |
| 10 | 191.92930000 | 3.71560000 | 0.00000000 |
| 11 | 201.07120000 | 0.18810000 | 0.00000000 |
| 12 | 211.15130000 | 1.56750000 | 0.00000000 |
| 13 | 241.50300000 | 0.18980000 | 0.00000000 |
| 14 | 262.62710000 | 1.15780000 | 0.00000000 |
| 15 | 272.70660000 | 0.07740000 | 0.00000000 |
| 16 | 282.42120000 | 0.44300000 | 0.00000000 |
| 17 | 324.23980000 | 7.80350000 | 0.00000000 |
| 18 | 354.69970000 | 1.40820000 | 0.00000000 |
| 19 | 361.82840000 | 1.47610000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 20 | 370.55270000 | 2.09520000 | 0.00000000 |
| 21 | 409.71310000 | 3.37910000 | 0.00000000 |
| 22 | 416.42160000 | 1.15560000 | 0.00000000 |
| 23 | 419.10020000 | 1.13830000 | 0.00000000 |
| 24 | 446.04990000 | 0.23510000 | 0.00000000 |
| 25 | 463.14660000 | 10.80840000 | 0.00000000 |
| 26 | 467.32400000 | 2.92060000 | 0.00000000 |
| 27 | 476.18130000 | 9.58680000 | 0.00000000 |
| 28 | 506.85780000 | 8.09920000 | 0.00000000 |
| 29 | 566.56470000 | 5.60460000 | 0.00000000 |
| 30 | 623.62620000 | 12.49160000 | 0.00000000 |
| 31 | 638.79960000 | 1.69680000 | 0.00000000 |
| 32 | 662.34740000 | 23.34970000 | 0.00000000 |
| 33 | 714.30570000 | 44.72200000 | 0.00000000 |
| 34 | 717.27160000 | 29.61410000 | 0.00000000 |
| 35 | 735.18610000 | 21.22240000 | 0.00000000 |
| 36 | 760.61120000 | 6.82790000 | 0.00000000 |
| 37 | 775.89410000 | 4.75030000 | 0.00000000 |
| 38 | 783.83840000 | 23.71400000 | 0.00000000 |
| 39 | 802.05500000 | 20.43040000 | 0.00000000 |
| 40 | 825.62200000 | 2.93690000 | 0.00000000 |
| 41 | 853.03730000 | 26.52530000 | 0.00000000 |
| 42 | 858.87890000 | 47.15520000 | 0.00000000 |
| 43 | 862.63370000 | 0.60710000 | 0.00000000 |
| 44 | 914.46750000 | 63.85320000 | 0.00000000 |
| 45 | 916.60890000 | 8.52560000 | 0.00000000 |
| 46 | 928.39330000 | 3.19280000 | 0.00000000 |
| 47 | 932.57090000 | 0.07570000 | 0.00000000 |
| 48 | 933.54890000 | 0.06970000 | 0.00000000 |
| 49 | 966.76650000 | 18.28770000 | 0.00000000 |
| 50 | 974.44450000 | 0.04580000 | 0.00000000 |
| 51 | 983.90780000 | 3.36710000 | 0.00000000 |
| 52 | 984.58540000 | 2.45280000 | 0.00000000 |
| 53 | 1001.36330000 | 3.79660000 | 0.00000000 |
| 54 | 1006.41400000 | 22.94210000 | 0.00000000 |
| 55 | 1017.40190000 | 88.10660000 | 0.00000000 |
| 56 | 1024.97090000 | 1.32510000 | 0.00000000 |
| 57 | 1034.91490000 | 46.51150000 | 0.00000000 |
| 58 | 1053.42260000 | 1.22520000 | 0.00000000 |
| 59 | 1056.94210000 | 6.21440000 | 0.00000000 |
| 60 | 1063.58720000 | 7.98150000 | 0.00000000 |
| 61 | 1105.96730000 | 113.92590000 | 0.00000000 |
| 62 | 1111.56520000 | 37.83290000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 63 | 1145.21760000 | 32.49280000 | 0.00000000 |
| 64 | 1157.00670000 | 728.46710000 | 0.00000000 |
| 65 | 1179.26360000 | 3.21350000 | 0.00000000 |
| 66 | 1189.19510000 | 32.04360000 | 0.00000000 |
| 67 | 1206.15150000 | 3.63580000 | 0.00000000 |
| 68 | 1220.62200000 | 13.08660000 | 0.00000000 |
| 69 | 1239.58220000 | 41.04680000 | 0.00000000 |
| 70 | 1242.80000000 | 89.00680000 | 0.00000000 |
| 71 | 1263.75390000 | 36.28720000 | 0.00000000 |
| 72 | 1272.81270000 | 18.97810000 | 0.00000000 |
| 73 | 1283.12050000 | 20.02690000 | 0.00000000 |
| 74 | 1299.21310000 | 0.15550000 | 0.00000000 |
| 75 | 1315.07490000 | 33.84820000 | 0.00000000 |
| 76 | 1329.91240000 | 8.90160000 | 0.00000000 |
| 77 | 1353.76960000 | 11.12780000 | 0.00000000 |
| 78 | 1360.12170000 | 2.01140000 | 0.00000000 |
| 79 | 1372.09550000 | 16.72420000 | 0.00000000 |
| 80 | 1388.46500000 | 30.60150000 | 0.00000000 |
| 81 | 1399.94710000 | 26.16950000 | 0.00000000 |
| 82 | 1402.46780000 | 35.93290000 | 0.00000000 |
| 83 | 1404.60300000 | 112.69910000 | 0.00000000 |
| 84 | 1425.96980000 | 17.55900000 | 0.00000000 |
| 85 | 1454.10090000 | 2.49510000 | 0.00000000 |
| 86 | 1467.92510000 | 0.10590000 | 0.00000000 |
| 87 | 1473.12600000 | 11.09810000 | 0.00000000 |
| 88 | 1481.96240000 | 8.50350000 | 0.00000000 |
| 89 | 1483.99980000 | 0.54870000 | 0.00000000 |
| 90 | 1484.64320000 | 1.71900000 | 0.00000000 |
| 91 | 1489.22540000 | 33.25490000 | 0.00000000 |
| 92 | 1490.73460000 | 12.80570000 | 0.00000000 |
| 93 | 1495.12570000 | 28.64690000 | 0.00000000 |
| 94 | 1497.43000000 | 3.72080000 | 0.00000000 |
| 95 | 1516.28150000 | 23.02430000 | 0.00000000 |
| 96 | 1532.87560000 | 20.55690000 | 0.00000000 |
| 97 | 1624.71720000 | 0.20600000 | 0.00000000 |
| 98 | 1645.07690000 | 7.04300000 | 0.00000000 |
| 99 | 1711.26920000 | 60.40630000 | 0.00000000 |
| 100 | 1748.87210000 | 591.63120000 | 0.00000000 |
| 101 | 3028.81140000 | 23.93120000 | 0.00000000 |
| 102 | 3032.59260000 | 28.21360000 | 0.00000000 |
| 103 | 3037.61720000 | 37.07980000 | 0.00000000 |
| 104 | 3043.23080000 | 15.25890000 | 0.00000000 |
| 105 | 3045.51350000 | 35.94040000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 106 | 3051.71260000 | 15.69310000 | 0.00000000 |
| 107 | 3060.44560000 | 27.43290000 | 0.00000000 |
| 108 | 3080.80520000 | 45.63880000 | 0.00000000 |
| 109 | 3090.73810000 | 43.73360000 | 0.00000000 |
| 110 | 3105.33030000 | 5.47760000 | 0.00000000 |
| 111 | 3106.00040000 | 33.63850000 | 0.00000000 |
| 112 | 3107.10360000 | 21.90450000 | 0.00000000 |
| 113 | 3113.15020000 | 42.91280000 | 0.00000000 |
| 114 | 3118.89820000 | 59.65160000 | 0.00000000 |
| 115 | 3129.70260000 | 14.73710000 | 0.00000000 |
| 116 | 3142.34920000 | 2.54930000 | 0.00000000 |
| 117 | 3145.84560000 | 22.92640000 | 0.00000000 |
| 118 | 3167.84600000 | 0.39200000 | 0.00000000 |
| 119 | 3176.50510000 | 18.74020000 | 0.00000000 |
| 120 | 3190.32060000 | 32.34200000 | 0.00000000 |
| 121 | 3201.20290000 | 15.17260000 | 0.00000000 |
| 122 | 3208.23080000 | 20.90180000 | 0.00000000 |
| 123 | 3215.78980000 | 15.95760000 | 0.00000000 |

## Equatorial Clockwise Transition State



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.0073 Debye

Energy : -867.282502567 a.u.

Gibbs Energy : -866.959664 a.u.

Number of imaginary frequencies : 1

### Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | 3.11774700 | -1.79716500 | 0.65711600 |
| C | 1.81122000 | -2.00477900 | -0.10579000 |
| C | 1.46272100 | 0.41244500 | -0.32782900 |
| C | 2.77455500 | 0.67896700 | 0.42961600 |
| H | 2.02327500 | -2.11170900 | -1.17886400 |
| H | 1.31757500 | -2.91725900 | 0.23135200 |
| H | 2.89725600 | -1.81527100 | 1.72935900 |
| H | 3.80364200 | -2.61662200 | 0.43936700 |
| H | 1.69462100 | 0.34940600 | -1.39959200 |
| H | 3.21766400 | 1.60219700 | 0.05524900 |
| H | 2.52976600 | 0.82825100 | 1.48554900 |
| C | 3.72601000 | -0.47380200 | 0.29120400 |
| C | 4.96903800 | -0.33964300 | -0.16106500 |
| H | 5.62803600 | -1.19349800 | -0.26432600 |
| H | 5.36906600 | 0.62906300 | -0.43596800 |
| N | 0.90056000 | -0.87476300 | 0.13957400 |

| | | | |
|---|---|---|---|
| C | -0.37655100 | -1.11204800 | -0.46445200 |
| O | -0.56214300 | -1.17523100 | -1.65732300 |
| O | -1.30020200 | -1.24376300 | 0.47676200 |
| C | -2.73977300 | -1.36276100 | 0.14570200 |
| C | -3.18557400 | -0.12434400 | -0.62306200 |
| H | -2.75072000 | -0.09401200 | -1.61838600 |
| H | -4.27218100 | -0.13811200 | -0.71757100 |
| H | -2.89741200 | 0.77917100 | -0.08479800 |
| C | -2.99299600 | -2.65632400 | -0.61700700 |
| H | -4.06839900 | -2.79443100 | -0.73759100 |
| H | -2.53252400 | -2.63305100 | -1.60115500 |
| H | -2.60126100 | -3.50836000 | -0.05945300 |
| C | -3.38856400 | -1.40560600 | 1.52210100 |
| H | -3.16884100 | -0.49281300 | 2.07632200 |
| H | -4.46975500 | -1.49743500 | 1.41742800 |
| H | -3.02125300 | -2.25858800 | 2.09346100 |
| C | 0.46092300 | 1.52537800 | -0.12586600 |
| C | -0.10421300 | 1.75812600 | 1.12848400 |
| C | 0.07773200 | 2.33001900 | -1.19514600 |
| C | -1.03089300 | 2.77598800 | 1.30784300 |
| H | 0.16765500 | 1.12182300 | 1.95971100 |
| C | -0.84796900 | 3.35327000 | -1.01915700 |
| H | 0.49865100 | 2.14533600 | -2.17578200 |
| C | -1.40560400 | 3.57800000 | 0.23356000 |
| H | -1.46676900 | 2.94075600 | 2.28497500 |
| H | -1.13868600 | 3.96727200 | -1.86183200 |
| H | -2.13141800 | 4.36885500 | 0.37251300 |

Frequencies

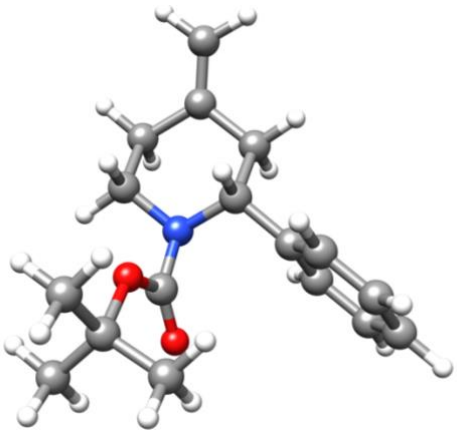
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | -39.47030000 | 2.26220000 | 0.00000000 |
| 2 | 38.91050000 | 0.02730000 | 0.00000000 |
| 3 | 47.98910000 | 0.24430000 | 0.00000000 |
| 4 | 56.92300000 | 0.92340000 | 0.00000000 |
| 5 | 71.03100000 | 0.87940000 | 0.00000000 |
| 6 | 82.09310000 | 0.94760000 | 0.00000000 |
| 7 | 110.58590000 | 0.36250000 | 0.00000000 |
| 8 | 131.69830000 | 2.49220000 | 0.00000000 |
| 9 | 169.68940000 | 3.60200000 | 0.00000000 |
| 10 | 194.69180000 | 3.12970000 | 0.00000000 |
| 11 | 204.87450000 | 0.23440000 | 0.00000000 |
| 12 | 210.08580000 | 0.19270000 | 0.00000000 |
| 13 | 236.71190000 | 1.48750000 | 0.00000000 |
| 14 | 240.97010000 | 0.38860000 | 0.00000000 |
| 15 | 270.84690000 | 0.16000000 | 0.00000000 |
| 16 | 280.07540000 | 5.80680000 | 0.00000000 |
| 17 | 303.68130000 | 2.04010000 | 0.00000000 |
| 18 | 318.60930000 | 3.25890000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 19 | 324.79350000 | 8.11840000 | 0.00000000 |
| 20 | 359.58360000 | 3.50000000 | 0.00000000 |
| 21 | 398.99980000 | 0.57560000 | 0.00000000 |
| 22 | 415.44560000 | 0.39430000 | 0.00000000 |
| 23 | 416.73260000 | 1.77420000 | 0.00000000 |
| 24 | 425.53520000 | 5.72040000 | 0.00000000 |
| 25 | 456.56500000 | 0.78770000 | 0.00000000 |
| 26 | 475.62050000 | 5.67650000 | 0.00000000 |
| 27 | 494.40260000 | 0.36960000 | 0.00000000 |
| 28 | 524.03070000 | 15.57160000 | 0.00000000 |
| 29 | 548.62870000 | 9.34360000 | 0.00000000 |
| 30 | 607.54710000 | 18.01940000 | 0.00000000 |
| 31 | 636.79160000 | 0.13910000 | 0.00000000 |
| 32 | 662.77380000 | 11.89950000 | 0.00000000 |
| 33 | 715.36630000 | 70.53890000 | 0.00000000 |
| 34 | 733.90810000 | 0.58180000 | 0.00000000 |
| 35 | 745.03640000 | 23.94530000 | 0.00000000 |
| 36 | 758.41210000 | 11.38350000 | 0.00000000 |
| 37 | 778.46840000 | 22.17820000 | 0.00000000 |
| 38 | 799.93540000 | 7.82720000 | 0.00000000 |
| 39 | 808.13820000 | 12.85460000 | 0.00000000 |
| 40 | 836.67340000 | 2.41810000 | 0.00000000 |
| 41 | 850.09220000 | 42.20760000 | 0.00000000 |
| 42 | 861.10890000 | 1.84030000 | 0.00000000 |
| 43 | 868.56240000 | 23.62850000 | 0.00000000 |
| 44 | 918.70820000 | 18.85890000 | 0.00000000 |
| 45 | 928.78900000 | 42.05080000 | 0.00000000 |
| 46 | 932.80550000 | 0.91130000 | 0.00000000 |
| 47 | 933.42260000 | 1.15300000 | 0.00000000 |
| 48 | 935.94080000 | 10.16590000 | 0.00000000 |
| 49 | 970.33280000 | 1.04890000 | 0.00000000 |
| 50 | 973.84040000 | 0.11710000 | 0.00000000 |
| 51 | 983.40850000 | 0.21090000 | 0.00000000 |
| 52 | 1003.14110000 | 0.75290000 | 0.00000000 |
| 53 | 1006.86270000 | 11.89700000 | 0.00000000 |
| 54 | 1020.42100000 | 45.69750000 | 0.00000000 |
| 55 | 1026.00290000 | 1.47100000 | 0.00000000 |
| 56 | 1039.05040000 | 12.63060000 | 0.00000000 |
| 57 | 1053.65100000 | 5.70480000 | 0.00000000 |
| 58 | 1053.82370000 | 6.39170000 | 0.00000000 |
| 59 | 1063.15680000 | 3.38860000 | 0.00000000 |
| 60 | 1082.35620000 | 15.11080000 | 0.00000000 |
| 61 | 1105.11370000 | 14.05590000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 62 | 1117.71290000 | 32.35900000 | 0.00000000 |
| 63 | 1122.06070000 | 73.26530000 | 0.00000000 |
| 64 | 1178.25390000 | 598.96420000 | 0.00000000 |
| 65 | 1179.80380000 | 11.84360000 | 0.00000000 |
| 66 | 1200.10580000 | 0.66780000 | 0.00000000 |
| 67 | 1204.86630000 | 10.87870000 | 0.00000000 |
| 68 | 1231.09980000 | 4.43350000 | 0.00000000 |
| 69 | 1248.95250000 | 25.34100000 | 0.00000000 |
| 70 | 1263.85290000 | 261.82070000 | 0.00000000 |
| 71 | 1271.71720000 | 44.86020000 | 0.00000000 |
| 72 | 1276.92080000 | 159.77430000 | 0.00000000 |
| 73 | 1285.44050000 | 39.08760000 | 0.00000000 |
| 74 | 1297.28940000 | 59.26740000 | 0.00000000 |
| 75 | 1307.30490000 | 2.16310000 | 0.00000000 |
| 76 | 1338.83170000 | 36.19790000 | 0.00000000 |
| 77 | 1347.01080000 | 6.86090000 | 0.00000000 |
| 78 | 1354.81750000 | 4.64680000 | 0.00000000 |
| 79 | 1363.50000000 | 32.25460000 | 0.00000000 |
| 80 | 1398.88240000 | 20.81290000 | 0.00000000 |
| 81 | 1399.27610000 | 29.97500000 | 0.00000000 |
| 82 | 1401.82940000 | 22.36960000 | 0.00000000 |
| 83 | 1406.34650000 | 15.90450000 | 0.00000000 |
| 84 | 1425.22130000 | 18.43580000 | 0.00000000 |
| 85 | 1452.95710000 | 1.65320000 | 0.00000000 |
| 86 | 1464.70880000 | 7.13160000 | 0.00000000 |
| 87 | 1468.26330000 | 0.44530000 | 0.00000000 |
| 88 | 1479.38230000 | 10.85980000 | 0.00000000 |
| 89 | 1483.72010000 | 0.17120000 | 0.00000000 |
| 90 | 1484.94500000 | 1.77500000 | 0.00000000 |
| 91 | 1489.50510000 | 12.11190000 | 0.00000000 |
| 92 | 1492.16620000 | 15.93620000 | 0.00000000 |
| 93 | 1497.52090000 | 2.55420000 | 0.00000000 |
| 94 | 1504.29240000 | 4.29950000 | 0.00000000 |
| 95 | 1516.21320000 | 23.91240000 | 0.00000000 |
| 96 | 1532.88730000 | 14.89370000 | 0.00000000 |
| 97 | 1628.44520000 | 1.16060000 | 0.00000000 |
| 98 | 1647.76620000 | 3.67280000 | 0.00000000 |
| 99 | 1714.72950000 | 43.52100000 | 0.00000000 |
| 100 | 1738.10260000 | 368.86690000 | 0.00000000 |
| 101 | 2967.13620000 | 64.02620000 | 0.00000000 |
| 102 | 2971.57480000 | 63.59170000 | 0.00000000 |
| 103 | 3020.73580000 | 29.54160000 | 0.00000000 |
| 104 | 3029.83300000 | 37.65400000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 105 | 3042.68120000 | 16.84340000 | 0.00000000 |
| 106 | 3046.12940000 | 28.98450000 | 0.00000000 |
| 107 | 3052.80500000 | 22.99980000 | 0.00000000 |
| 108 | 3076.01760000 | 45.24360000 | 0.00000000 |
| 109 | 3086.89610000 | 44.42280000 | 0.00000000 |
| 110 | 3091.17950000 | 25.84970000 | 0.00000000 |
| 111 | 3104.66740000 | 13.89400000 | 0.00000000 |
| 112 | 3110.09420000 | 3.83530000 | 0.00000000 |
| 113 | 3113.70270000 | 43.40250000 | 0.00000000 |
| 114 | 3119.19330000 | 55.52020000 | 0.00000000 |
| 115 | 3130.39240000 | 16.96080000 | 0.00000000 |
| 116 | 3142.98780000 | 4.16990000 | 0.00000000 |
| 117 | 3146.95710000 | 21.61530000 | 0.00000000 |
| 118 | 3167.27750000 | 4.23140000 | 0.00000000 |
| 119 | 3173.15570000 | 1.49220000 | 0.00000000 |
| 120 | 3182.35090000 | 28.54420000 | 0.00000000 |
| 121 | 3192.27580000 | 32.83000000 | 0.00000000 |
| 122 | 3198.66290000 | 8.82900000 | 0.00000000 |
| 123 | 3209.85930000 | 20.46900000 | 0.00000000 |

Equatorial Anticlockwise Transition State



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 3.0946 Debye

Energy : -867.280856122 a.u.

Gibbs Energy : -866.958475 a.u.

Number of imaginary frequencies : 1

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -2.53577700 | -2.39902300 | -0.66626400 |
| C | -1.02728600 | -2.22702400 | -0.49539700 |
| C | -1.29038000 | 0.06187200 | 0.31377100 |
| C | -2.81932200 | -0.05307600 | 0.18563500 |
| H | -0.72946600 | -2.57112500 | 0.50338900 |
| H | -0.49273000 | -2.82951600 | -1.23006700 |
| H | -2.79651400 | -2.15103400 | -1.70016800 |
| H | -2.80925600 | -3.43981300 | -0.48879000 |
| H | -1.01030600 | -0.29931700 | 1.31353400 |
| H | -3.28561800 | 0.55164000 | 0.96395000 |
| H | -3.10880100 | 0.36442500 | -0.78304700 |
| C | -3.26775700 | -1.48325300 | 0.27228500 |
| C | -4.18626000 | -1.90373300 | 1.13686000 |
| H | -4.48009100 | -2.94543700 | 1.18712800 |
| H | -4.67889200 | -1.21826500 | 1.81618100 |
| N | -0.66558400 | -0.81671800 | -0.70659900 |
| C | 0.73997200 | -0.60582100 | -0.82483000 |
| O | 1.23686000 | 0.02762400 | -1.72145100 |
| O | 1.40588400 | -1.19160100 | 0.17288600 |

| | | | |
|---|---|---|---|
| C | 2.87857600 | -1.11052800 | 0.29932700 |
| C | 3.53753600 | -1.76690500 | -0.90696800 |
| H | 3.36251500 | -1.19670100 | -1.81548600 |
| H | 4.61305100 | -1.82886900 | -0.73559700 |
| H | 3.15598100 | -2.78000800 | -1.04215900 |
| C | 3.29368400 | 0.34430500 | 0.47807800 |
| H | 4.36172000 | 0.38598600 | 0.69602100 |
| H | 3.09681600 | 0.92680000 | -0.41793100 |
| H | 2.75540100 | 0.79179400 | 1.31409600 |
| C | 3.14584500 | -1.91102200 | 1.56598600 |
| H | 2.80489800 | -2.94015700 | 1.44917500 |
| H | 4.21529300 | -1.92149400 | 1.77707600 |
| H | 2.62858100 | -1.46611500 | 2.41651800 |
| C | -0.82021300 | 1.49051400 | 0.19328500 |
| C | -1.04510400 | 2.23178400 | -0.96700900 |
| C | -0.15224200 | 2.09212100 | 1.25605600 |
| C | -0.61333300 | 3.54715000 | -1.05804300 |
| H | -1.54120400 | 1.76847700 | -1.80918800 |
| C | 0.28127600 | 3.41143600 | 1.16992300 |
| H | 0.03426200 | 1.52074700 | 2.15721100 |
| C | 0.05101400 | 4.14216600 | 0.01156100 |
| H | -0.78962200 | 4.10947100 | -1.96605700 |
| H | 0.80079800 | 3.86372400 | 2.00490400 |
| H | 0.38895500 | 5.16784400 | -0.06150900 |

Frequencies

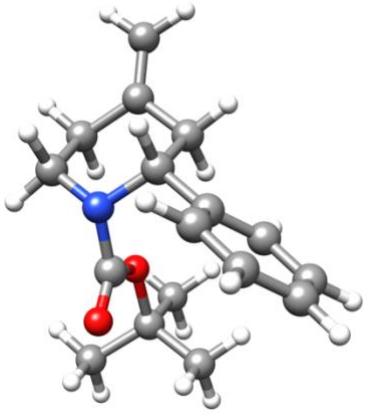
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | -42.48740000 | 0.88420000 | 0.00000000 |
| 2 | 35.05330000 | 0.42770000 | 0.00000000 |
| 3 | 42.40640000 | 0.28900000 | 0.00000000 |
| 4 | 45.62610000 | 0.28600000 | 0.00000000 |
| 5 | 75.81450000 | 1.74350000 | 0.00000000 |
| 6 | 82.59030000 | 0.36540000 | 0.00000000 |
| 7 | 107.38750000 | 1.07350000 | 0.00000000 |
| 8 | 132.44440000 | 2.22120000 | 0.00000000 |
| 9 | 168.81710000 | 4.49220000 | 0.00000000 |
| 10 | 197.13810000 | 2.40750000 | 0.00000000 |
| 11 | 201.22090000 | 0.32400000 | 0.00000000 |
| 12 | 213.18560000 | 0.30310000 | 0.00000000 |
| 13 | 225.64620000 | 1.34280000 | 0.00000000 |
| 14 | 241.54980000 | 0.21250000 | 0.00000000 |
| 15 | 269.88320000 | 0.14970000 | 0.00000000 |
| 16 | 278.17730000 | 1.17640000 | 0.00000000 |
| 17 | 308.41920000 | 0.68990000 | 0.00000000 |
| 18 | 322.49200000 | 7.74770000 | 0.00000000 |
| 19 | 346.03140000 | 2.18850000 | 0.00000000 |
| 20 | 363.57470000 | 3.02640000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 21 | 389.17030000 | 3.42530000 | 0.00000000 |
| 22 | 413.90550000 | 1.71630000 | 0.00000000 |
| 23 | 417.65560000 | 0.38440000 | 0.00000000 |
| 24 | 425.45120000 | 1.20040000 | 0.00000000 |
| 25 | 463.21940000 | 6.66380000 | 0.00000000 |
| 26 | 472.72180000 | 5.07540000 | 0.00000000 |
| 27 | 495.32920000 | 2.14250000 | 0.00000000 |
| 28 | 540.41530000 | 2.45830000 | 0.00000000 |
| 29 | 545.88580000 | 17.52430000 | 0.00000000 |
| 30 | 614.64620000 | 25.30710000 | 0.00000000 |
| 31 | 636.26050000 | 0.30200000 | 0.00000000 |
| 32 | 647.63560000 | 2.98880000 | 0.00000000 |
| 33 | 694.34840000 | 19.73390000 | 0.00000000 |
| 34 | 715.26600000 | 65.64530000 | 0.00000000 |
| 35 | 735.72760000 | 0.74200000 | 0.00000000 |
| 36 | 773.03040000 | 34.33490000 | 0.00000000 |
| 37 | 782.54240000 | 5.21440000 | 0.00000000 |
| 38 | 800.60960000 | 10.40250000 | 0.00000000 |
| 39 | 806.34300000 | 7.55160000 | 0.00000000 |
| 40 | 836.11720000 | 1.66770000 | 0.00000000 |
| 41 | 853.30340000 | 54.52430000 | 0.00000000 |
| 42 | 860.42500000 | 0.58380000 | 0.00000000 |
| 43 | 872.01190000 | 8.67530000 | 0.00000000 |
| 44 | 920.27020000 | 28.05880000 | 0.00000000 |
| 45 | 928.85020000 | 32.47810000 | 0.00000000 |
| 46 | 932.33110000 | 0.54280000 | 0.00000000 |
| 47 | 933.13090000 | 0.13980000 | 0.00000000 |
| 48 | 935.65370000 | 16.48160000 | 0.00000000 |
| 49 | 969.70690000 | 0.47840000 | 0.00000000 |
| 50 | 972.95520000 | 0.05900000 | 0.00000000 |
| 51 | 980.66360000 | 0.50140000 | 0.00000000 |
| 52 | 995.73730000 | 1.31790000 | 0.00000000 |
| 53 | 1007.94300000 | 18.45660000 | 0.00000000 |
| 54 | 1018.48290000 | 28.69020000 | 0.00000000 |
| 55 | 1025.71540000 | 1.74820000 | 0.00000000 |
| 56 | 1037.19490000 | 15.04570000 | 0.00000000 |
| 57 | 1052.89870000 | 1.79970000 | 0.00000000 |
| 58 | 1054.02020000 | 10.64950000 | 0.00000000 |
| 59 | 1062.15930000 | 1.88270000 | 0.00000000 |
| 60 | 1081.87920000 | 14.18900000 | 0.00000000 |
| 61 | 1103.90540000 | 49.07390000 | 0.00000000 |
| 62 | 1111.79650000 | 11.59640000 | 0.00000000 |
| 63 | 1121.66430000 | 120.28380000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 64 | 1162.60540000 | 747.42000000 | 0.00000000 |
| 65 | 1179.90730000 | 0.10890000 | 0.00000000 |
| 66 | 1201.02030000 | 2.27120000 | 0.00000000 |
| 67 | 1204.69730000 | 10.38180000 | 0.00000000 |
| 68 | 1233.45330000 | 5.57100000 | 0.00000000 |
| 69 | 1240.85300000 | 144.51120000 | 0.00000000 |
| 70 | 1251.55850000 | 12.58690000 | 0.00000000 |
| 71 | 1271.87900000 | 25.84670000 | 0.00000000 |
| 72 | 1277.72420000 | 78.68680000 | 0.00000000 |
| 73 | 1283.93960000 | 24.76750000 | 0.00000000 |
| 74 | 1297.42430000 | 48.28560000 | 0.00000000 |
| 75 | 1307.91710000 | 1.65890000 | 0.00000000 |
| 76 | 1339.76610000 | 13.04040000 | 0.00000000 |
| 77 | 1350.20740000 | 2.76380000 | 0.00000000 |
| 78 | 1356.16710000 | 3.70000000 | 0.00000000 |
| 79 | 1368.89920000 | 7.52650000 | 0.00000000 |
| 80 | 1396.91810000 | 42.74210000 | 0.00000000 |
| 81 | 1399.51930000 | 25.61690000 | 0.00000000 |
| 82 | 1402.09170000 | 11.85820000 | 0.00000000 |
| 83 | 1408.96060000 | 16.54140000 | 0.00000000 |
| 84 | 1425.47030000 | 17.10870000 | 0.00000000 |
| 85 | 1452.78500000 | 4.51110000 | 0.00000000 |
| 86 | 1463.89070000 | 7.56770000 | 0.00000000 |
| 87 | 1467.45520000 | 0.35390000 | 0.00000000 |
| 88 | 1478.67490000 | 11.12470000 | 0.00000000 |
| 89 | 1483.14210000 | 0.02790000 | 0.00000000 |
| 90 | 1484.11640000 | 1.37570000 | 0.00000000 |
| 91 | 1488.99970000 | 17.34530000 | 0.00000000 |
| 92 | 1492.62760000 | 13.52950000 | 0.00000000 |
| 93 | 1497.03910000 | 3.58940000 | 0.00000000 |
| 94 | 1503.24400000 | 5.70480000 | 0.00000000 |
| 95 | 1515.70710000 | 22.76620000 | 0.00000000 |
| 96 | 1533.60560000 | 12.09980000 | 0.00000000 |
| 97 | 1628.95930000 | 0.67030000 | 0.00000000 |
| 98 | 1648.38660000 | 2.04990000 | 0.00000000 |
| 99 | 1714.00030000 | 53.15130000 | 0.00000000 |
| 100 | 1762.34840000 | 504.90030000 | 0.00000000 |
| 101 | 2959.22230000 | 49.26570000 | 0.00000000 |
| 102 | 2982.38180000 | 67.53720000 | 0.00000000 |
| 103 | 3022.00090000 | 31.16210000 | 0.00000000 |
| 104 | 3032.65310000 | 35.06550000 | 0.00000000 |
| 105 | 3042.58560000 | 16.72340000 | 0.00000000 |
| 106 | 3046.55090000 | 32.59210000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 107 | 3053.10670000 | 18.00930000 | 0.00000000 |
| 108 | 3083.08500000 | 45.32810000 | 0.00000000 |
| 109 | 3086.66820000 | 43.90960000 | 0.00000000 |
| 110 | 3091.62700000 | 24.30400000 | 0.00000000 |
| 111 | 3105.34650000 | 11.67880000 | 0.00000000 |
| 112 | 3109.51670000 | 8.44340000 | 0.00000000 |
| 113 | 3112.88400000 | 47.70500000 | 0.00000000 |
| 114 | 3118.64150000 | 63.48340000 | 0.00000000 |
| 115 | 3130.26630000 | 16.50410000 | 0.00000000 |
| 116 | 3143.71740000 | 2.68810000 | 0.00000000 |
| 117 | 3146.76130000 | 22.35930000 | 0.00000000 |
| 118 | 3166.04800000 | 5.82570000 | 0.00000000 |
| 119 | 3172.92640000 | 0.97550000 | 0.00000000 |
| 120 | 3181.98550000 | 26.93430000 | 0.00000000 |
| 121 | 3191.54270000 | 36.17120000 | 0.00000000 |
| 122 | 3198.47670000 | 10.69830000 | 0.00000000 |
| 123 | 3209.70780000 | 20.52620000 | 0.00000000 |

Equatorial Clockwise Transition State Re-Optimized



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 3.1521 Debye

Energy : -867.276495435 a.u.

Gibbs Energy : -866.953764 a.u.

Number of imaginary frequencies : 1

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -2.45954600 | 1.87277700 | 0.32747800 |
| C | -1.61477400 | 1.47622400 | 1.55014300 |
| C | 0.45822800 | 1.55169800 | 0.22947900 |
| C | -0.34904900 | 1.89881300 | -1.03814700 |
| H | -1.36519300 | 2.38008800 | 2.11302500 |
| H | -2.18307800 | 0.82706500 | 2.21689200 |
| H | -2.85322800 | 0.96590600 | -0.13705400 |
| H | -3.30468500 | 2.48128400 | 0.65387200 |
| H | 0.70049800 | 2.50161900 | 0.71692800 |
| H | 0.26552400 | 2.51089500 | -1.69992000 |
| H | -0.60593600 | 0.97811000 | -1.56575000 |
| C | -1.61368900 | 2.61801700 | -0.66415800 |
| C | -1.92193600 | 3.82745400 | -1.12543600 |
| H | -2.83149700 | 4.33265500 | -0.82288200 |
| H | -1.27830900 | 4.34613400 | -1.82608400 |
| N | -0.34277000 | 0.81429500 | 1.23433700 |
| C | -0.42022300 | -0.59498900 | 1.05379600 |
| O | 0.15794500 | -1.37843300 | 1.76466800 |
| O | -1.20987500 | -0.92983300 | 0.02738000 |

| | | | |
|---|---|---|---|
| C | -1.48609800 | -2.33770600 | -0.34072500 |
| C | -0.19150500 | -3.03283400 | -0.74102700 |
| H | 0.48619100 | -3.12859300 | 0.10281200 |
| H | -0.42646700 | -4.02930200 | -1.11777100 |
| H | 0.30926500 | -2.47695700 | -1.53372300 |
| C | -2.19633700 | -3.03729000 | 0.81063900 |
| H | -2.52377900 | -4.02428300 | 0.48130000 |
| H | -1.53976600 | -3.15773800 | 1.66850700 |
| H | -3.07787800 | -2.46975100 | 1.11236000 |
| C | -2.41197300 | -2.18672000 | -1.53985800 |
| H | -1.91636600 | -1.63338900 | -2.33805400 |
| H | -2.68786500 | -3.17065700 | -1.91964400 |
| H | -3.32167300 | -1.65497700 | -1.25963800 |
| C | 1.76303700 | 0.83081400 | -0.03166600 |
| C | 1.98036000 | 0.05802700 | -1.16898500 |
| C | 2.77724200 | 0.91387300 | 0.92353100 |
| C | 3.18219700 | -0.62089800 | -1.34731600 |
| H | 1.21298700 | -0.02437000 | -1.92522000 |
| C | 3.97751200 | 0.24055800 | 0.74997400 |
| H | 2.61397000 | 1.50730200 | 1.81470700 |
| C | 4.18308200 | -0.53313800 | -0.38918800 |
| H | 3.33239900 | -1.21944100 | -2.23664800 |
| H | 4.75262000 | 0.31713800 | 1.50164800 |
| H | 5.11793500 | -1.06074400 | -0.52761500 |

Frequencies

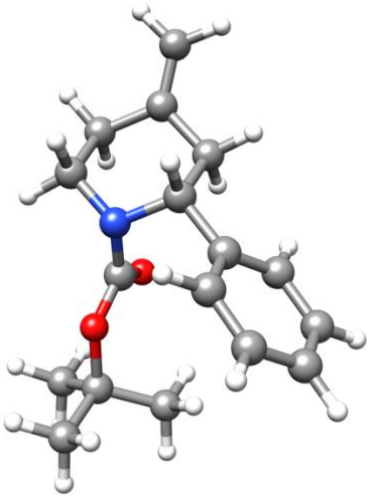
| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | -43.55750000 | 1.22530000 | 0.00000000 |
| 2 | 27.49670000 | 0.02790000 | 0.00000000 |
| 3 | 42.04470000 | 0.45600000 | 0.00000000 |
| 4 | 54.28840000 | 0.13690000 | 0.00000000 |
| 5 | 73.42250000 | 2.03530000 | 0.00000000 |
| 6 | 99.11210000 | 0.06530000 | 0.00000000 |
| 7 | 109.37080000 | 1.13150000 | 0.00000000 |
| 8 | 130.55660000 | 1.61310000 | 0.00000000 |
| 9 | 167.12840000 | 2.89180000 | 0.00000000 |
| 10 | 188.51880000 | 2.88820000 | 0.00000000 |
| 11 | 201.12330000 | 0.34030000 | 0.00000000 |
| 12 | 208.88270000 | 0.41460000 | 0.00000000 |
| 13 | 246.69360000 | 0.57830000 | 0.00000000 |
| 14 | 260.26260000 | 1.37140000 | 0.00000000 |
| 15 | 272.22480000 | 0.07660000 | 0.00000000 |
| 16 | 279.90700000 | 0.27290000 | 0.00000000 |
| 17 | 323.62200000 | 7.21350000 | 0.00000000 |
| 18 | 328.08850000 | 0.35390000 | 0.00000000 |
| 19 | 356.50670000 | 0.83810000 | 0.00000000 |
| 20 | 365.17370000 | 2.25960000 | 0.00000000 |
| 21 | 394.80640000 | 4.24150000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 22 | 414.12130000 | 0.15180000 | 0.00000000 |
| 23 | 418.24070000 | 0.60610000 | 0.00000000 |
| 24 | 433.22280000 | 1.87710000 | 0.00000000 |
| 25 | 457.18530000 | 7.51370000 | 0.00000000 |
| 26 | 473.50990000 | 2.24380000 | 0.00000000 |
| 27 | 490.53090000 | 7.20430000 | 0.00000000 |
| 28 | 522.25190000 | 10.04710000 | 0.00000000 |
| 29 | 565.76800000 | 5.86380000 | 0.00000000 |
| 30 | 612.64990000 | 15.68930000 | 0.00000000 |
| 31 | 630.13510000 | 13.98290000 | 0.00000000 |
| 32 | 638.82640000 | 1.79480000 | 0.00000000 |
| 33 | 680.53840000 | 35.98380000 | 0.00000000 |
| 34 | 712.37400000 | 66.13550000 | 0.00000000 |
| 35 | 732.38320000 | 1.02790000 | 0.00000000 |
| 36 | 768.08430000 | 47.15980000 | 0.00000000 |
| 37 | 778.88280000 | 7.96020000 | 0.00000000 |
| 38 | 793.48070000 | 1.91280000 | 0.00000000 |
| 39 | 807.88350000 | 5.83560000 | 0.00000000 |
| 40 | 832.73290000 | 2.97120000 | 0.00000000 |
| 41 | 854.53300000 | 55.34800000 | 0.00000000 |
| 42 | 857.79410000 | 0.39300000 | 0.00000000 |
| 43 | 865.07590000 | 12.08790000 | 0.00000000 |
| 44 | 915.57850000 | 59.63140000 | 0.00000000 |
| 45 | 925.29670000 | 5.35910000 | 0.00000000 |
| 46 | 932.30310000 | 0.31480000 | 0.00000000 |
| 47 | 933.49310000 | 0.06810000 | 0.00000000 |
| 48 | 943.66090000 | 12.73690000 | 0.00000000 |
| 49 | 954.11380000 | 5.76170000 | 0.00000000 |
| 50 | 974.23640000 | 0.06830000 | 0.00000000 |
| 51 | 978.80900000 | 0.24020000 | 0.00000000 |
| 52 | 983.43840000 | 12.79900000 | 0.00000000 |
| 53 | 993.85670000 | 1.62290000 | 0.00000000 |
| 54 | 1006.74480000 | 7.76670000 | 0.00000000 |
| 55 | 1016.94030000 | 38.08610000 | 0.00000000 |
| 56 | 1026.70680000 | 1.57300000 | 0.00000000 |
| 57 | 1049.63490000 | 37.95240000 | 0.00000000 |
| 58 | 1054.39490000 | 1.74500000 | 0.00000000 |
| 59 | 1058.79420000 | 7.26680000 | 0.00000000 |
| 60 | 1063.89020000 | 10.30190000 | 0.00000000 |
| 61 | 1108.81390000 | 24.19110000 | 0.00000000 |
| 62 | 1122.69550000 | 111.72410000 | 0.00000000 |
| 63 | 1134.69170000 | 87.36940000 | 0.00000000 |
| 64 | 1151.00610000 | 677.38790000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 65 | 1181.20220000 | 0.04520000 | 0.00000000 |
| 66 | 1191.76110000 | 11.93480000 | 0.00000000 |
| 67 | 1206.43390000 | 3.51460000 | 0.00000000 |
| 68 | 1222.91660000 | 11.37360000 | 0.00000000 |
| 69 | 1233.46940000 | 61.09110000 | 0.00000000 |
| 70 | 1254.32870000 | 11.12180000 | 0.00000000 |
| 71 | 1272.62380000 | 25.79670000 | 0.00000000 |
| 72 | 1281.84680000 | 8.96320000 | 0.00000000 |
| 73 | 1283.42500000 | 18.84460000 | 0.00000000 |
| 74 | 1299.86020000 | 49.61730000 | 0.00000000 |
| 75 | 1306.17410000 | 23.14810000 | 0.00000000 |
| 76 | 1342.13010000 | 3.11710000 | 0.00000000 |
| 77 | 1349.91380000 | 7.83080000 | 0.00000000 |
| 78 | 1357.44580000 | 2.68220000 | 0.00000000 |
| 79 | 1382.61080000 | 24.60660000 | 0.00000000 |
| 80 | 1390.54990000 | 51.27420000 | 0.00000000 |
| 81 | 1400.19530000 | 25.99290000 | 0.00000000 |
| 82 | 1402.57680000 | 16.84250000 | 0.00000000 |
| 83 | 1409.11140000 | 47.58000000 | 0.00000000 |
| 84 | 1424.94590000 | 19.13440000 | 0.00000000 |
| 85 | 1452.92880000 | 0.58790000 | 0.00000000 |
| 86 | 1468.09160000 | 1.56420000 | 0.00000000 |
| 87 | 1468.76570000 | 9.84700000 | 0.00000000 |
| 88 | 1482.61690000 | 10.14690000 | 0.00000000 |
| 89 | 1484.04640000 | 15.87120000 | 0.00000000 |
| 90 | 1485.00810000 | 1.35750000 | 0.00000000 |
| 91 | 1488.04540000 | 13.64210000 | 0.00000000 |
| 92 | 1489.45000000 | 2.79600000 | 0.00000000 |
| 93 | 1490.45890000 | 16.88350000 | 0.00000000 |
| 94 | 1497.39230000 | 3.80900000 | 0.00000000 |
| 95 | 1515.78960000 | 24.23540000 | 0.00000000 |
| 96 | 1535.26060000 | 11.67470000 | 0.00000000 |
| 97 | 1628.26770000 | 2.21110000 | 0.00000000 |
| 98 | 1648.79480000 | 2.06420000 | 0.00000000 |
| 99 | 1709.40250000 | 72.67880000 | 0.00000000 |
| 100 | 1755.98490000 | 538.78110000 | 0.00000000 |
| 101 | 3010.69150000 | 30.14110000 | 0.00000000 |
| 102 | 3025.24060000 | 57.76750000 | 0.00000000 |
| 103 | 3041.56550000 | 31.45630000 | 0.00000000 |
| 104 | 3042.62320000 | 19.30020000 | 0.00000000 |
| 105 | 3045.46900000 | 17.82330000 | 0.00000000 |
| 106 | 3046.57920000 | 33.52120000 | 0.00000000 |
| 107 | 3053.98530000 | 18.79750000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 108 | 3083.48340000 | 46.42970000 | 0.00000000 |
| 109 | 3090.17650000 | 19.38330000 | 0.00000000 |
| 110 | 3091.33050000 | 51.79810000 | 0.00000000 |
| 111 | 3105.73280000 | 13.21500000 | 0.00000000 |
| 112 | 3109.63950000 | 4.41830000 | 0.00000000 |
| 113 | 3112.95840000 | 47.74350000 | 0.00000000 |
| 114 | 3118.57130000 | 69.00070000 | 0.00000000 |
| 115 | 3128.96180000 | 16.55610000 | 0.00000000 |
| 116 | 3142.47140000 | 8.70530000 | 0.00000000 |
| 117 | 3149.33170000 | 15.98330000 | 0.00000000 |
| 118 | 3167.72170000 | 3.47740000 | 0.00000000 |
| 119 | 3174.17500000 | 1.86610000 | 0.00000000 |
| 120 | 3183.41830000 | 29.21860000 | 0.00000000 |
| 121 | 3193.98510000 | 34.64070000 | 0.00000000 |
| 122 | 3203.56560000 | 10.60060000 | 0.00000000 |
| 123 | 3208.19560000 | 22.23090000 | 0.00000000 |

Equatorial Anticlockwise Transition State Re-Optimized



Route : # opt freq b3lyp scrf=(solvent=thf) geom=connectivity def2tzvp empiricaldispersion=gd3bj int=ultrafine pop=(regular,mk)

SMILES : C=C2CCN(C(=O)OC(C)(C)C)C(c1ccccc1)C2

Formula : $C_{17}H_{23}NO_2$

Charge : 0

Multiplicity : 1

Dipole : 2.0699 Debye

Energy : -867.277898089 a.u.

Gibbs Energy : -866.954363 a.u.

Number of imaginary frequencies : 1

Cartesian Coordinates (XYZ format)

43

| | | | |
|---|---|---|---|
| C | -3.07647900 | -1.62868300 | 0.03361200 |
| C | -2.00625900 | -1.55150600 | 1.13494100 |
| C | -1.43258100 | 0.75266300 | 0.50356700 |
| C | -2.47889700 | 0.72396400 | -0.62679000 |
| H | -2.47653900 | -1.23349700 | 2.06932900 |
| H | -1.56024600 | -2.53102200 | 1.31137100 |
| H | -2.62816000 | -2.07666700 | -0.85724000 |
| H | -3.89472200 | -2.27173900 | 0.36219300 |
| H | -1.94895600 | 1.09393400 | 1.40716100 |
| H | -2.88414300 | 1.72615700 | -0.77461800 |
| H | -1.99187100 | 0.40955600 | -1.55225200 |
| C | -3.57365400 | -0.24990900 | -0.29374800 |
| C | -4.85763300 | 0.09523100 | -0.23987200 |
| H | -5.62578700 | -0.62390900 | 0.01877300 |
| H | -5.18109100 | 1.10536400 | -0.46179200 |
| N | -0.92835100 | -0.59537700 | 0.85459500 |
| C | 0.05454900 | -1.08630400 | -0.05576800 |

| | | | |
|---|---|---|---|
| O | -0.13111200 | -1.31177600 | -1.23053500 |
| O | 1.20477600 | -1.25321800 | 0.58695000 |
| C | 2.44822100 | -1.64058900 | -0.11702400 |
| C | 2.29874300 | -3.03442800 | -0.71272500 |
| H | 1.57175700 | -3.04534400 | -1.52047200 |
| H | 3.26305900 | -3.35921300 | -1.10609700 |
| H | 1.98911100 | -3.74405300 | 0.05602100 |
| C | 2.79071700 | -0.58385000 | -1.16033300 |
| H | 3.78687000 | -0.78600200 | -1.55635300 |
| H | 2.08149700 | -0.59076800 | -1.98365900 |
| H | 2.79439300 | 0.40770400 | -0.70682900 |
| C | 3.47370700 | -1.63740300 | 1.00838500 |
| H | 3.19567800 | -2.35255800 | 1.78312400 |
| H | 4.45282600 | -1.91312300 | 0.61634200 |
| H | 3.54435700 | -0.64620700 | 1.45691000 |
| C | -0.25837000 | 1.68263200 | 0.26913700 |
| C | 0.04211600 | 2.22334300 | -0.97752100 |
| C | 0.58158400 | 1.97789000 | 1.34530200 |
| C | 1.15742200 | 3.03935000 | -1.14793800 |
| H | -0.58522900 | 2.00715700 | -1.83013700 |
| C | 1.69468100 | 2.78825900 | 1.18002500 |
| H | 0.36284500 | 1.55000800 | 2.31538300 |
| C | 1.98776800 | 3.32229900 | -0.07233800 |
| H | 1.37719300 | 3.44748000 | -2.12608500 |
| H | 2.33546700 | 3.00330200 | 2.02557800 |
| H | 2.85703600 | 3.95329600 | -0.20558300 |

Frequencies

| Mode | IR frequency | IR intensity | Raman intensity |
|---|---|---|---|
| 1 | -36.28790000 | 2.05310000 | 0.00000000 |
| 2 | 37.24280000 | 0.08640000 | 0.00000000 |
| 3 | 49.74100000 | 0.29480000 | 0.00000000 |
| 4 | 61.86440000 | 0.57400000 | 0.00000000 |
| 5 | 71.24450000 | 1.21260000 | 0.00000000 |
| 6 | 109.41120000 | 0.67950000 | 0.00000000 |
| 7 | 114.68320000 | 0.41520000 | 0.00000000 |
| 8 | 140.34340000 | 1.78870000 | 0.00000000 |
| 9 | 162.81490000 | 3.85650000 | 0.00000000 |
| 10 | 187.13370000 | 1.09280000 | 0.00000000 |
| 11 | 202.32970000 | 2.83310000 | 0.00000000 |
| 12 | 208.36590000 | 0.28120000 | 0.00000000 |
| 13 | 244.73410000 | 2.31520000 | 0.00000000 |
| 14 | 253.06100000 | 2.48280000 | 0.00000000 |
| 15 | 272.68680000 | 0.12720000 | 0.00000000 |
| 16 | 295.43020000 | 2.75540000 | 0.00000000 |
| 17 | 306.50560000 | 2.81630000 | 0.00000000 |
| 18 | 325.41930000 | 10.49390000 | 0.00000000 |
| 19 | 343.39340000 | 0.81660000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 20 | 363.83060000 | 2.52690000 | 0.00000000 |
| 21 | 403.74110000 | 2.55460000 | 0.00000000 |
| 22 | 413.71490000 | 0.13760000 | 0.00000000 |
| 23 | 420.74010000 | 0.70130000 | 0.00000000 |
| 24 | 434.04670000 | 5.72880000 | 0.00000000 |
| 25 | 460.99460000 | 1.26950000 | 0.00000000 |
| 26 | 474.58600000 | 0.97420000 | 0.00000000 |
| 27 | 486.88530000 | 7.34920000 | 0.00000000 |
| 28 | 519.54160000 | 9.98000000 | 0.00000000 |
| 29 | 565.56850000 | 3.17100000 | 0.00000000 |
| 30 | 605.90480000 | 14.68880000 | 0.00000000 |
| 31 | 638.04990000 | 0.60350000 | 0.00000000 |
| 32 | 658.94680000 | 7.04080000 | 0.00000000 |
| 33 | 698.14420000 | 55.51060000 | 0.00000000 |
| 34 | 713.99140000 | 74.42750000 | 0.00000000 |
| 35 | 732.89530000 | 1.37990000 | 0.00000000 |
| 36 | 757.87930000 | 28.34230000 | 0.00000000 |
| 37 | 776.35480000 | 19.28570000 | 0.00000000 |
| 38 | 796.20120000 | 4.23400000 | 0.00000000 |
| 39 | 811.90100000 | 12.80450000 | 0.00000000 |
| 40 | 833.29830000 | 0.79140000 | 0.00000000 |
| 41 | 852.72670000 | 31.85500000 | 0.00000000 |
| 42 | 859.40010000 | 1.00810000 | 0.00000000 |
| 43 | 864.83070000 | 19.26960000 | 0.00000000 |
| 44 | 915.66040000 | 60.64890000 | 0.00000000 |
| 45 | 925.03390000 | 5.71840000 | 0.00000000 |
| 46 | 932.67220000 | 0.29930000 | 0.00000000 |
| 47 | 933.90050000 | 0.11840000 | 0.00000000 |
| 48 | 941.77150000 | 9.98540000 | 0.00000000 |
| 49 | 958.82090000 | 10.02800000 | 0.00000000 |
| 50 | 974.33460000 | 0.12950000 | 0.00000000 |
| 51 | 983.15540000 | 0.38010000 | 0.00000000 |
| 52 | 987.10690000 | 24.10100000 | 0.00000000 |
| 53 | 1003.13710000 | 3.34600000 | 0.00000000 |
| 54 | 1007.19090000 | 4.12040000 | 0.00000000 |
| 55 | 1020.64780000 | 38.80560000 | 0.00000000 |
| 56 | 1026.78400000 | 1.12500000 | 0.00000000 |
| 57 | 1051.09410000 | 23.51510000 | 0.00000000 |
| 58 | 1053.55380000 | 1.52700000 | 0.00000000 |
| 59 | 1059.54260000 | 4.23210000 | 0.00000000 |
| 60 | 1064.84910000 | 3.34920000 | 0.00000000 |
| 61 | 1110.97630000 | 20.26700000 | 0.00000000 |
| 62 | 1128.04780000 | 51.43140000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 63 | 1134.77840000 | 91.13630000 | 0.00000000 |
| 64 | 1175.25910000 | 681.85100000 | 0.00000000 |
| 65 | 1181.33980000 | 0.17950000 | 0.00000000 |
| 66 | 1191.33540000 | 10.17590000 | 0.00000000 |
| 67 | 1207.57890000 | 3.99950000 | 0.00000000 |
| 68 | 1221.24570000 | 8.66970000 | 0.00000000 |
| 69 | 1252.25000000 | 33.47820000 | 0.00000000 |
| 70 | 1260.09310000 | 372.56950000 | 0.00000000 |
| 71 | 1272.16790000 | 25.28810000 | 0.00000000 |
| 72 | 1280.96240000 | 10.59340000 | 0.00000000 |
| 73 | 1283.78560000 | 13.75040000 | 0.00000000 |
| 74 | 1296.42570000 | 50.57480000 | 0.00000000 |
| 75 | 1304.25800000 | 4.10520000 | 0.00000000 |
| 76 | 1342.46550000 | 3.45940000 | 0.00000000 |
| 77 | 1348.39500000 | 15.08020000 | 0.00000000 |
| 78 | 1358.68630000 | 3.97410000 | 0.00000000 |
| 79 | 1380.27810000 | 11.78640000 | 0.00000000 |
| 80 | 1388.51230000 | 36.16720000 | 0.00000000 |
| 81 | 1399.25420000 | 28.84380000 | 0.00000000 |
| 82 | 1401.49220000 | 36.48890000 | 0.00000000 |
| 83 | 1405.26040000 | 70.77100000 | 0.00000000 |
| 84 | 1425.36940000 | 20.36770000 | 0.00000000 |
| 85 | 1451.55430000 | 5.01230000 | 0.00000000 |
| 86 | 1468.16750000 | 11.01480000 | 0.00000000 |
| 87 | 1468.62230000 | 0.55320000 | 0.00000000 |
| 88 | 1483.55060000 | 17.47110000 | 0.00000000 |
| 89 | 1484.56480000 | 0.48250000 | 0.00000000 |
| 90 | 1485.03750000 | 1.38040000 | 0.00000000 |
| 91 | 1487.36000000 | 15.48730000 | 0.00000000 |
| 92 | 1488.84540000 | 7.67330000 | 0.00000000 |
| 93 | 1490.21620000 | 14.36330000 | 0.00000000 |
| 94 | 1497.81580000 | 2.87930000 | 0.00000000 |
| 95 | 1517.12830000 | 24.13950000 | 0.00000000 |
| 96 | 1535.59420000 | 14.79500000 | 0.00000000 |
| 97 | 1627.76810000 | 2.86190000 | 0.00000000 |
| 98 | 1648.62060000 | 3.63680000 | 0.00000000 |
| 99 | 1709.32370000 | 59.19490000 | 0.00000000 |
| 100 | 1727.93210000 | 354.39160000 | 0.00000000 |
| 101 | 3007.13080000 | 27.60430000 | 0.00000000 |
| 102 | 3027.98990000 | 53.98430000 | 0.00000000 |
| 103 | 3035.28300000 | 24.97730000 | 0.00000000 |
| 104 | 3042.47400000 | 17.39470000 | 0.00000000 |
| 105 | 3043.83100000 | 22.28220000 | 0.00000000 |

| | | | |
|---|---|---|---|
| 106 | 3045.98350000 | 29.71080000 | 0.00000000 |
| 107 | 3052.56700000 | 23.91970000 | 0.00000000 |
| 108 | 3081.09680000 | 53.36990000 | 0.00000000 |
| 109 | 3087.53080000 | 35.11190000 | 0.00000000 |
| 110 | 3090.79380000 | 31.74670000 | 0.00000000 |
| 111 | 3104.57240000 | 13.84260000 | 0.00000000 |
| 112 | 3110.20040000 | 2.77120000 | 0.00000000 |
| 113 | 3113.27760000 | 43.27270000 | 0.00000000 |
| 114 | 3118.79710000 | 57.30710000 | 0.00000000 |
| 115 | 3128.52420000 | 16.93260000 | 0.00000000 |
| 116 | 3143.10270000 | 1.12020000 | 0.00000000 |
| 117 | 3146.03960000 | 26.51310000 | 0.00000000 |
| 118 | 3168.63970000 | 1.08180000 | 0.00000000 |
| 119 | 3176.20050000 | 4.25420000 | 0.00000000 |
| 120 | 3184.86650000 | 30.23030000 | 0.00000000 |
| 121 | 3194.17050000 | 29.97500000 | 0.00000000 |
| 122 | 3206.31400000 | 9.01640000 | 0.00000000 |
| 123 | 3207.73580000 | 22.25460000 | 0.00000000 |

## Thermochemistry Values

### Left Rotamer Axial:

| | Temperature | | |
|---|---|---|---|
| | 298 K | 213 K | 195 K |
| $\varepsilon_0$ | –867.300243526 a.u. | –867.300243526 a.u. | –867.300243526 a.u. |
| $\varepsilon_{ZPE}$ | 0.370384 a.u. | 0.370384 a.u. | 0.370384 a.u. |
| $E_{tot}$ | 0.389867 a.u. | 0.380965 a.u. | 0.379439 a.u. |
| $H_{corr}$ | 0.390811 a.u. | 0.381640 a.u. | 0.380057 a.u. |
| $G_{corr}$ | 0.320714 a.u. | 0.339211 a.u. | 0.342727 a.u. |
| $S_{tot}$ | 147.533 calmol$^{-1}$K$^{-1}$ | 124.998 calmol$^{-1}$K$^{-1}$ | 120.127 calmol$^{-1}$K$^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.929859 a.u. | –866.929860 a.u. | –866.929860 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.910376 a.u. | –866.919279 a.u. | –866.920805 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.909432 a.u. | –866.918604 a.u. | –866.920187 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.979530 a.u. | –866.961033 a.u. | –866.957517 a.u. |

### Right Rotamer Axial:

| | Temperature | | |
|---|---|---|---|
| | 298 K | 223 K | 195 K |
| $\varepsilon_0$ | –867.300166083 a.u. | –867.300166083 a.u. | –867.300166083 a.u. |
| $\varepsilon_{ZPE}$ | 0.370126 a.u. | 0.370126 a.u. | 0.370126 a.u. |
| $E_{tot}$ | 0.389725 a.u. | 0.380814 a.u. | 0.379285 a.u. |
| $H_{corr}$ | 0.390669 a.u. | 0.381488 a.u. | 0.379903 a.u. |
| $G_{corr}$ | 0.317101 a.u. | 0.336588 a.u. | 0.340312 a.u. |
| $S_{tot}$ | 154.836 calmol$^{-1}$K$^{-1}$ | 132.279 calmol$^{-1}$K$^{-1}$ | 127.402 calmol$^{-1}$K$^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.930040 a.u. | –866.930040 a.u. | –866.930040 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.910441 a.u. | –866.919352 a.u. | –866.920881 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.909497 a.u. | –866.918678 a.u. | –866.920263 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.983065 a.u. | –866.963578 a.u. | –866.959854 a.u. |

### Left Rotamer Equatorial:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.295403418 a.u. | –867.295403418 a.u. |
| $\varepsilon_{ZPE}$ | 0.369956 a.u. | 0.369956 a.u. |
| $E_{tot}$ | 0.389434 a.u. | 0.378969 a.u. |
| $H_{corr}$ | 0.390379 a.u. | 0.379587 a.u. |
| $G_{corr}$ | 0.321920 a.u. | 0.343360 a.u. |
| $S_{tot}$ | 144.083 calmol$^{-1}$K$^{-1}$ | 116.578 calmol$^{-1}$K$^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.925448 a.u. | –866.925447 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.905969 a.u. | –866.916434 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.905025 a.u. | –866.915816 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.973483 a.u. | –866.952043 a.u. |

Right Rotamer Equatorial:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.292815979 a.u. | –867.292815979 a.u. |
| $\varepsilon_{ZPE}$ | 0.369571 a.u. | 0.369571 a.u. |
| $E_{tot}$ | 0.389259 a.u. | 0.378763 a.u. |
| $H_{corr}$ | 0.390203 a.u. | 0.379380 a.u. |
| $G_{corr}$ | 0.320236 a.u. | 0.342192 a.u. |
| $S_{tot}$ | 147.258 $calmol^{-1}K^{-1}$ | 119.671 $calmol^{-1}K^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.923245 a.u. | –866.923245 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.903557 a.u. | –866.914053 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.902613 a.u. | –866.913436 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.972580 a.u. | –866.950624 a.u. |

Left Rotamer Equatorial Re-Optimized:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.296096363 a.u. | –867.296096363 a.u. |
| $\varepsilon_{ZPE}$ | 0.370295 a.u. | 0.370295 a.u. |
| $E_{tot}$ | 0.389628 a.u. | 0.379210 a.u. |
| $H_{corr}$ | 0.390572 a.u. | 0.379828 a.u. |
| $G_{corr}$ | 0.322547 a.u. | 0.343845 a.u. |
| $S_{tot}$ | 143.171 $calmol^{-1}K^{-1}$ | 115.792 $calmol^{-1}K^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.925801 a.u. | –866.925801 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.906468 a.u. | –866.916886 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.905524 a.u. | –866.916268 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.973549 a.u. | –866.952251 a.u. |

Right Rotamer Equatorial Re-Optimized:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.293496677 a.u. | –867.293496677 a.u. |
| $\varepsilon_{ZPE}$ | 0.370033 a.u. | 0.370033 a.u. |
| $E_{tot}$ | 0.389484 a.u. | 0.379051 a.u. |
| $H_{corr}$ | 0.390428 a.u. | 0.379668 a.u. |
| $G_{corr}$ | 0.321322 a.u. | 0.342991 a.u. |
| $S_{tot}$ | 145.446 $calmol^{-1}K^{-1}$ | 118.028 $calmol^{-1}K^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.923464 a.u. | –866.923464 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.904013 a.u. | –866.914446 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.903069 a.u. | –866.913829 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.972175 a.u. | –866.950506 a.u. |

Axial Clockwise Transition State:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.274004513 a.u. | –867.274004513 a.u. |
| $\varepsilon_{ZPE}$ | 0.369562 a.u. | 0.369562 a.u. |
| $E_{tot}$ | 0.388146 a.u. | 0.378026 a.u. |
| $H_{corr}$ | 0.389090 a.u. | 0.378644 a.u. |
| $G_{corr}$ | 0.322532 a.u. | 0.343381 a.u. |
| $S_{tot}$ | 140.084 $calmol^{-1}K^{-1}$ | 113.477 $calmol^{-1}K^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.904443 a.u. | –866.904443 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.885859 a.u. | –866.895979 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.884914 a.u. | –866.895361 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.951473 a.u. | –866.930624 a.u. |

Axial Anticlockwise Transition State:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.273949768 a.u. | –867.273949768 a.u. |
| $\varepsilon_{ZPE}$ | 0.369571 a.u. | 0.369571 a.u. |
| $E_{tot}$ | 0.388153 a.u. | 0.378034 a.u. |
| $H_{corr}$ | 0.389097 a.u. | 0.378651 a.u. |
| $G_{corr}$ | 0.322809 a.u. | 0.343564 a.u. |
| $S_{tot}$ | 139.515 $calmol^{-1}K^{-1}$ | 112.910 $calmol^{-1}K^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.904379 a.u. | –866.904379 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.885797 a.u. | –866.895916 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.884853 a.u. | –866.895299 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.951141 a.u. | –866.930386 a.u. |

Equatorial Clockwise Transition State:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.282502567 a.u. | –867.282502567 a.u. |
| $\varepsilon_{ZPE}$ | 0.369283 a.u. | 0.369283 a.u. |
| $E_{tot}$ | 0.387984 a.u. | 0.377829 a.u. |
| $H_{corr}$ | 0.388928 a.u. | 0.378447 a.u. |
| $G_{corr}$ | 0.322839 a.u. | 0.343520 a.u. |
| $S_{tot}$ | 139.095 $calmol^{-1}K^{-1}$ | 112.393 $calmol^{-1}K^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.913219 a.u. | –866.913220 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.894519 a.u. | –866.904674 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.893575 a.u. | –866.904056 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.959664 a.u. | –866.938983 a.u. |

Equatorial Anticlockwise Transition State:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.280856122 a.u. | –867.280856122 a.u. |
| $\varepsilon_{ZPE}$ | 0.369200 a.u. | 0.369200 a.u. |
| $E_{tot}$ | 0.387933 a.u. | 0.377775 a.u. |
| $H_{corr}$ | 0.388877 a.u. | 0.378393 a.u. |
| $G_{corr}$ | 0.322381 a.u. | 0.343203 a.u. |
| $S_{tot}$ | 139.953 calmol$^{-1}$K$^{-1}$ | 113.243 calmol$^{-1}$K$^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.911656 a.u. | –866.911656 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.892923 a.u. | –866.903081 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.891979 a.u. | –866.902463 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.958475 a.u. | –866.937653 a.u. |

Equatorial Clockwise Transition State Re-Optimized:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.276495435 a.u. | –867.276495435 a.u. |
| $\varepsilon_{ZPE}$ | 0.369342 a.u. | 0.369342 a.u. |
| $E_{tot}$ | 0.387999 a.u. | 0.377845 a.u. |
| $H_{corr}$ | 0.388944 a.u. | 0.378462 a.u. |
| $G_{corr}$ | 0.322732 a.u. | 0.343454 a.u. |
| $S_{tot}$ | 139.354 calmol$^{-1}$K$^{-1}$ | 112.656 calmol$^{-1}$K$^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.907154 a.u. | –866.907153 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.888496 a.u. | –866.898650 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.887552 a.u. | –866.898033 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.953764 a.u. | –866.933041 a.u. |

Equatorial Anticlockwise Transition State Re-Optimized:

| | Temperature | |
|---|---|---|
| | 298 K | 195 K |
| $\varepsilon_0$ | –867.277898089 a.u. | –867.277898089 a.u. |
| $\varepsilon_{ZPE}$ | 0.369540 a.u. | 0.369540 a.u. |
| $E_{tot}$ | 0.388109 a.u. | 0.377970 a.u. |
| $H_{corr}$ | 0.389053 a.u. | 0.378588 a.u. |
| $G_{corr}$ | 0.323535 a.u. | 0.344021 a.u. |
| $S_{tot}$ | 137.895 calmol$^{-1}$K$^{-1}$ | 111.237 calmol$^{-1}$K$^{-1}$ |
| $\varepsilon_0 + \varepsilon_{ZPE}$ | –866.908358 a.u. | –866.908358 a.u. |
| $\varepsilon_0 + E_{tot}$ | –866.889789 a.u. | –866.899928 a.u. |
| $\varepsilon_0 + H_{corr}$ | –866.888845 a.u. | –866.899310 a.u. |
| $\varepsilon_0 + G_{corr}$ | –866.954363 a.u. | –866.933877 a.u. |