Electronic Supplementary Material (ESI) for ChemComm.

Supporting Information for

"A Hydrogen Borrowing Annulation Strategy for the Stereocontrolled Synthesis of Saturated Aza-Heterocycles"

Anna E. R. Chamberlain, Kieran J. Paterson, Roly J. Armstrong,

Heather C. Twin and Timothy J. Donohoe

Contents

1. General Information

All reactions were performed in flame-dried reaction vessels under an argon atmosphere, unless otherwise stated. Anhydrous solvents were obtained from MBRAUN SP-5 solvent purification system and were dried by passage through double filtration columns under nitrogen. Anhydrous benzylamine (≥99.5%, purified by redistillation) was purchased from Sigma Aldrich. All other reagents were acquired from Sigma Aldrich, Fluorochem, Acros Organics, Alfa Aesar or TCI and used without further purification. Brine refers to a saturated aqueous solution of NaCl.

Reactions were monitored by TLC using Merck Silicagel 60 F_{254} aluminium-backed silica plates (particle size 0.20 mm) and visualised by exposure to UV light (λ = 254 nm) and/or staining and heating with phosphomolybdic acid, vanillin or potassium permanganate as appropriate. Flash column chromatography was performed using Merck Geduran® Silicagel 60 (40–63 μm) according to the method of Still and co-workers.[1] The required solvent system is specified in parentheses and where mixtures of solvents are described, the ratios are given as volume:volume. *N*-Benzyl piperidine and pyrrolidine products were purified on pre-basified silica (as noted in **General Procedure A** and **B**) which was prepared as follows; silica (400 g), pentane (250 mL), Et_2O (250 mL) and triethylamine (5 mL) were combined in a 1 L beaker and stirred for 15 minutes. The solvent was allowed to evaporate overnight, and the resulting silica could be stored in a sealed bottle for a few weeks.

Nuclear magnetic resonance (NMR) spectra were recorded on 400 or 500 MHz spectrometers at ambient temperature, unless otherwise stated. ^{1}H and ^{13}C spectra were referenced to residual solvent peaks. Chemical shifts (δ) are recorded in parts per million (ppm) to the nearest 0.01 ppm for ^{1}H NMR or 0.1 ppm for ^{13}C and ^{19}F NMR, except where additional precision was required to distinguish two close peaks. Coupling constants (*J*) are measured in hertz (Hz) and quoted to the nearest 0.1 Hz. Peaks are assigned as singlet (s), doublet (d), triplet (t), quartet (q), pentet (p), heptet (hept), multiplet (m), broad (br.) or a combination such as doublet of doublets (dd), doublet of triplets (dt) etc. Multiplicities are based on appearance rather than interpretation. For cyclic compounds, the abbreviation 'ax' denotes the axial proton and 'eq' the equatorial proton. For diastereotopic CH_2 groups in acyclic molecules or in cases where it was not possible to definitively assign axial *vs* equatorial environments, the CH_2 protons are labelled 'a' and 'b'. ^{1}H NMR yields were calculated by integration with respect to an internal standard (1,1,2,2-tetracholoroethane) run with an extended relaxation delay of 25 seconds.

Chiral phase HPLC was performed on an Agilent 1260 Series HPLC unit equipped with UV-vis diode-array detector, fitted with the appropriate Daicel Chiralpak column (dimensions: 0.46 cm ø x 25 cm)

along with the corresponding guard column (0.4 cm ø x 1 cm). Wavelengths (λ) are reported in nm, retention times (t_R) are reported in minutes and solvent flow rates are reported in mL min^{-1}. The Cbz-protected saturated heterocycles are extremely non-polar and we observed significant variation in their retention times from day to day. It was therefore essential to run enantiopure samples back to back with the corresponding authentic racemic sample.

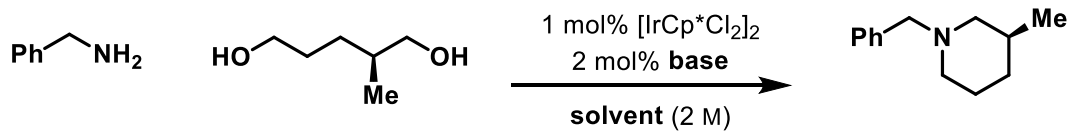
Fourier-transformed infrared (FT-IR) spectra were recorded as a thin film or solid on a Bruker Tensor 27 FT-IR spectrometer equipped with a Pike Miracle Attenuated Total Reflectance sampling accessory. Absorption maxima are quoted in wavenumbers (cm^{-1}). The abbreviation br. denotes a broad peak.

Electrospray ionisation (ESI) HRMS were recorded on a Thermo Exactive orbitrap spectrometer equipped with a Waters Equity LC system, with a flow rate of 0.2 mL/min using water:methanol:formic acid (10:89.9:0.1) as eluent. The system uses a heated electrospray ionisation (HESI-II) probe for ESI^+ and has a resolution of 50,000 FWHM under conditions for maximum sensitivity, with an accuracy of better than 5 ppm for 24 h following external calibration on the day of analysis. The mass reported is that containing the most abundant isotopes, with each value rounded to 4 decimal places and within 5 ppm of the calculated mass.

Melting point analysis was carried out using a Lecia VMTG heated-stage microscope equipped with a Testo 720 thermometer.

Optical rotations were recorded on a Schmidt Haensch Unipol L2000 polarimeter in a cell with a path length of 1 dm (using the sodium D line, 589 nm). Concentrations are reported in g/100 mL. Temperatures are reported in °C.

2. Extended Optimization Table for Enantiospecific Annulation[a]



1 *1.5 equiv.* | (–)-**2i** >99:1 er | (+)-**3i**

Entry	Base	Solvent	T / °C	Yield / %[b]	er[c]
1	-	Toluene	110	(54)	57:43
2	$NaHCO_3$	Toluene	110	92(80)	71:29
3	$KHCO_3$	Toluene	110	85	73:27
4	$CsHCO_3$	Toluene	110	98	74:26
5	NaOAc	Toluene	110	90(86)	62:38
6	KOAc	Toluene	110	95	62:38
7	Na_2CO_3	Toluene	110	94	67:33
8	K_2CO_3	Toluene	110	61	54:46
9	Cs_2CO_3	Toluene	110	21	78:22
10	NaOH	Toluene	110	94	76:24
11	KOH	Toluene	110	92	71:29
12	$CsOH.xH_2O$	Toluene	110	n.r.	-
13	^{t}BuOK	Toluene	110	88	69:31
14	^{t}BuOK (5 mol%)	Toluene	110	n.r.	-
15	^{t}BuOK (10 mol%)	Toluene	110	n.r.	-
16	$CsHCO_3$	Heptane	110	82	76:24
17	$CsHCO_3$	^{t}BuOH	110	84	76:24
18	$CsHCO_3$	TFE	110	69	56:44
19	$CsHCO_3$	1,4-dioxane	110	85	79:21
20	$CsHCO_3$	CPME	110	81	80:20
21	$CsHCO_3$	-	110	93	82:18
22	$CsHCO_3$	Water	110	79	84:16
23	-	Water	110	79	83:17
24	-	Brine	110	81	65:35
25	$CsHCO_3$	1:1 Water:CPME	110	95	81:19
26	-	Water	65	11	80:20
27	-	Water	70	41	85:15
28	-	Water	75	61	88:12
29	-	Water	80	69(72)	90:10
30	-	Water	90	78	86:14
31	-	Water	100	82	85:15

(a) Reaction conditions: diol (–)-**2i** (1 equiv), benzylamine (1.5 equiv), $[Cp^*IrCl_2]_2$ (1 mol%), base (2 mol%), solvent (2 M), 65-110 °C, 16 h. (b) Yields determined by ^{1}H NMR analysis with 1,1,2,2-tetrachloroethane as an internal standard. Yields in parentheses refer to isolated material after column chromatography. (c) Enantiomeric purity determined after conversion to the corresponding Cbz-protected amine by HPLC using a chiral stationary phase (see Experimental Procedures for details).

3. General Procedures

3.1 General procedure A: Hydrogen borrowing alkylation of amines with diols in toluene

To a 2-5 mL Biotage® microwave vial equipped with a stirrer bar was added the appropriate alcohol substrate (1.0 equiv.), $[IrCp^*Cl_2]_2$ (1.0 mol%) and $NaHCO_3$ (2.0 mol%). The vial was sealed with a microwave vial crimp cap (containing a Reseal® septum), evacuated under vacuum and refilled with argon three times. Anhydrous toluene (2 M) was added *via* syringe, followed by the appropriate amine (1.5 equiv.). The vial was sealed with Parafilm®, placed in a preheated oil bath and stirred at 110 °C for 16 hours. The reaction mixture was cooled to room temperature and concentrated under a flow of nitrogen. Purification by column chromatography (SiO_2 was basified with Et_3N prior to use, see General Information for details) afforded the piperidine product.

3.2 General procedure B: Hydrogen borrowing alkylation of amines with diols in water

To a 2-5 mL Biotage® microwave vial equipped with a stirrer bar was added the appropriate alcohol substrate (1.0 equiv.) and $[IrCp^*Cl_2]_2$ (1.0 mol%). The vial was sealed with a microwave vial crimp cap (containing a Reseal® septum), evacuated under vacuum and refilled with argon three times. Deionised water (2 M) was added *via* syringe, followed by the appropriate amine (1.5 equiv.). The vial was sealed with Parafilm®, placed in a preheated oil bath and stirred at the appropriate temperature for 16 hours. The reaction mixture was cooled to room temperature and extracted with CH_2Cl_2 (3 $\times$ 10 mL). The organic phase was dried over $MgSO_4$, filtered and concentrated *in vacuo*. Purification by column chromatography (SiO_2 was basified with Et_3N prior to use, see General Information for details) afforded the title compound.

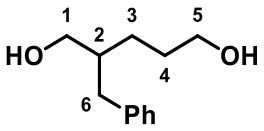
3.3 General procedure C: Carboxybenzyl (Cbz) protection for HPLC analysis

To a 2-5 mL Biotage® microwave vial equipped with a stirrer bar was added the appropriate *N*-benzyl substrate (1.0 equiv.). Benzyl chloroformate (3 M in toluene, 6.0 equiv.) was added slowly *via* syringe. The vial was sealed with a microwave vial crimp cap (containing a Reseal® septum) and equipped with a balloon (caution: gas evolution!). The reaction mixture was stirred at 80 °C for 2 hours. The reaction mixture was cooled to room temperature and transferred directly onto a silica column. Purification by column chromatography (SiO_2) afforded the title compound.

4. Experimental Procedures

4.1 Synthesis of Starting Materials

2-Benzylpentane-1,5-diol, *rac*-2k



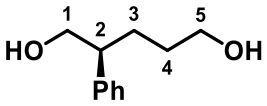
$LiAlH_4$ (1.20 g, 38.0 mmol) was suspended in anhydrous THF (150mL) at 0 °C and a solution of 3-benzyltetrahydro-2*H*-pyran-2-one[2] (2.00 g, 10.5 mmol) in anhydrous THF (25 mL) added dropwise. The reaction mixture was warmed to room temperature and stirred for 1 hour. The reaction was cooled to 0 °C, diluted with a further portion of THF (100 mL) and quenched with dropwise addition of water (1.2 mL) followed by 15% aq. NaOH (1.2 mL) and water (3.6 mL). The mixture was warmed to room temperature and stirred for 10 minutes after which $MgSO_4$ was added, and the mixture was stirred for a further 30 minutes at room temperature. The mixture was filtered through Celite® eluting with Et_2O and concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2:MeOH 95:5) afforded diol *rac*-**2k** as a viscous, colourless oil (1.74 g, 85%).

^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.30-7.26 (2H, m, ArH), 7.21-7.17 (3H, m, ArH), 3.66-3.55 (3H, m, CH_2-1_a and CH_2-5), 3.50 (1H, dt, *J* = 10.7, 5.3 Hz, CH_2-1_b), 2.67-2.59 (2H, m, CH_2-6), 2.03-2.01 (1H, m, OH), 2.00-1.98 (1H, m, OH), 1.86-1.79 (1H, m, CH-2), 1.67-1.54 (2H, m, CH_2-4), 1.52-1.45 (1H, m, CH_2-3_a), 1.41-1.34 (1H, m, CH_2-3_b).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 140.8, 129.2, 128.4, 126.0, 64.5, 63.0, 42.3, 37.9, 29.8, 26.9.

The data are consistent with the literature.[3]

(*S*)-2-Phenylpentane-1,5-diol, (+)-2j



Racemic: $LiAlH_4$ (1.45 g, 38.3 mmol) was suspended in anhydrous THF (50 mL) at 0 °C and 2-phenylglutaric anhydride (2.43 g, 12.8 mmol) was added portionwise. The reaction mixture was warmed to room temperature and then heated at reflux, with stirring, for 4 hours. The reaction was cooled to 0 °C, diluted with a further portion of THF (50 mL) and quenched with dropwise addition of water (1.5 mL) followed by 15% aq. NaOH (1.5 mL), and water (4.5 mL). The mixture was warmed to room temperature and stirred for 10 minutes after which $MgSO_4$ was added and the mixture stirred for a further 30 minutes. The mixture was filtered through Celite® (eluting with Et_2O) and

concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2:MeOH 95:5) afforded the title compound *rac*-**2j** (1.70 g, 74%) as a viscous, colourless oil.

Enantioenriched: (+)-**2j** (>99:1 e.r.) was prepared by preparative SFC separation of racemic diol *rac*-**2j** using a Chiralpak® ID column, 80:20 CO_2:MeOH, 10 mL min^{-1}, 260 nm, 35°C, 20 µL injections of 100 mg/mL diol *rac*-**2j** in MeOH; t_r (*S*) = 4.3 min, t_r (*R*) = 5.0 min. Absolute configuration was determined to be (*S*) by comparison of the optical rotation value with literature data.[4]

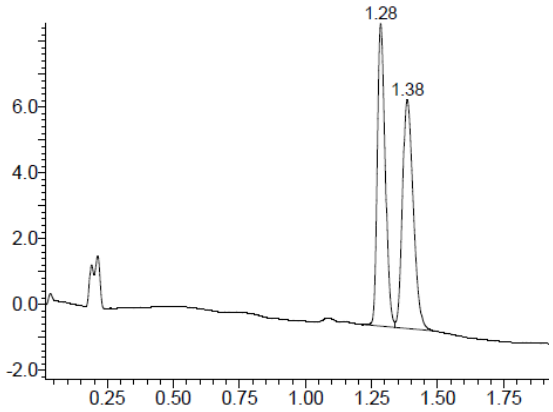
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.19 (5H, m, ArH), 3.80-3.71 (2H, m, CH_2-1), 3.63-3.56 (2H, m, CH_2-5), 2.84-2.76 (1H, m, CH-2), 1.87-1.79 (1H, m, CH_2-3$_a$), 1.70-1.19 (5H, m, CH_2-3$_b$, CH_2-4, 2 × OH).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 142.3, 128.8, 128.2, 126.9, 67.6, 62.8, 48.5, 30.5, 28.3.

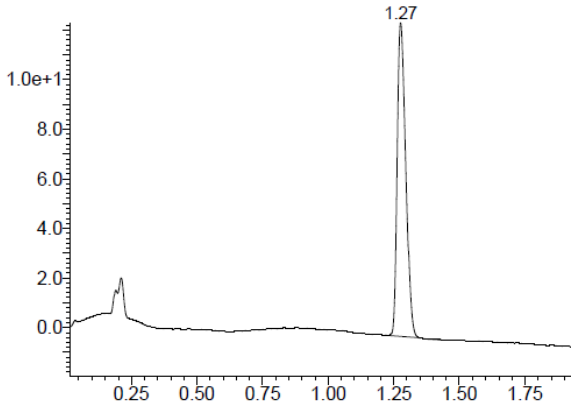
These spectral data are consistent with the literature.[5]

$[\alpha]_D^{25}$ = +22.5 (*c* = 1.0, EtOH). Literature value $[\alpha]_D^{25}$ = +18.3 (*c* = 1.0, EtOH, 80% ee);[4]

Enantiomeric excess was determined by SFC; Chiralpak® ID column (5-50% MeOH:CO_2 gradient over 3.5 min, 2 mL min^{-1}, DAD 210-400 nm, 40 °C):

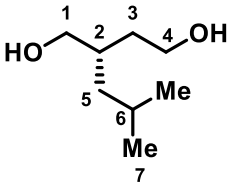


Time	Height	Area	Area%
1.2833	9194984	321196.88	49.32
1.3833	6952907	330014.28	50.68



Time	Height	Area	Area%
1.2750	12656653	483572.59	99.86
1.3833	11786	660.40	0.14

(*S*)-2-Isobutylbutane-1,4-diol, (–)-2al



Racemic: $LiAlH_4$ (661 mg, 17.4 mmol) was suspended in anhydrous THF (40 mL) at 0 °C and a solution of isobutylsuccinic acid (1.01 g, 5.80 mmol) in anhydrous THF (15 mL) was added dropwise. The reaction mixture was warmed to room temperature and then heated to 70 °C for 16 hours. The reaction was then cooled to 0 °C, diluted with Et_2O (50 mL) and quenched by dropwise addition of water (0.66 mL) followed by 15% aq. NaOH (0.66 mL) and water (2.0 mL). The mixture was warmed

to room temperature and stirred for 10 minutes after which $MgSO_4$ was added, and the mixture was stirred for a further 30 minutes at room temperature. The mixture was filtered through Celite® eluting with Et_2O and concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2:MeOH 95:5) afforded diol *rac*-**2al** as a viscous, colourless oil (671 mg, 79%).

Enantioenriched: $LiAlH_4$ (678 mg, 17.9 mmol) was suspended in anhydrous THF (40 mL) at 0 °C and a solution of (*S*)-(–)-2-isobutylsuccinic acid 1-methyl ester (1.12 g, 5.95 mmol) in anhydrous THF (15 mL) was added dropwise. The reaction mixture was warmed to room temperature and then heated to 70 °C for 16 hours. The reaction was then cooled to 0 °C, diluted with Et_2O (50 mL) and quenched by dropwise addition of water (0.68 mL) followed by 15% aq. NaOH (0.68 mL) and water (2.1 mL). The mixture was warmed to room temperature and stirred for 10 minutes after which $MgSO_4$ was added, and the mixture was stirred for a further 30 minutes at room temperature. The mixture was filtered through Celite® eluting with Et_2O and concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2:MeOH 95:5) afforded diol (–)-**2al** as a viscous, colourless oil (691 mg, 79%).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 3.75 (1H, ddd, *J* = 10.7, 6.4, 4.4 Hz, CH_2-4$_a$), 3.66 – 3.58 (4H, m, CH_2-4$_b$, CH_2-1$_a$ and 2 x OH), 3.41 (1H, dd, *J* = 10.5, 7.3 Hz, CH_2-1$_b$), 1.76 – 1.47 (4H, m, CH-2, CH-6, CH_2-3), 1.15 (1H, dt, *J* = 13.9, 7.0 Hz, CH_2-5$_a$), 1.06 (1H, dt, *J* = 13.9, 7.1 Hz, CH_2-5$_b$), 0.88 (3H, d, *J* = 6.4 Hz, CH_3-7a), 0.86 (3H, d, *J* = 6.4 Hz, CH_3-7b).

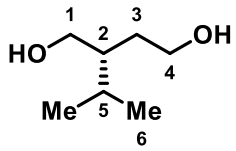
^{13}C NMR (101 MHz, $CDCl_3$) δ = 66.6, 61.2, 41.3, 37.2, 36.2, 25.4, 23.0, 22.8.

HRMS: ESI+ found $[M+H]^+$ = 147.1380, $C_8H_{19}O_2$ requires 147.1380, Δ = 0.20 ppm.

FTIR (film): ν_{max} = 3286 (br), 2954, 1466, 1367, 1036 cm^{-1}.

$[\alpha]_D^{25}$ = –12.6 (*c* = 1.0, $CHCl_3$).

(*R*)-2-Isopropylbutane-1,4-diol, (–)-2am



$LiAlH_4$ (1.64 g, 43.1 mmol) was suspended in anhydrous THF (100 mL) at 0 °C and a solution of (*R*)-2-isopropylsuccinic acid-1-methyl ester (2.50 g, 14.4 mmol) in anhydrous THF (30 mL) was added dropwise. The reaction mixture was warmed to room temperature and then heated to 70 °C for 16 hours. The reaction was then cooled to 0 °C, diluted with Et_2O (100 mL) and quenched by dropwise addition of water (1.6 mL) followed by 15% aq. NaOH (1.6 mL) and water (4.9 mL). The mixture was warmed to room temperature and stirred for 10 minutes after which $MgSO_4$ was added, and the mixture was stirred for a further 30 minutes at room temperature. The mixture was filtered

through Celite® eluting with Et_2O and concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2:MeOH 95:5) afforded diol (–)-**2am** as a viscous, colourless oil (1.53 g, 81%). The corresponding racemic diol *rac*-**2am** was prepared by an identical procedure starting from racemic 2-isobutylsuccinic acid 1-methyl ester.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 3.77 (1H, ddd, *J* = 10.7, 6.3, 4.3 Hz, CH_2-4$_a$), 3.71 – 3.63 (3H, m, CH_2-1$_a$ and 2 x OH), 3.60 (1H, ddd, *J* = 10.4, 8.1, 4.1 Hz, CH_2-4$_b$), 3.51 (1H, dd, *J* = 10.2, 7.8 Hz, CH_2-1$_b$), 1.79 – 1.65 (2H, m, CH_2-3$_a$ and CH-5), 1.55 (1H, dtd, *J* = 14.3, 8.3, 4.1 Hz, CH_2-3$_b$), 1.45 (1H, dddd, *J* = 11.7, 8.3, 4.8, 3.2 Hz, CH-2), 0.89 (3H, d, *J* = 7.0 Hz, CH_3-6a), 0.87 (3H, d, *J* = 7.4 Hz, CH_3-6b).

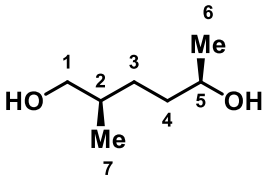
^{13}C NMR (101 MHz, $CDCl_3$) δ = 65.1, 62.0, 45.7, 33.1, 29.8, 20.0, 19.5.

HRMS: ESI+ found $[M+H]^+$ = 133.1223, $C_7H_{17}O_2$ requires 133.1223, Δ = –0.17 ppm.

FTIR (film): ν_{max} = 3296 (br), 2957, 1465, 1387, 1369, 1023 cm^{-1}.

$[\alpha]_D^{25}$ = –20.1 (*c* = 1.0, $CHCl_3$).

(2*R*,5*R*)-2-methylhexane-1,5-diol, (+)-2o



Racemic: We have previously reported the synthesis of diol *rac*-**2o** (12:88 d.r.).[6]

Enantioenriched: According to a modified literature procedure,[7] to a pre-cooled vial at 0 °C was added (*S*)-(–)-α,α-diphenyl-2-pyrrolidinemethanol trimethylsilyl ether (1.00 g, 3.10 mmol), methyl-3,4-dihydroxybenzoate (1.90 g, 12.3 mmol), propanal (4.43 mL, 61.4 mmol) and methyl vinyl ketone (7.48 mL, 92.2 mmol). The vial was sealed and stirred at 0 °C for 24 hours. The reaction solution was transferred into pre-cooled ethanol (500 mL) at 0 °C *via* syringe and sodium borohydride (11.6 g, 0.31 mol) was added portionwise. The reaction mixture was allowed to warm to room temperature and stirred for a further 16 hours. The mixture was poured onto ice and allowed to warm to room temperature. The solution was concentrated *in vacuo* to remove the majority of the EtOH and then extracted with Et_2O (3 × 400 mL). The combined organic phases were dried over $MgSO_4$, filtered and concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2:MeOH 95:5) afforded diol (+)-**2o** (1.23 g, 15%, ~53:47 dr,* 94:6 er) as a colourless oil and an inseparable mixture of diastereomers. The enantiomeric purity of (+)-**2o** was determined by chiral HPLC analysis after conversion to the corresponding dibenzoyl ester (see below).

* It was not possible to calculate dr of the crude reaction mixture or purified compound due to overlapping peaks in the ^{1}H NMR spectrum, but a dr of ~53:47 was estimated by HPLC for the benzoyl ester derivative **S1.** N.B. the major diastereoisomer of racemic and enantioenriched diols were opposite.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 3.81-3.77 (1H, m, C<u>H-5</u>), 3.49-3.43 (2H, m, C<u>H$_2$-1</u>), 2.29-1.39 (6H, m, 2 × O<u>H</u>, C<u>H-2</u>, C<u>H$_2$-3</u>, and C<u>H$_2$-4$_a$</u>), 1.29-1.11 (1H, m, C<u>H$_2$-4$_b$</u>), 1.19 (3H, d, *J* = 6.2 Hz, C<u>H$_3$-6</u>), 0.94-0.90 (3H, m, C<u>H$_3$-7</u>). N.B. no separate signals were observed for the minor diastereoisomer.

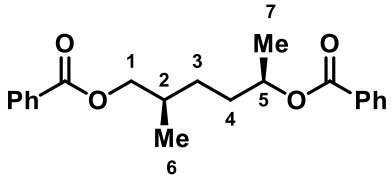
^{13}C NMR (101 MHz, $CDCl_3$) δ = 68.6, 68.1, 36.6, 35.9, 29.2, 23.7, 16.8. N.B. the minor diastereoisomer displays signals at δ = 68.3, 68.2, 36.3, 35.6, 29.0, 23.8, 16.7.

HRMS: ESI+ found $[M+Na]^+$ = 155.1040, $C_7H_{16}O_2{}^{23}Na$ requires 155.1043, Δ = –1.69 ppm.

FTIR (film): ν_{max} = 3318, 2927, 2872, 1459, 1374, 1112, 1021, 984, 943 cm^{-1}.

$[\alpha]_D^{25}$ = +11.0 (*c* = 1.0, $CHCl_3$).

(2*R*,5*R*)-2-Methylhexane-1,5-diyl dibenzoate, S1



To a solution of (2*R*)-2-Methylhexane-1,5-diol (+)-**2o** (26 mg, 0.20 mmol, ~53:47 d.r.) in anhydrous CH_2Cl_2 (5 mL) was added pyridine (0.05 mL, 0.60 mmol) and benzoyl chloride (0.06 mL, 0.50 mmol). The resulting solution was stirred at room temperature for 2 hours before addition of saturated aqueous NH_4Cl solution (10 mL). The mixture was extracted with CH_2Cl_2 (3 × 10 mL) and the combined organic phases dried over $MgSO_4$, filtered and concentrated *in vacuo*. Purification by column chromatography (CH_2Cl_2) afforded diester **S1** (9.5 mg, 14%, ~53:47 dr,* 94:6 er) as a colourless oil and an inseparable mixture of diastereomers. The corresponding racemic diester *rac*-**S1** (~13:87 d.r.) was prepared by an identical procedure starting from *rac*-**2o**.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.04-8.00 (4H, m, Ar<u>H</u>), 7.57-7.52 (2H, m, Ar<u>H</u>), 7.43-7.38 (4H, m, Ar<u>H</u>), 5.22-5.13 (1H, m, C<u>H-5</u>), 4.22-4.13 (2H, m, C<u>H$_2$-1</u>), 2.03-1.94 (1H, m, C<u>H-2</u>), 1.90-1.56 (3H, m, C<u>H$_2$-3</u> and C<u>H$_2$-4$_a$</u>), 1.45-1.28 (1H, m, C<u>H$_2$-4$_b$</u>), 1.36 (3H, d, *J* = 6.3 Hz, C<u>H$_3$-7</u>), 1.05 (3H, d, *J* = 6.8 Hz, C<u>H$_3$-6</u>). N.B. no separate signals were observed for the minor diastereoisomer.

^{13}C NMR (101 MHz, $CDCl_3$) δ = 166.7, 166.3, 133.0, 132.9, 130.9, 130.5, 129.6 (two overlapping signals), 128.5, 128.4, 71.5, 69.5, 33.6, 33.8, 29.4, 20.3, 17.2. N.B. the minor diastereoisomer displays signals at δ = 166.7, 166.3, 133.0, 132.9, 130.9, 130.5, 129.6 (two overlapping signals), 128.5, 128.4, 71.7, 69.6, 33.4, 33.7, 29.2, 20.3, 17.0.

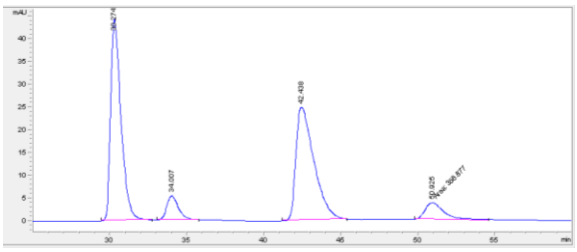
HRMS: ESI+ found $[M+H]^+$ = 341.1749, $C_{21}H_{25}O_4$ requires 341.1747, Δ = 0.47.

FTIR (film): ν_{max} = 1714, 1451, 1314, 1272, 1109, 1070, 1026, 710 cm^{-1}.

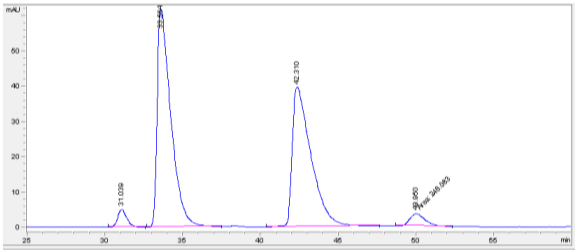
$[\alpha]_D^{25}$ = +1.6 (*c* = 0.79, $CHCl_3$).

* It was not possible to calculate dr of the crude reaction mixture or purified compound due to overlapping peaks in the ^{1}H NMR spectrum, but a dr of ~53:47 was estimated by HPLC.

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IA column (99.7:0.3 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature), ~53:47 dr; major diastereomer t_r (major) = 33.6 min, t_r (minor) = 50.0 min, 94:6 er; minor diastereomer t_r (minor) = 31.0 min, t_r (major) = 42.3 min; 94:6 er. [N.B. racemate with ~13:87 d.r.].



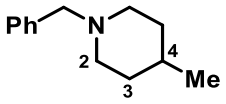
#	Time	Type	Area	Height	Width	Area%	Symmetry
1	30.274	BB	2066.9	44.3	0.7003	43.804	0.521
2	34.007	BB	273.9	5.3	0.731	5.806	0.712
3	42.438	BB	2020.9	24.9	1.1189	42.827	0.427
4	50.925	MM	356.9	3.8	1.5701	7.563	0.51



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	31.039	BB	207	5	0.6157	2.747	0.738
2	33.564	BB	3761.4	61.5	0.8959	49.913	0.357
3	42.31	BB	3321.3	39.4	1.1645	44.074	0.337
4	49.95	MM	246.1	3.5	1.1826	3.266	0.672

4.2 Hydrogen Borrowing Annulation

_N_-Benzyl-4-methylpiperidine, 3a



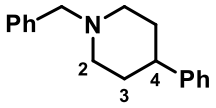
Commercially available 4-methylpentane-1,5-diol **2a** (118 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 50:50) afforded piperidine **3a** (182 mg, 96%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.32-7.21 (5H, m, Ar<u>H</u>), 3.48 (2H, s, NC<u>H_2</u>Ph), 2.87-2.82 (2H, m, 2 × C<u>H_2-2$_{eq}$</u>), 1.93 (2H, td, *J* = 11.5, 2.4 Hz, 2 × C<u>H_2-2$_{ax}$</u>), 1.62-1.56 (2H, m, 2 × C<u>H_2-3$_a$</u>), 1.41-1.30 (1H, m, C<u>H-4</u>), 1.29-1.19 (2H, m, 2 × C<u>H_2-3$_b$</u>), 0.91 (3H, d, *J* = 6.2 Hz, C<u>H_3</u>).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 138.9, 129.4, 128.2, 127.0, 63.7, 54.1, 34.5, 30.9, 22.1.

The data are consistent with the literature.[8]

_N_-Benzyl-4-phenylpiperidine, 3b



3-Phenylpentane-1,5-diol[6] **2b** (180 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 60:40) afforded piperidine **3b** (208 mg, 83%) as a yellow oil.

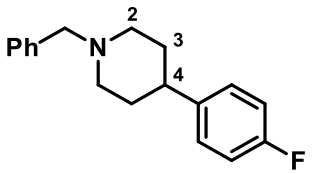
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.18-7.39 (10H, m, Ar<u>H</u>), 3.58 (2H, s, NC<u>H_2</u>Ph), 3.06-3.01 (2H, m, 2 × C<u>H_2-2$_a$</u>), 2.58-2.46 (1H, m, C<u>H-4</u>), 2.16-2.08 (2H, m, 2 × C<u>H_2-2$_b$</u>), 1.86-1.80 (4H, m, 2 × C<u>H_2-3</u>).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 146.7, 138.7, 129.4, 128.5, 128.3, 127.1, 127.0, 126.2, 63.7, 54.4, 42.9, 33.7.

HRMS: ESI+ found $[M+H]^+$ = 252.1742, $C_{18}H_{22}N$ requires 252.1747, Δ = –2.09 ppm.

FTIR (film): ν_{max} = 3027, 2934, 2798, 2750, 1493, 1452, 1366, 991, 735, 696 cm^{-1}.

***N*-Benzyl-4-(4-fluorophenyl)piperidine, 3c**



3-(4-Fluorophenyl)-pentane-1,5-diol[6] **2c** (198 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 60:40) afforded piperidine **3c** (215 mg, 80%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.37-7.31 (4H, m, ArH), 7.29-7.24 (1H, m, ArH), 7.21-7.15 (2H, m, ArH), 7.01-6.94 (2H, m, ArH), 3.55 (2H, s, NCH_2Ph), 3.05-2.98 (2H, m, 2 x CH_2-2_{eq}), 2.48 (1H, tt, *J* = 10.3, 5.2 Hz, CH-4_{ax}), 2.08 (2H, td, *J* = 11.2, 3.7 Hz, 2 x CH_2-2_{ax}), 1.83-1.75 (4H, m, 2 x CH_2-3).

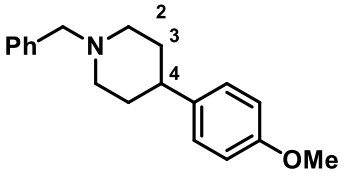
^{13}C NMR (101 MHz, $CDCl_3$) δ = 161.3 (d, *J* = 243.3 Hz), 142.2 (d, *J* = 3.1 Hz), 138.4, 129.3, 128.2, 128.2, 127.0, 115.1 (d, *J* = 20.9 Hz), 63.5, 54.2, 42.0, 33.7.

^{19}F NMR (376 MHz, $CDCl_3$) δ = –117.5.

HRMS: ESI+ found $[M+H]^+$ = 270.1651, $C_{18}H_{21}FN$ requires 270.1653, Δ –0.46 ppm.

FTIR (film): ν_{max} = 2935, 2800, 1604, 1509, 1453, 1366, 1342, 1223, 1159, 1031, 992, 832, 795, 773, 737, 698, 613 cm^{-1}.

***N*-Benzyl-4-(4-methoxyphenyl)piperidine, 3d**



3-(4-Methoxyphenyl)-pentane-1,5-diol[6] **2d** (198 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 50:50) afforded piperidine **3d** (258 mg, 92%) as a colourless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.80-7.31 (4H, m, ArH), 7.29-7.24 (1H, m, ArH), 7.18-7.14 (2H, m, ArH), 6.87-6.83 (2H, m, ArH), 3.79 (3H, s, OCH_3), 3.56 (2H, s, NCH_2Ph), 3.04-2.98 (2H, m, 2 x CH_2-2_{eq}), 2.46 (1H, tt, *J* = 11.0, 5.5 Hz, CH-4_{ax}), 2.08 (2H, td, *J* = 10.9, 3.8 Hz, 2 x CH_2-2_{ax}), 1.83 – 1.70 (4H, m, 2 x CH_2-3).

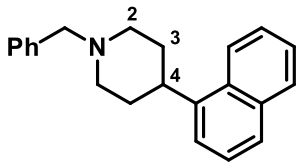
^{13}C NMR (101 MHz, $CDCl_3$) δ = 157.9, 138.8, 138.5, 129.3, 128.2, 127.7, 127.0, 113.8, 63.6, 55.3, 54.4, 41.8, 33.8.

HRMS: ESI+ found $[M+H]^+$ = 282.1851, $C_{19}H_{24}NO$ requires 282.1852, Δ −0.54 ppm.

FTIR (film): ν_{max} = 2941, 2795, 2752, 1608, 1512, 1467, 1365, 1327, 1244, 1176, 1146, 1115, 1033, 989, 833, 808, 766, 739, 696, 613 cm^{-1}.

Melting point = 68–71 °C.

***N*-Benzyl-4-(naphthalen-2-yl)piperidine, 3e**



3-(Naphthalene-1-yl)-pentane-1,5-diol[6] **2e** (230 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 60:40) afforded piperidine **3e** (261 mg, 87%) as a colourless solid.

^1H NMR (400 MHz, $CDCl_3$) δ = 8.11 (1H, d, *J* = 8.4 Hz, ArH), 7.87 (1H, dd, *J* = 7.6, 2.0 Hz, ArH), 7.72 (1H, dd, *J* = 6.8, 2.6 Hz, ArH), 7.55-7.33 (8H, m, ArH), 7.31-7.27 (1H, m, ArH), 3.63 (2H, s, NCH_2Ph), 3.34 (1H, tt, *J* = 10.7, 5.2 Hz, $CH\text{-}4_{ax}$), 3.15-3.07 (2H, m, 2 x $CH_2\text{-}2_{eq}$), 2.27 (2H, td, *J* = 11.1, 4.2 Hz, 2 x $CH_2\text{-}2_{ax}$), 2.03-1.92 (4H, m, 2 x $CH_2\text{-}3$).

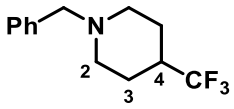
^{13}C NMR (101 MHz, $CDCl_3$) δ = 142.2, 138.5, 133.9, 131.4, 129.3, 129.0, 128.2, 127.0, 126.5, 125.7, 125.7, 125.3, 123.0, 122.5, 63.6, 54.6, 37.6, 33.2.

HRMS: ESI+ found $[M+H]^+$ = 302.1902, $C_{22}H_{24}N$ requires 302.1903, Δ −0.44 ppm.

FTIR (film): ν_{max} = 3048, 2936, 2799, 1597, 1494, 1453, 1396, 1366, 1343, 1144, 988, 778, 737, 699 cm^{-1}.

Melting point = 76–78 °C.

***N*-Benzyl-4-(trifluoromethyl)piperidine, 3f**



4-(Trifluoromethyl)-pentane-1,5-diol[9] **2f** (172 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3f** (192 mg, 79%) as a pale yellow oil.

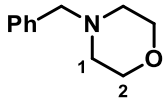
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.36-7.24 (5H, m, Ar<u>H</u>), 3.51 (2H, s, NC<u>H_2</u>Ph), 2.97 (2H, m, 2 × C<u>H_2-2$_{eq}$</u>), 2.05-1.91 (3H, m, C<u>H-4</u> and 2 × C<u>H_2-2$_{ax}$</u>), 1.85-1.78 (2H, m, 2 × C<u>H_2-3$_{eq}$</u>), 1.64 (2H, qd, *J* = 12.7, 3.9 Hz, 2 × C<u>H_2-3$_{ax}$</u>).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 138.3, 129.2, 128.4, 127.7 (q, *J* = 278.4 Hz), 127.2, 63.2, 52.5, 40.5 (q, *J* = 27.1 Hz), 24.8.

^{19}F NMR (376 MHz, $CDCl_3$) δ = -73.7

The data are consistent with the literature.[10]

_N_-Benzylmorpholine, 3g



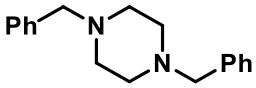
Commercially available diethylene glycol **2g** (106 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 110 °C. Purification by column chromatography (pentane:Et_2O 80:20) afforded piperazine **3g** as a colourless oil (74 mg, 35%) as an inseparable mixture with dibenzylamine (14 mol%, *the spectral data for dibenzylamine are consistent with the literature*[12]).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.36-7.24 (5H, m, Ar<u>H</u>), 3.72-3.70 (4H, m, 2 × C<u>H_2-2</u>), 3.50 (2H, s, NC<u>H_2</u>Ph), 2.46-2.43 (4H, m, 2 × C<u>H_2-1</u>).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 137.9, 129.3, 128.4, 127.3, 67.2, 63.6, 53.8.

The data are consistent with the literature.[11]

***N, N'*-Dibenzylpiperazine, 3h**



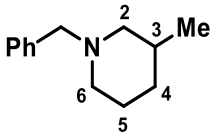
Commercially available *N*-benzyldiethanolamine **2h** (195 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 110 °C. Purification by column chromatography (pentane:Et_2O 80:20) afforded piperazine **3h** (48 mg, 16%) as a pale yellow solid as an inseparable mixture with dibenzylamine (15 mol%, *the spectral data for dibenzylamine are consistent with the literature* [12]).

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.22 (10<u>H</u>, m, ArH), 3.51 (4H, s, 2 × NC<u>H_2</u>Ph), 2.48 (8H, br. s, 4 × C<u>H_2-2</u>).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 138.3, 129.4, 128.3, 127.1, 63.2, 53.2.

The data are consistent with the literature.[13]

1-Benzyl-3-methylpiperidine, 3i



2-Methylhexane-1,5-diol[6] *rac*-**2i** (118 mg, 1.0 mmol, >99:1 er), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3i** (122 mg, 64%) as a colourless oil.

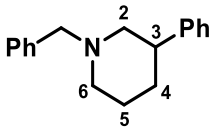
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.33-7.22 (5H, m, ArH), 3.48 (2H, s, NCH_2Ph), 2.79 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.85 (1H, td, *J* = 11.1, 3.7 Hz, CH_2-6_{ax}), 1.72-1.51 (5H, m, CH_2-2_b, CH-3, CH_2-4_a and CH_2-5), 0.90-0.86 (1H, m, CH_2-4_b), 0.83 (3H, d, *J* = 6.4 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 138.8, 129.3, 128.2, 126.9, 63.8, 62.1, 54.1, 33.2, 31.3, 25.7, 19.9.

HRMS: ESI+ found $[M+H]^+$ = 190.1590, $C_{13}H_{20}N$ requires 190.1590, Δ = –0.04 ppm.

FTIR (film): ν_{max} = 2927, 2794, 2756, 1454, 1346, 1120, 1073, 1028, 976, 737, 698 cm^{-1}.

***N*-Benzyl-3-phenylpiperidine, 3j**



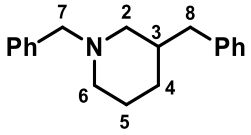
2-Phenylpentane-1,5-diol[6] *rac*-**2j** (180 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3j** (162 mg, 64%) as a colourless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.39-7.22 (10H, m, ArH), 3.55 (2H, s, NCH_2Ph), 3.01 (1H, ddt, *J* = 11.0, 3.6, 1.7 Hz, CH_2-2_{eq}), 2.96-2.91 (1H, m, CH_2-6_a), 2.85 (1H, tt, *J* = 11.6, 3.7 Hz, CH-3_{ax}), 2.05 (1H, t, *J* = 11.1 Hz, CH_2-2_{ax}), 2.03-1.90 (2H, m, CH_2-6_b and CH_2-4_a), 1.81-1.67 (2H, m, CH_2-5), 1.51-1.41 (1H, m, CH_2-4_b).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 145.0, 138.5, 129.3, 128.4, 128.3, 127.4, 127.0, 126.4, 63.7, 61.2, 53.9, 43.1, 31.8, 25.9.

Melting point = 45–47 °C.

1,3-Dibenzylpiperidine, 3k



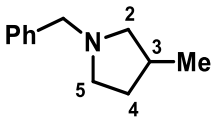
2-Benzylpentane-1,5-diol *rac*-**2k** (194 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3k** (208 mg, 78%) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.34-7.13 (10H, m, ArH), 3.57-3.40 (2H, m, CH_2-7), 2.81 (1H, dd, *J* = 10.9, 3.0 Hz, CH_2-2_{eq}), 2.76 (1H, d, *J* = 11.0 Hz, CH_2-6_a), 2.61-2.43 (2H, m, CH_2-8), 1.96-1.86 (2H, m, CH-3 and CH_2-6_b), 1.79 (1H, t, *J* = 10.4 Hz, CH_2-2_{ax}), 1.71-1.61 (2H, m, CH_2-4_a and CH_2-5_a), 1.56-1.45 (1H, m, CH_2-4_b), 1.00-0.92 (1H, m, CH_2-5_b).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 140.8, 138.8, 129.3, 129.2, 128.3, 128.2, 127.0, 125.9, 63.7, 60.4, 54.1, 41.1, 38.2, 30.7, 25.3.

The data are consistent with the literature.[14]

***N*-Benzyl-3-methylpyrrolidine, 3l**



2-Methylpentane-1,4-diol[15] *rac*-**2l** (104 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $NaHCO_3$ (1.7 mg, 2.0 mol%), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded pyrrolidine **3l** (74 mg, 42%) as a colourless oil.

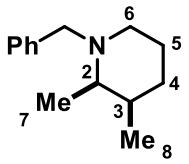
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.21 (5H, m, ArH), 3.63-3.56 (2H, m, NCH_2Ph), 2.82 (1H, dd, *J* = 9.0, 7.4 Hz, CH_2-2_a), 2.70 (1H, ddd, *J* = 9.2, 8.0, 5.4 Hz, CH_2-5_a), 2.45 (1H, td, *J* = 8.8, 6.4 Hz, CH_2-5_b), 2.32-2.19 (1H, m, CH-3), 2.07-1.96 (2H, m, CH_2-2_b and CH_2-4_a), 1.34 (1H, dddd, *J* = 12.6, 8.5, 6.3, 5.4 Hz, CH_2-4_b), 1.01 (3H, d, *J* = 6.8 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.6, 129.0, 128.3, 126.9, 62.4, 61.0, 54.3, 32.8, 32.0, 20.6.

HRMS: ESI+ found $[M+H]^+$ = 176.1434, $C_{12}H_{18}N$ requires 176.1434, Δ = – 0.03 ppm.

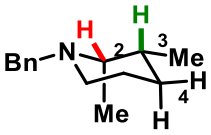
FTIR (film): ν_{max} = 2955, 2783, 1453, 1375, 1155, 1136, 1124, 1029, 907, 739, 698 cm^{-1}.

***rac*-(2*R*,3*R*)-1-Benzyl-2,3-dimethylpiperidine, 3m**



4-methylhexane-1,5-diol[6] *rac*-**2m** (132 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. NMR analysis of the crude reaction mixture indicated the presence of two diastereomers in 89:11 dr. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3m$_{maj}$** (132 mg, 65%, >95:5 d.r.) as a colourless oil and piperidine **3m$_{min}$** (20 mg, 10%, >95:5 d.r.) as a colourless oil. The relative stereochemistry was determined by *J*-coupling constant analysis.

Data for the major diastereoisomer:



H-2, qd, *J* = 6.7, 4.0 Hz
H-3, dqt, *J* = 10.9, 7.0, 4.0 Hz

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.37-7.20 (5H, m, ArH), 3.66-3.50 (2H, m, NCH_2Ph), 2.77 (1H, qd, *J* = 6.7, 4.0 Hz, CH-2), 2.45 (1H, ddd, *J* = 11.7, 9.9, 3.9 Hz, CH_2-6_{ax}), 2.32 (1H, dt, *J* = 11.7, 4.1 Hz, CH_2-6_{eq}), 1.89 (1H, dqt, *J* = 10.9, 7.0, 4.0 Hz, CH-3), 1.61-1.40 (3H, m, CH_2-4 and CH_2-5_{eq}), 1.32-1.21 (1H, m, CH_2-5_{ax}), 0.90 (3H, d, *J* = 6.7 Hz, CH_3-7), 0.86 (3H, d, *J* = 7.0 Hz, CH_3-8).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 140.5, 128.7, 128.2, 126.7, 59.3, 57.8, 46.8, 35.1, 28.1, 25.2, 18.1, 6.7.

HRMS: ESI+ found $[M+H]^+$ = 204.1747, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.26 ppm.

FTIR (film): ν_{max} = 2926, 2793, 1494, 1452, 1373, 1142, 1122, 1090, 1027, 955, 731, 697 cm^{-1}.

Data for the minor diastereoisomer:

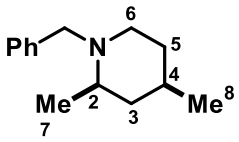
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.34-7.21 (5H, m, ArH), 3.99 (1H, d, *J* = 13.6 Hz, $NCH_{2a}Ph$), 3.28 (1H, d, *J* = 13.6 Hz, $NCH_{2b}Ph$), 2.75 (1H, dtd, *J* = 11.6, 3.9, 1.5 Hz, CH_2-6_{eq}), 2.07-1.96 (2H, m, CH-2 and CH_2-6_{ax}), 1.71-1.64 (1H, m, CH_2-4_a), 1.54-1.48 (2H, m, CH_2-5), 1.44-1.35 (1H, m, CH-3), 1.21 (3H, d, *J* = 6.1 Hz, CH_3-7), 1.09-0.97 (1H, m, CH_2-4_b), 0.95 (3H, d, *J* = 6.6 Hz, CH_3-8).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.9, 129.2, 128.2, 126.7, 62.8, 58.1, 52.3, 37.0, 33.1, 24.8, 20.1, 17.0.

HRMS: ESI+ found $[M+H]^+$ = 204.1747, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.11 ppm.

FTIR (film): ν_{max} = 2928, 2787, 1494, 1454, 1368, 1119, 1028, 733, 698 cm^{-1}.

***rac*-(2S,4S)-1-Benzyl-2,4-dimethylpiperidine, 3n**

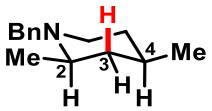


3-Methylhexane-1,5-diol[6] *rac*-**2n** (132 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A** at 110 °C. Purification by column chromatography (pentane:Et_2O 75:25) afforded piperidine **3n** (126 mg, 62%, 82:18 d.r.) as a colourless oil as a mixture of diastereoisomers. The relative stereochemistry was determined by *J*-coupling constant analysis. A small quantity of diastereoisomerically pure *cis*-**3n** (34 mg, >95:5 d.r.) was isolated by column chromatography (pentane:Et_2O 85:15).

HRMS: ESI+ found $[M+H]^+$ = 204.1747, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.26 ppm.

FTIR (film): ν_{max} = 2949, 2916, 1494, 1453, 1373, 1328, 1192, 1135, 1123, 1065, 1029, 730, 697 cm^{-1}.

Data for the major diastereoisomer:



H-3$_{ax}$ q, *J* = 12.0 Hz

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.30 – 7.11 (5H, m, ArH), 4.03 (1H, d, *J* = 13.3 Hz, NCH_{2a}Ph), 3.03 (1H, d, *J* = 13.3 Hz, NCH_{2b}Ph), 2.71 (1H, ddd, *J* = 11.6, 3.9, 2.8 Hz, CH_2-6$_{eq}$), 2.11 (1H, dqd, *J* = 12.0, 6.0, 2.7 Hz, CH-2), 1.81 (1H, ddd, *J* = 12.5, 11.6, 2.6 Hz, CH_2-6$_{ax}$), 1.56 – 1.25 (3H, m, CH_2-3$_{eq}$, CH_2-5$_{eq}$, CH-4), 1.13 (3H, d, *J* = 6.1 Hz, CH_3-7), 1.04 (1H, qd, *J* = 12.6, 3.8 Hz, CH_2-5$_{ax}$), 0.97 (1H, q, *J* = 12.0 Hz, CH_2-3$_{ax}$), 0.81 (3H, d, *J* = 6.6 Hz, CH_3-8).

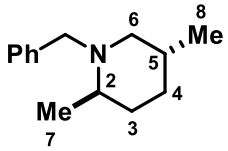
^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.6, 129.3, 128.2, 126.7, 58.3, 57.0, 53.2, 44.1, 34.6, 31.5, 22.2, 21.6.

Data for the minor diastereoisomer:

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.30 – 7.11 (5H, m, ArH), 3.55 (1H, d, *J* = 13.5 Hz, NCH_{2a}Ph), 3.45 (1H, d, *J* = 13.5 Hz, NCH_{2b}Ph), 2.93 – 2.85 (1H, m, CH-2), 2.44 – 2.31 (2H, m, CH_2-6), 1.70 – 1.58 (1H, m, CH-4), 1.56 – 1.25 (3H, m, CH_2-3 and CH_2-5$_a$), 1.15 – 1.09 (1H, m, CH_2-5$_b$), 0.95 (3H, d, *J* = 6.7 Hz, CH_3-7), 0.84 – 0.81 (3H, m, CH_3-8).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 140.2, 128.9, 128.2, 126.7, 59.2, 52.0, 45.9, 40.7, 34.1, 25.2, 21.8, 11.9.

***rac*-(2*R*,5*R*)-*N*-Benzyl-2,5-dimethylpiperidine, 3o**

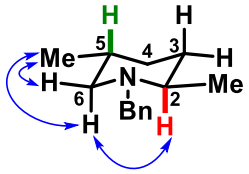


2-Methylhexane-1,5-diol[6] *rac*-**2o** (132 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A** at 110 °C. ^{1}H NMR analysis of the crude reaction mixture indicated the presence of two diastereomers in 71:29 dr. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3o** (138 mg, 68%, 72:28 d.r.) as a colourless oil as a mixture of diastereoisomers. An small quantity of each diastereoisomer was obtained by column chromatography (pentane:Et_2O 90:10). The relative stereochemistry was determined by a combination of *J*-coupling constant and nOe analysis.

HRMS: ESI+ found $[M+H]^+$ = 204.1748, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.63 ppm.

FTIR (film): ν_{max} = 2925, 1494, 1454, 1370, 1144, 1125, 1064, 732, 697 cm^{-1}.

Data for the major diastereomer:

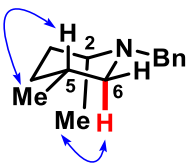


H-2$_{ax}$ dqd, *J* = 12.0, 6.1, 2.7 Hz
H-5$_{ax}$ was not fully resolved but contains large J values indicative of axial geometry.
nOe correlations shown with solid blue arrows.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.34-7.21 (5H, m, ArH), 4.07 (1H, d, *J* = 13.5 Hz, NCH_{2a}Ph), 3.14 (1H, d, *J* = 13.5 Hz, NCH_{2b}Ph), 2.74-2.70 (1H, m, CH_2-6$_a$), 2.12 (1H, dqd, *J* = 12.0, 6.1, 2.7 Hz, CH-2$_{ax}$), 1.70-1.33 (5H, m, CH_2-3, CH_2-4$_a$, CH-5, and CH_2-6$_b$), 1.21 (3H, d, *J* = 6.1 Hz, CH_3-7), 0.96-0.85 (1H, m, CH_2-4$_b$), 0.76 (3H, d, *J* = 6.2 Hz, CH_3-8).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.5, 129.3, 128.2, 126.7, 61.1, 58.3, 56.7, 35.3, 33.7, 31.4, 22.3, 19.9.

Data for the minor diastereomer:

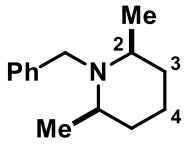


H-6$_{ax}$ dd, *J* = 11.6, 9.0 Hz
nOe correlations shown with solid blue arrows.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.37-7.21 (5H, m, ArH), 3.66-3.46 (2H, m, NCH_2Ph), 2.81-2.88 (1H, m, CH-2), 2.34 (1H, dd, *J* = 11.6, 4.2 Hz, CH_2-6$_{eq}$), 2.17 (1H, dd, *J* = 11.6, 9.0 Hz, CH_2-6$_{ax}$), 1.81-1.61 (2H, m, CH_2-4$_a$ and CH-5), 1.55-1.44 (2H, m, CH_2-3$_a$ and CH_2-4$_b$), 1.30-1.16 (1H, m, CH_2-3$_b$), 1.01 (3H, d, *J* = 6.6 Hz, CH_3-7), 0.87 (3H, d, *J* = 6.7 Hz, CH_3-8).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 140.4, 128.7, 128.2, 126.7, 59.2, 54.7, 52.8, 31.4, 30.8, 28.4, 19.4, 11.9.

***rac*-(2*R*,6*S*)-1-Benzyl-2,6-dimethylpiperidine, 3p**



Heptane-2,6-diol[6] *rac*-**2p** (132 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 60:40) afforded piperidine **3p** (135 mg, 66%, 80:20 dr) as an orange oil as an inseparable mixture of diastereoisomers. The major diastereomer was identified as *cis* by comparison with literature data.[16]

HRMS: ESI+ found $[M+H]^+$ = 207.1747, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.03 ppm.

FTIR (film): ν_{max} = 2927, 1494, 1453, 1374, 1340, 1312, 1201, 1121, 1094, 1056, 1028, 943, 753, 723, 696 cm^{-1}.

Data for the major diastereomer:

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.42-7.37 (2H, m, ArH), 7.33-7.25 (2H, m, ArH), 7.24-7.18 (1H, m, ArH), 3.82 (2H, s, NCH_2Ph), 2.54-2.45 (2H, m, 2 x CH-2), 1.69-1.51 (3H, m, 2 x CH_2-3_a and CH_2-4_a), 1.39-1.26 (3H, m, 2 x CH_2-3_b and CH_2-4_b), 1.09 (6H, d, J = 6.3 Hz, 2 $\times$ CH_3).

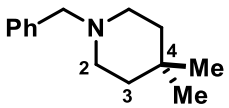
^{13}C NMR (101 MHz, $CDCl_3$) δ = 142.7, 128.7, 128.5, 126.7, 58.0, 54.3, 35.4, 25.0, 22.9.

Data for the minor diastereomer:

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.42-7.37 (2H, m, ArH), 7.33-7.25 (2H, m, ArH), 7.24-7.18 (1H, m, ArH), 3.93 (1H, d, J = 13.8 Hz, $NCH_{2a}Ph$), 3.42 (1H, d, J = 13.9 Hz, $NCH_{2b}Ph$), 2.92-2.82 (2H, m, CH-2 and CH-6), 1.69-1.51 (3H, m, 2 x CH_2-3_a and CH_2-4_a), 1.39-1.26 (3H, m, 2 x CH_2-3_b and CH_2-4_b), 1.02 (6, d, J = 6.5 Hz, 2 $\times$ CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 142.7, 129.0, 128.7, 126.9, 54.0, 50.3, 33.5, 20.1, 16.6.

***N*-Benzyl-4,4-dimethylpiperidine, 3q**



3,3-Dimethylpentane-1,5-diol[6] **2q** (132 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 80:20) afforded piperidine **3q** (149 mg, 73%) as a colourless oil.

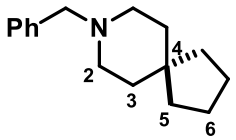
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.21 (5H, m, Ar<u>H</u>), 3.51 (2H, s, NC<u>H_2</u>Ph), 2.40-2.37 (4H, m, 2 × C<u>H_2-2</u>), 1.41-1.38 (4H, m, 2 × C<u>H_2-3</u>), 0.92 (6H, s, 2 × C<u>H_3</u>).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 138.9, 129.4, 128.2, 127.0, 63.7, 50.2, 38.9, 28.6, 28.4 (br).

HRMS: ESI+ found $[M+H]^+$ = 204.1749, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.85 ppm.

FTIR (film): ν_{max} = 2948, 2910, 2803, 2760, 1473, 1454, 1385, 1118, 1028, 988, 919, 736 cm^{-1}.

8-Benzyl-8-azaspiro[4.5]decane, 3r



2,2'-(Cyclopentane-1,1-diyl)bis(ethan-1-ol)[6] **2r** (158 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O:Et_3N 79.5:19.5:1) afforded piperidine **3r** (170 mg, 74%) as a pale yellow oil.

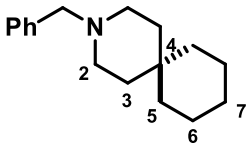
^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.33-7.22 (5H, m, Ar<u>H</u>), 3.48 (2H, s, NC<u>H_2</u>Ph), 2.37 (4H, br. s, 2 × C<u>H_2-2</u>), 1.59-1.55 (4H, m, 2 × C<u>H_2-6</u>), 1.49-1.46 (4H, m, 2 × C<u>H_2-3</u>), 1.41-1.38 (4H, m, 2 × C<u>H_2-5</u>).

^{13}C NMR (125 MHz, $CDCl_3$) δ = 138.9, 129.4, 128.2, 127.0, 63.8, 51.6, 40.9, 38.2 (br), 37.8, 24.5.

HRMS: ESI+ found $[M+H]^+$ = 230.1905, $C_{16}H_{24}N$ requires 230.1903, Δ = 0.65 ppm.

FTIR (film): ν_{max} = 2940, 2917, 2867, 2801, 2759, 1468, 1366, 1342, 1122, 735, 697 cm^{-1}.

3-Benzyl-3-azaspiro[5.5]undecane, 3s



2,2'-(Cyclohexane-1,1-diyl)bis(ethan-1-ol)[6] **2s** (172 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 80:20) afforded piperidine **3s** (166 mg, 68%) as a pale yellow solid.

^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.33-7.22 (5H, m, Ar<u>H</u>), 3.50 (2H, s, NC<u>H_2</u>Ph), 2.37 (4H, t, *J* = 5.6 Hz, 2 × C<u>H_2-2</u>), 1.46 (4H, t, *J* = 5.7 Hz, 2 × C<u>H_2-3</u>), 1.42-1.39 (6H, m, 2 × C<u>H_2-6</u> and C<u>H_2-7</u>), 1.33-1.31 (4H, m, 2 × C<u>H_2-5</u>).

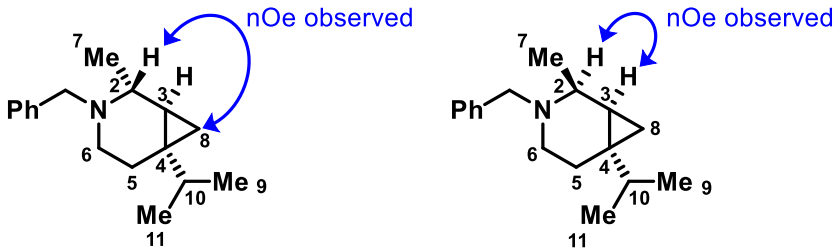
^{13}C NMR (125 MHz, $CDCl_3$) δ = 138.8, 129.4, 128.2, 127.0, 63.8, 49.5, 36.8 (br), 36.4, 30.9, 27.0, 21.7.

HRMS: ESI+ found $[M+H]^+$ = 244.2058, $C_{17}H_{26}N$ requires 244.2060, Δ = –0.72 ppm.

FTIR (film): ν_{max} = 2919, 2848, 2802, 2763, 1450, 1125, 987, 914, 736, 697 cm^{-1}.

Melting point = 44–46 °C.

(1*S*,6*S*)-3-Benzyl-6-isopropyl-2-methyl-3-azabicyclo[4.1.0]heptane, 3t



3t *(major)* **3t** *(minor)*

2-((1*S*,2*S*)-2-(1-Hydroxyethyl)-1-isopropylcyclopropyl)ethan-1-ol[6] **2t** (172 mg, 1.0 mmol), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3t** (174 mg, 71%, 62:38 dr) as an orange oil as an inseparable mixture of diastereoisomers. The relative stereochemistry was assigned by nOe analysis.

FTIR (film): ν_{max} = 3061, 2955, 2793, 1494, 1452, 1365, 1156, 1028, 734, 698 cm^{-1}.

HRMS: ESI+ found $[M+H]^+$ = 244.2060, $C_{17}H_{26}N$ requires 244.2060, Δ = 0.07 ppm.

$[\alpha]_D^{25}$ = +19.8 (*c* = 1.0, $CHCl_3$).

Data for the major diastereomer:

^1H NMR (500 MHz, $CDCl_3$) δ = 7.34-7.19 (5H, m, ArH), 3.69 (1H, d, *J* = 14.0 Hz, $NCH_{2a}Ph$), 3.34 (d, *J* = 13.9 Hz, $NCH_{2b}Ph$), 2.83 (1H, q, *J* = 6.4 Hz, CH-2), 2.51-2.39 (1H, m, CH_2-6_a), 1.95 (1H, ddd, *J* = 12.2, 7.1, 5.3 Hz, CH_2-6_b), 1.72-1.59 (1H, m, CH_2-5_a), 1.54 (1H, ddd, *J* = 12.8, 6.9, 5.3 Hz, CH_2-5_b), 1.24-1.18 (3H, m, CH_3-7), 1.04-0.81 (7H, m, CH_3-9, CH-10, CH_3-11), 0.56-0.49 (2H, m, CH-3 and CH_2-8_a), 0.36-0.32 (1H, m, CH_2-8_b).

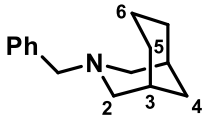
^{13}C NMR (125 MHz, $CDCl_3$) δ = 140.2, 128.5, 128.0, 126.5, 57.6, 54.1, 43.6, 37.5, 25.8, 24.6, 23.6, 19.1, 18.4, 18.1, 16.4.

Data for the major diastereomer:

^1H NMR (500 MHz, $CDCl_3$) δ = 7.34-7.19 (5H, m, ArH), 3.99 (1H, d, *J* = 14.0 Hz, $NCH_{2a}Ph$), 3.04 (d, *J* = 14.0 Hz, $NCH_{2b}Ph$), 2.62 (1H, qd, *J* = 6.0, 4.1 Hz, CH-2), 2.51-2.39 (1H, m, CH_2-6_{eq}), 1.77 (1H, td, *J* = 11.7, 4.6 Hz, CH_2-6_{ax}), 1.72-1.59 (1H, m, CH_2-5_a), 1.47-1.39 (1H, m, CH_2-5_b), 1.24-1.18 (3H, m, CH_3-7), 1.04-0.81 (7H, m, CH_3-9, CH-10, CH_3-11), 0.71 (1H, ddd, *J* = 9.4, 5.5, 4.3 Hz, CH-3), 0.56-0.49 (1H, m, CH_2-8_a), 0.25 (1H, dd, *J* = 9.0, 3.7 Hz, CH_2-8_b).

^{13}C NMR (125 MHz, $CDCl_3$) δ = 140.3, 128.6, 128.0, 126.5, 58.5, 53.8, 50.5, 37.8, 26.7, 25.1, 23.5, 20.0, 18.9, 18.2, 14.4.

3-Benzyl-3-azabicyclo[3.3.1]nonane, 3u



((1*R*,3*S*)-Cyclohexane-1,3-diyl)dimethanol[15] **2u** (144 mg, 1.0 mmol), benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 98:2) afforded piperidine **3u** (162 mg, 75%) as a colourless oil.

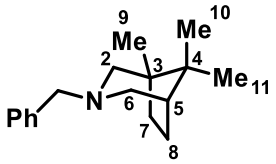
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.36-7.28 (4H, m, ArH), 7.26-7.20 (1H, m, ArH), 3.37 (2H, s, NCH_2Ph), 2.88 (2H, d, *J* = 11.3 Hz, 2 x CH_2-2_a), 2.74 (1H, qt, *J* = 12.7, 6.1 Hz, CH_2-5_{ax}), 2.22 (2H, d, *J* = 10.9 Hz, 2 x CH_2-2_b), 1.83-1.47 (9H, m, 2 x CH-3, CH_2-4, 2 x CH_2-5, CH_2-5_{eq}).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.9, 128.7, 128.1, 126.5, 64.2, 59.9, 34.4, 31.5, 29.7, 22.6.

HRMS: ESI+ found $[M+H]^+$ = 216.1746, $C_{15}H_{22}N$ requires 216.1747, Δ = –0.32 ppm.

FTIR (film): ν_{max} = 3387, 2909, 1644, 1495, 1454, 1391, 1250, 1146, 1073, 1017, 968, 830, 764, 728, 698 cm^{-1}.

(1*R*,5*S*)-3-Benzyl-1,8,8-trimethyl-3-azabicyclo[3.2.1]octane, 3v



((1*R*,3*S*)-1,2,2-Trimethylcyclopentane-1,3-diyl)dimethanol[6] **2v** (172 mg, 1.0 mmol), benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3v** (163 mg, 67%) as a yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.36-7.20 (5H, m, ArH), 3.55 (2H, s, NCH_2Ph), 2.59 (1H, dd, *J* = 10.5, 2.3 Hz, CH_2-6_a), 2.45 (1H, dd, *J* = 10.5, 3.7 Hz, CH_2-6_b), 2.35 (1H, d, *J* = 10.5 Hz, CH_2-2_a), 2.17 (1H, d, *J* = 10.5 Hz, CH_2-2_b), 1.84-1.65 (3H, m, CH_2-7_a and CH_2-8), 1.61-1.49 (2H, m, CH_2-7_b and CH-5), 0.91 (3H, s, CH_3-11), 0.86 (3H, s, CH_3-10), 0.76 (3H, s, CH_3-9).

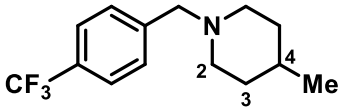
^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.9, 128.6, 128.1, 126.6, 61.9, 61.2, 54.6, 46.1, 42.8, 41.7, 35.6, 26.8, 24.4, 18.3, 17.9.

HRMS: ESI+ found $[M+H]^+$ = 244.2058, $C_{17}H_{26}N$ requires 244.2060, Δ = –0.87 ppm.

FTIR (film): ν_{max} = 2952, 2803, 1653, 1454, 1366, 1343, 1276, 1097, 1028, 799, 746, 727, 698 cm^{-1}.

$[\alpha]_D^{25}$ = +37.5 (*c* = 1.0, $CHCl_3$).

***N*-Methyl-1-(4-(trifluoromethyl)benzyl)piperidine, 3w**



3-Methylpentane-1,5-diol **2a** (118 mg, 1.0 mmol), *p*-(trifluoromethyl)benzylamine (0.21 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine **3w** (220 mg, 86%) as a pale yellow oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.57-7.54 (2H, m, ArH), 7.45-7.42 (2H, m, ArH), 3.52 (2H, s, NCH_2Ph), 2.83-2.78 (2H, m, 2 × CH_2-2$_{eq}$), 1.95 (2H, td, *J* = 11.5, 2.5 Hz, 2 × CH_2-2$_{ax}$), 1.63-1.57 (2H, m, 2 × CH_2-3$_a$), 1.42-1.31 (1H, m, CH-4), 1.29-1.19 (2H, m, 2 × CH_2-3$_b$), 0.92 (3H, d, *J* = 6.4 Hz, CH_3).

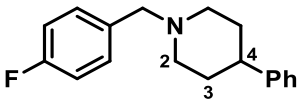
^{13}C NMR (101 MHz, $CDCl_3$) δ = 143.4, 129.3, 129.2 (q, *J* = 32.4 Hz), 125.2 (q, *J* = 3.9 Hz), 124.5 (q, *J* = 271.7 Hz), 63.1, 54.2, 34.5, 30.9, 22.1.

^{19}F NMR (376 MHz, $CDCl_3$) δ = –62.3.

HRMS: ESI+ found $[M+H]^+$ = 258.1466, $C_{14}H_{19}F_3N$ requires 258.1475, Δ = –3.61 ppm.

FTIR (film): ν_{max} = 2924, 2797, 1324, 1161, 1123, 1102, 1066, 847, 812 cm^{-1}.

***N*-(4-Fluorobenzyl)-4-phenylpiperidine, 3x**



3-Phenylpentane-1,5-diol[6] **2b** (180 mg, 1.0 mmol), *p*-fluorobenzylamine (0.17 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 90:10 → 80:20) afforded piperidine **3x** (167 mg, 62%) as a colourless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.34-7.28 (4H, m, ArH), 7.25-7.18 (3H, m, ArH), 7.05-6.99 (2H, m, ArH), 3.52 (2H, s, NCH_2Ar), 3.02-2.97 (2H, m, 2 × CH_2-2$_a$), 2.56-2.45 (1H, m, CH-4), 2.12-2.05 (2H, m, 2 × CH_2-2$_b$), 1.85-1.72 (4H, m, 2 × CH_2-3).

^{13}C NMR (126 MHz, $CDCl_3$) δ = 163.1 (d, *J* = 244.6 Hz), 146.6, 134.3 (d, *J* = 3.0 Hz), 130.8 (d, *J* = 8.0 Hz) 128.5, 127.0, 126.2, 115.1 (d, *J* = 21.1 Hz), 62.8, 54.4, 42.8, 33.6.

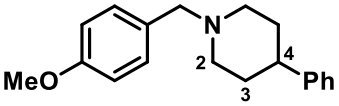
^{19}F NMR (376 MHz, $CDCl_3$) δ = –116.13.

HRMS: ESI+ found $[M+H]^+$ = 270.1651, $C_{18}H_{21}FN$ requires 270.1653, Δ = –0.67 ppm.

FTIR (film): ν_{max} = 2936, 2795, 2756, 1603, 1507, 1221, 1154, 1090, 992, 835, 755, 699 cm^{-1}.

Melting point = 69–70 °C.

***N*-(4-Methoxybenzyl)-4-phenylpiperidine, 3y**



3-Phenylpentane-1,5-diol[6] **2b** (180 mg, 1.0 mmol), *para*-methoxybenzylamine (0.20 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 60:40) afforded piperidine **3y** (95 mg, 34%) as a colourless oil.

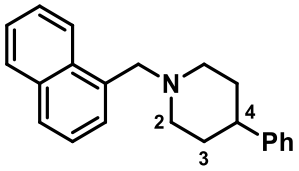
^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.30-7.15 (7H, m, ArH), 6.88-6.84 (2H, m, ArH), 3.80 (3H, s, OCH_3), 3.48 (2H, s, NCH_2Ph), 3.02-2.97 (2H, m, 2 × CH_2-2$_a$), 2.51-2.44 (1H, m, CH-4), 2.08-2.02 (2H, m, 2 × CH_2-2$_b$), 1.81-1.76 (4H, m, 2 × CH_2-3).

^{13}C NMR (125 MHz, $CDCl_3$) δ = 158.8, 146.7, 130.6, 130.6, 128.5, 127.0, 126.2, 113.7, 63.0, 55.4, 54.3, 42.9, 33.7.

HRMS: ESI+ found $[M+H]^+$ = 282.1847, $C_{19}H_{24}NO$ requires 282.1852, Δ = –1.76 ppm.

FTIR (film): ν_{max} = 2933, 2796, 2754, 1611, 1510, 1453, 1243, 833, 757, 699 cm^{-1}.

***N*-(Naphthalen-1-ylmethyl)-4-phenylpiperidine, 3z**



3-Phenylpentane-1,5-diol[6] **2b** (180 mg, 1.0 mmol), 1-naphthylethylamine (0.22 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 95:5) afforded piperidine **3z** (137 mg, 45%) as a colourless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.38-8.36 (1H, m, ArH), 7.87 (1H, d, *J* = 7.8 Hz, ArH), 7.79 (1H, d, *J* = 7.8 Hz, ArH), 7.57-7.42 (4H, m, ArH), 7.32-7.17 (5H, m, ArH), 3.96 (2H, s, NCH_2Ar), 3.09 (2H, dt, *J* = 11.0, 3.6 Hz, 2 × CH_2-2$_{eq}$), 2.55 (1H, tt, *J* = 10.8, 5.6 Hz, CH-4), 2.23-2.16 (2H, m, 2 × CH_2-2$_{ax}$), 1.85-1.74 (4H, m, 2 × CH_2-3).

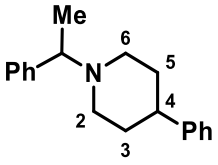
^{13}C NMR (101 MHz, $CDCl_3$) δ = 146.8, 134.8, 134.0, 132.8, 128.52, 128.48, 127.9, 127.4, 127.0, 126.2, 125.8, 125.7, 125.3, 125.0, 61.6, 54.8, 43.0, 33.8.

HRMS**:** ESI+ found $[M+H]^+$ = 302.1901, $C_{22}H_{24}N$ requires 302.1903, Δ = –0.67 ppm.

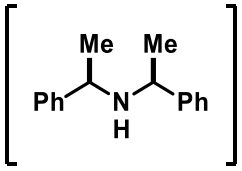
FTIR (film): ν_{max} = 1598, 1493, 1452, 1365, 1334, 1167, 1108, 988, 784, 699cm^{-1}.

Melting point = 106–107 °C.

4-Phenyl-*N*-(1-phenylethyl)piperidine, 3aa



2b



S2

3-Phenylpentane-1,5-diol[6] **2b** (180 mg, 1.0 mmol), α–methylbenzylamine (0.19 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 60:40) afforded piperidine **3aa** (184 mg, 65%) contaminated with 8% *meso*-bis(1-phenylethyl)amine **S2** as a yellow oil.

Data for **3aa**:

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.33-7.05 (10H, m, ArH), 3.40 (1H, q, *J* = 6.8 Hz, NCH(CH_3)Ph), 3.11 (1H, dtd, *J* = 11.1, 3.5, 2.1 Hz, CH_2-2_{eq}), 2.86 (1H, dtd, *J* = 11.3, 3.4, 2.0, CH_2-6_{eq}), 2.40-2.32 (1H, m, CH-4), 2.06-1.97 (1H, m, CH_2-2_{ax}), 1.88 (1H, td, *J* = 11.2, 3.4 Hz, CH_2-6_{ax}), 1.81-1.51 (4H, m, CH_2-3 and CH_2-5), 1.34 (3H, d, *J* = 6.5 Hz, CH_3).

^{13}C NMR (125 MHz, $CDCl_3$) δ = 146.8, 144.0, 128.5, 128.1, 127.8, 126.9, 126.8, 126.0, 65.1, 51.4, 51.3, 43.1, 33.9, 33.8, 19.7.

HRMS: ESI+ found $[M+H]^+$ = 266.1904, $C_{19}H_{24}N$ requires 266.1903, Δ = 0.27 ppm.

FTIR (film): ν_{max} = 3026, 2932, 2796, 1493, 1451, 1129, 1022, 756, 699 cm^{-1}.

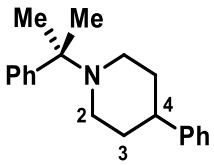
Data for **S2**:

^{1}H NMR (400 MHz, $CDCl_3$) δ = 3.69 (2H, q, *J* = 6.5 Hz, NCH(CH_3)Ph), 1.28 (6H, d, *J* = 6.6 Hz, CH_3).

^{13}C NMR (125 MHz, $CDCl_3$) δ = 146.1, 128.6, 127.0, 126.7, 55.0, 23.3.

The data are consistent with the literature.[17]

4-Phenyl-*N*-(2-phenylpropan-2-yl)piperidine, 3ab



3-Phenylpentane-1,5-diol[6] **2b** (180 mg, 1.0 mmol), cumylamine (0.22 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%), $NaHCO_3$ (1.7 mg, 2.0 mol%) and anhydrous toluene (0.5 mL) were subjected to **general procedure A**. Purification by column chromatography (pentane:Et_2O 95:5) afforded piperidine **3ab** (185 mg, 66%) as a colourless solid.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.60-7.57 (2H, m, ArH), 7.35-7.17 (8H, m, ArH), 2.95-2.93 (2H, m, 2 × CH_2-2_{eq}), 2.47 (1H, tt, *J* = 11.8, 4.3 Hz, CH-4_{ax}), 2.22 (2H, td, *J* = 11.4, 2.7 Hz, 2 × CH_2-2_{ax}), 1.82-1.68 (4H, m, 2 × CH_2-3), 1.39 (6H, s, 2 × CH_3).

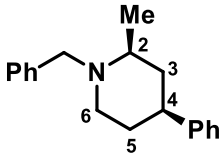
^{13}C NMR (101 MHz, $CDCl_3$) δ = 150.0, 147.1, 128.5, 128.1, 127.1, 126.2, 126.13, 126.08, 60.1, 47.3, 43.5, 34.6, 24.5.

HRMS: ESI+ found $[M+H]^+$ = 280.2060, $C_{20}H_{26}N$ requires 280.2060, Δ = 0.17 ppm.

FTIR (film): ν_{max} = 2972, 2930, 1493, 1446, 1271, 1177, 1073, 1024, 959, 759, 698 cm^{-1}.

Melting point = 101–102 °C.

(2*S*,4*S*)-1-Benzyl-2-methyl-4-phenylpiperidine, (+)-3ac



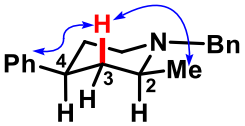
(3*S*)-3-Phenylhexane-1,5-diol[6] (–)-**2ac** (110 mg, 0.56 mmol, 60:40 d.r., >99:1 e.r.), anhydrous benzylamine (0.09 mL, 0.84 mmol), $[IrCp^*Cl_2]_2$ (4.5 mg, 1.0 mol%), $NaHCO_3$ (0.9 mg, 2.0 mol%) and anhydrous toluene (0.28 mL, 2 M) were subjected to **general procedure A**. Purification by column chromatography afforded piperidine (+)-**3ac** as a colourless oil as an inseparable mixture of diastereoisomers (169 mg, 64%, 80:20 d.r., >99:1 e.r.). The corresponding racemic piperidine *rac*-**3ac** was prepared by an identical procedure starting from *rac*-**2ac**.[6] The enantiomeric purity was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

HRMS: ESI+ found $[M+H]^+$ = 266.1902, $C_{19}H_{24}N$ requires 266.1903, Δ = –0.32 ppm.

FTIR (film): ν_{max} = 3027, 2931, 2790, 1602, 1494, 1451, 1374, 1329, 1137, 1066, 1028, 756, 732, 698 cm^{-1}.

$[\alpha]_D^{25}$ = +45.3 (*c* = 1.00, CH_2Cl_2).

Data for the major diastereomer:

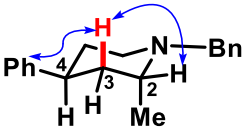


H-3_{ax} td, *J* = 12.8, 10.9 Hz
nOe correlations shown with solid blue arrows.

^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.38-7.17 (10H, m, ArH), 4.17 (1H, d, *J* = 13.4 Hz, $NCH_{2a}Ph$), 3.21 (1H, d, *J* = 13.3 Hz, $NCH_{2b}Ph$), 2.94 (1H, dt, *J* = 11.7, 3.4 Hz, CH_2-6_{eq}), 2.58 (1H, tt, *J* = 12.0, 4.1 Hz, CH-4_{ax}), 2.37 (1H, dqd, *J* = 12.1, 5.9, 2.6 Hz, CH-2_{ax}), 2.07 (1H, td, *J* = 11.6, 3.4 Hz, CH_2-6_{ax}), 1.87-1.82 (1H, m, CH_2-3_{eq}), 1.78-1.65 (2H, m, CH_2-5), 1.60 (1H, td, *J* = 12.8, 10.9 Hz, CH_2-3_{ax}), 1.28 (3H, d, *J* = 6.1 Hz, CH_3).

^{13}C NMR (126 MHz, $CDCl_3$) δ = 146.6, 139.3, 129.4, 128.5, 128.3, 126.94, 126.89, 126.2, 58.2, 57.3, 53.4, 43.2, 43.1, 33.5, 21.5.

Data for the minor diastereomer:

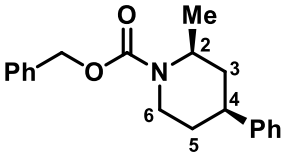


H-3$_{ax}$ td, *J* = 12.7, 4.8 Hz
nOe correlations shown with solid blue arrows.

^{1}H NMR (500 MHz, $CDCl_3$) δ = 7.39 (2H, d, *J* = 7.5 Hz, ArH), 7.34-7.17 (8H, m, ArH), 3.70-3.54 (2H, m, NCH_2Ph), 3.24-3.19 (1H, m, CH-2$_{eq}$), 2.88-2.81 (1H, m, CH-4$_{ax}$), 2.64-2.61 (2H, m, CH_2-6), 2.03 (1H, td, *J* = 12.7, 4.8 Hz, CH_2-3$_{ax}$), 1.78-1.74 (2H, m, CH_2-5), 1.68 (1H, dt, *J* = 12.9, 3.1 Hz, CH_2-3$_{eq}$), 1.12 (3H, d, *J* = 6.7 Hz, CH_3).

^{13}C NMR (126 MHz, $CDCl_3$) δ = 146.9, 140.0, 128.8, 128.5, 128.3, 127.1, 126.9, 126.1, 59.3, 52.2, 45.8, 39.5, 36.6, 33.6, 10.0.

Benzyl (2*S*,4*S*)-2-methyl-4-phenylpiperidine-1-carboxylate, S3



(2*S*,4*S*)-1-Benzyl-2-methyl-4-phenylpiperidine (+)-**3ac** (30 mg, 0.11 mmol, 80:20 d.r.) and benzyl chloroformate (3 M in toluene, 0.23 mL, 0.68 mmol) were subjected to **general procedure C**. Purification by column chromatography (80:20 pentane:Et_2O) afforded Cbz-piperidine **S3** (34 mg, 97%, 76:24 dr, >99:1 e.r.) as a colourless oil. The corresponding racemic piperidine *rac*-**S3** was prepared by an identical procedure starting from *rac*-**3ac**.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.42 – 7.17 (10H, m, ArH), 5.21 – 5.13 (2H, m, NCH_2Ph), 4.05 (1H, dp, *J* = 10.2, 6.4 Hz, CH-2), 3.89 (1H, dddd, *J* = 13.9, 7.6, 3.3, 0.7 Hz, CH_2-6$_a$), 3.34 (1H, ddd, *J* = 13.9, 9.8, 6.4 Hz, CH_2-6$_b$), 2.77 (1H, dddd, *J* = 12.9, 10.4, 7.6, 3.3 Hz, CH-4), 2.18 (1H, ddtd, *J* = 13.5, 9.9, 7.6, 1.4 Hz, CH_2-5$_a$), 1.94 (1H, dddd, *J* = 13.5, 6.3, 3.3, 1.4 Hz, CH_2-3$_a$), 1.74 – 1.55 (2H, m, CH_2-3$_b$ and CH_2-5$_b$), 1.24 (3H, d, *J* = 6.4 Hz, CH_3). The minor diastereoisomer displays diagnostic signals at δ = 4.72 – 4.55 (1H, m, CH-2), 4.30 – 4.10 (1H, m, CH_2-6$_a$), 3.15 – 3.01 (1H, m, CH_2-6$_b$), 2.98 – 2.85 (1H, m, CH-4).

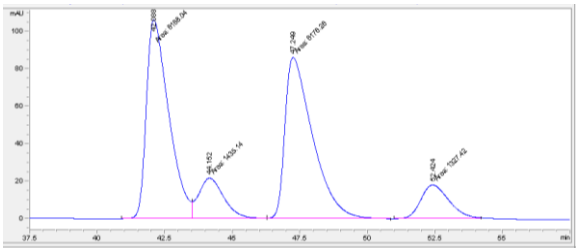
^{13}C NMR (101 MHz, $CDCl_3$) δ = 155.8, 145.8, 137.1, 128.5, 128.5, 127.9, 127.8, 126.8, 126.2, 66.8, 50.5, 38.0, 38.0, 37.0, 31.2, 19.9.

HRMS: ESI+ found $[M+Na]^+$ = 332.1620, $C_{20}H_{23}O_2NNa$ requires 332.1621, Δ = –0.16 ppm.

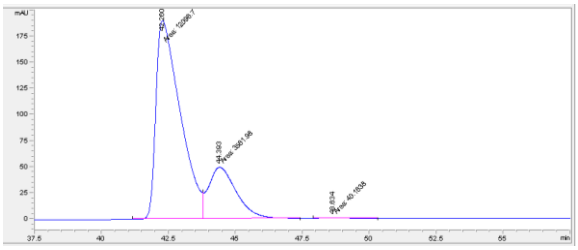
FTIR (film): ν_{max} = 2970, 1696, 1454, 1421, 1334, 1281, 1243, 1212, 1140, 1066, 1029, 757, 699 cm^{-1}.

$[\alpha]_D^{25}$ = +42.1 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IA column (99.5:0.5 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature), major diastereomer t_r (major) = 42.1 min, t_r (minor) = 47.2 min, >99:1 er; minor diastereomer t_r (major) = 44.2 min, t_r (minor) = 52.4 min; >99:1 er.

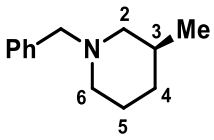


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	42.088	MF	6168	106.2	0.9676	40.829	0
2	44.152	FM	1435.1	21.8	1.0978	9.500	0.719
3	47.249	FM	6176.3	86.1	1.1954	40.884	0.408
4	52.424	MF	1327.4	18	1.2261	8.787	0.701



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	42.26	MF	12096.7	191.2	1.0546	77.055	0.367
2	44.393	FM	3562	49.7	1.1936	22.689	0.616
3	48.634	FM	40.2	6.1E-1	1.1057	0.256	0.721

(*S*)-1-Benzyl-3-methylpiperidine, (+)-3i

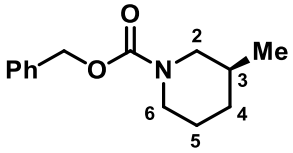


(*S*)-2-Methylpentane-1,5-diol [6] (–)-**2i** (132 mg, 1.0 mmol, >99:1 er), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine (+)-**3i** (136 mg, 72%, 90:10 er) as a colourless oil. The spectral data was identical to that of the corresponding racemate described above.

$[\alpha]_D^{25}$ = +8.9 (*c* = 1.0, $CHCl_3$).

The enantiomeric purity was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

Benzyl (*S*)-3-methylpiperidine-1-carboxylate, S4



(*S*)-1-Benzyl-3-methylpiperidine (+)-**3i** (26 mg, 0.14 mmol) and benzyl chloroformate (3 M in toluene, 0.5 mL, 1.5 mmol) were subjected to **general procedure C**. Purification by column chromatography (75:25 pentane:Et_2O) afforded piperidine **S4** (27 mg, 82%, 90:10 er) as a colourless oil. The

corresponding racemic Cbz-piperidine *rac*-**S4** was prepared by an identical procedure starting from *rac*-**3i**.

^{1}H NMR (400 MHz, $CDCl_3$, 298 K) δ = 7.36-7.28 (5H, m, ArH), 5.13 (2H, s, OCH_2Ph), 4.10-4.02 (1H, m, CH_2-6$_{eq}$), 3.99-3.92 (1H, m, CH_2-2$_a$), 2.76 (1H, td, *J* = 12.9, 3.0 Hz, CH_2-6$_{ax}$), 2.50-2.36 (1H, m, CH_2-2$_b$), 1.82-1.75 (1H, m, CH_2-4$_a$), 1.66-1.54 (2H, m, CH_2-5$_a$ and CH-3), 1.49-1.40 (1H, m, CH_2-5$_b$) 1.11-1.01 (1H, m, CH_2-4$_b$), 0.88 (3H, d, *J* = 6.6 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$, 298 K) δ = 155.4, 137.2, 128.6, 128.0, 127.9, 67.0, 51.5, 44.5, 33.1, 31.1, 25.3 (br), 19.0.

The data are consistent with the literature.[18]

^{1}H NMR (500 MHz, d_8-toluene, 363 K) δ = 5.11-5.06 (2H, m, OCH_2Ph), 3.97-3.92 (2H, m, CH_2-2$_{eq}$ and CH_2-6$_{eq}$), 2.55 (1H, ddd, *J* = 13.1, 11.2, 3.5 Hz, CH_2-6$_{ax}$), 2.25 (1H, dd, *J* = 13.0, 10.1 Hz, CH_2-2$_{ax}$), 1.45-1.41 (1H, m, CH_2-4$_a$), 1.37-1.16 (3H, m, CH-3, CH_2-5), 0.78-0.70 (1H, m, CH_2-4$_b$), 0.63 (3H, d, *J* = 6.6 Hz, CH_3). *Signals corresponding to the aromatic protons are obscured by the d_8-toluene solvent signals. The aromatic signals can be clearly observed in the room temperature $CDCl_3$ data above.*

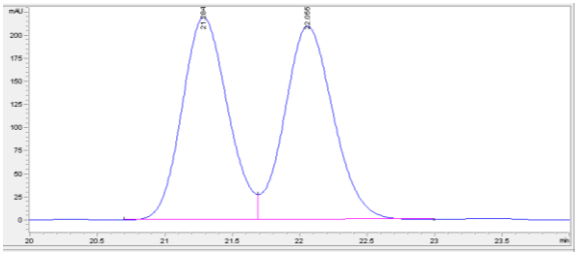
^{13}C NMR (125 MHz, d_8-toluene, 363 K) δ = 155.3, 138.3, 128.6, 128.3, 128.0, 67.1, 51.8, 44.8, 33.4, 31.2, 25.4, 18.8.

HRMS: ESI+ found $[M+H]^+$ = 234.1491, $C_{14}H_{20}NO_2$ requires 234.1489, Δ = 1.08 ppm.

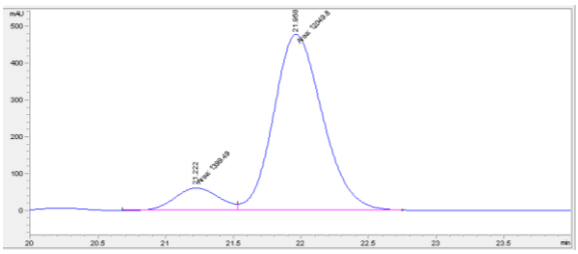
FTIR (film): ν_{max} = 2929, 2852, 1697, 1428, 1257, 1235, 1154, 1097, 972 cm^{-1}.

$[\alpha]_D^{25}$ = +19.1 (*c* = 1.7, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

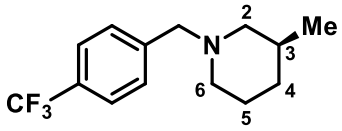


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	21.284	BV	5151.3	218.6	0.3669	49.503	0.863
2	22.055	VB	5254.7	209.2	0.387	50.497	0.859



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	21.222	MF	1399.5	61.2	0.3808	10.406	0.927
2	21.958	MF	12049.8	479.4	0.4189	89.594	0.815

(*S*)-3-Methyl-1-(4-(trifluoromethyl)benzyl)piperidine, (+)-3ad



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), *para*-(trifluoromethyl)benzylamine (0.21 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine (+)-**3ad** (166 mg, 65%, 91:9 er) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.57-7.55 (2H, m, ArH), 7.45-7.43 (2H, m, ArH), 3.51 (2H, s, NCH_2Ph), 2.79-2.71 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.89 (1H, td, *J* = 11.1, 3.4 Hz, CH_2-6_{ax}), 1.73-1.51 (5H, m, CH_2-2_b, CH-3, CH_2-4_a, CH_2-5), 0.92-0.84 (1H, m, CH_2-4_b), 0.84 (3H, d, *J* = 6.3 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 143.4, 129.3, 129.2 (q, *J* = 32.4 Hz), 125.2 (q, *J* = 3.8 Hz), 124.5 (q, *J* = 272.1 Hz), 63.2, 62.2, 54.2, 33.1, 31.3, 25.7, 19.8.

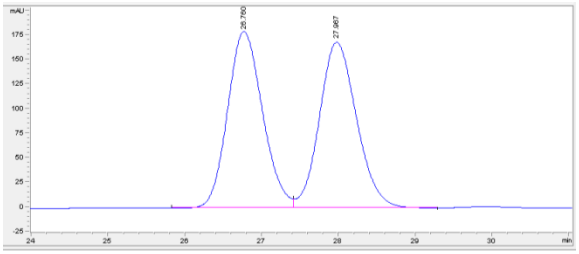
^{19}F NMR (376 MHz, $CDCl_3$) δ = –62.3.

HRMS: ESI+ found $[M+H]^+$ = 258.1463, $C_{14}H_{19}F_3N$ requires 258.1464, Δ = –0.31 ppm.

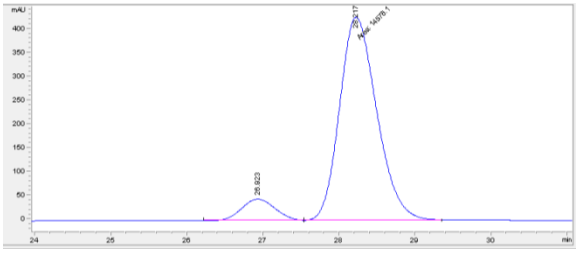
FTIR (film): ν_{max} = 2930, 1323, 1162, 1123, 1103, 1066, 1019, 836, 819 cm^{-1}.

$[\alpha]_D^{25}$ = +6.7 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

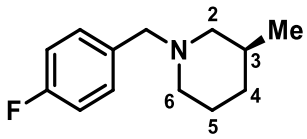


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	26.76	BV	5692.6	179.6	0.4918	50.131	0.842
2	27.967	VB	5662.9	168.7	0.5197	49.869	0.833



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	26.923	BV	1393.7	45.3	0.4829	8.727	0.913
2	28.217	MF	14576.1	428.1	0.5675	91.273	0.776

(*S*)-1-(4-Fluorobenzyl)-3-methylpiperidine, (+)-3ae



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), 4-fluorobenzylamine (0.17 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine (+)-**3ae** (150 mg, 72%, 90:10 er) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.29-7.21 (2H, m, ArH), 7.01-6.96 (2H, m, ArH), 3.43 (2H, s, NCH_2Ph), 2.79-2.71 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.84 (1H, td, *J* = 11.2, 3.3 Hz, CH_2-6_{ax}), 1.72-1.49 (5H, m, CH_2-2_b, CH-3, CH_2-4_a, CH_2-5), 0.91-0.82 (1H, m, CH_2-4_b), 0.84 (3H, d, *J* = 6.4 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 162.0 (d, *J* = 244.0 Hz), 134.6 (d, *J* = 3.2 Hz), 130.7 (d, *J* = 7.9 Hz), 115.0 (d, *J* = 20.8 Hz), 62.9, 62.0, 54.1, 33.2, 31.3, 25.7, 19.9.

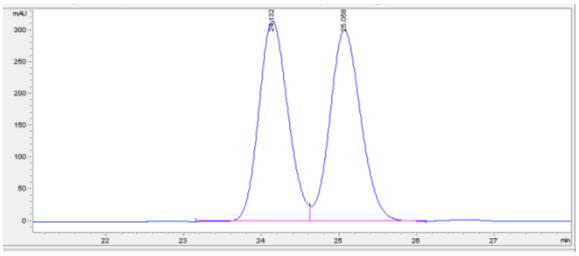
^{19}F NMR (376 MHz, $CDCl_3$) δ = –116.40.

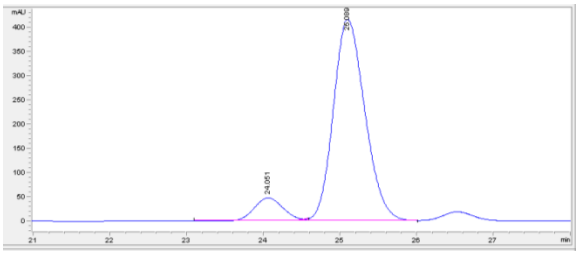
HRMS: ESI+ found $[M+H]^+$ = 208.1497, $C_{13}H_{19}FN$ requires 208.1496, Δ = 0.48 ppm.

FTIR (film): ν_{max} = 2928, 1604, 1508, 1465, 1458, 1356, 1293, 1221, 1154, 1120, 1091, 1078, 1039, 844, 822 cm^{-1}.

$[\alpha]_D^{25}$ = +8.7 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

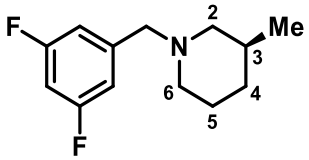




#	Time	Type	Area	Height	Width	Area%	Symmetry
1	24.132	BV	8247.6	316.3	0.4042	49.766	0.839
2	25.058	VB	8325.2	301.9	0.4277	50.234	0.835

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	24.051	BV E	1251.2	47.6	0.4085	9.524	0.919
2	25.089	VB R	11885.9	416.2	0.4432	90.476	1.324

(S)-1-(3,5-Difluorobenzyl)-3-methylpiperidine, (+)-3af



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), 3,5-difluorobenzylamine (0.18 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 95:5) afforded piperidine (+)-**3af** (152 mg, 67%, 93:7 er) as a colourless oil.

^{1}H NM**R** (400 MHz, $CDCl_3$) δ = 6.90-6.84 (2H, m, ArH), 6.66 (1H, tt, *J* = 9.0, 2.4 Hz, ArH), 3.42 (2H, s, NCH_2Ph), 2.77-2.69 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.89 (1H, td, *J* = 11.1, 3.4 Hz, CH_2-6_{ax}), 1.72-1.52 (5H, m, CH_2-2_b, CH-3, CH_2-4_a, CH_2-5), 0.92-0.82 (1H, m, CH_2-4_b), 0.85 (3H, d, *J* = 6.2 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 162.1 (dd, *J* = 247.8, 12.7 Hz), 142.7 (t, *J* = 8.7 Hz), 110.5-110.3 (m), 101.2 (t, *J* = 25.6 Hz), 61.8 (t, *J* = 1.9 Hz), 61.1, 53.2, 32.0, 30.3, 24.7, 18.8.

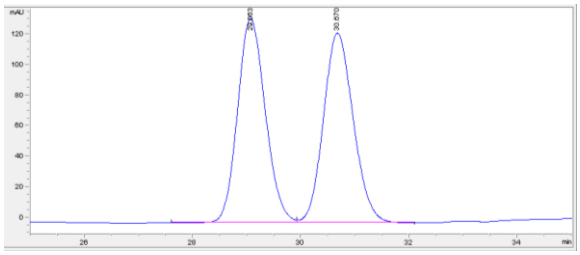
^{19}F NMR (376 MHz, $CDCl_3$) δ = –110.9.

HRMS: ESI+ found $[M+H]^+$ = 226.1403, $C_{13}H_{18}F_2N$ requires 226.1402, Δ = 0.61 ppm.

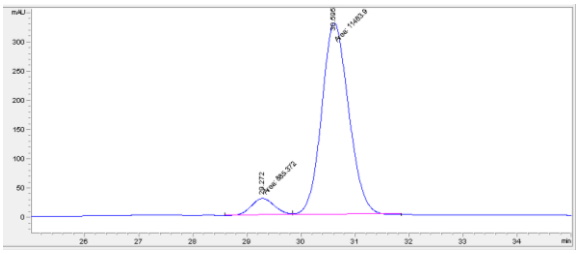
FTIR (film): ν_{max} = 2930, 1626, 1597, 1458, 1438, 1346, 1317, 1115, 976, 965, 846 cm^{-1}.

$[\alpha]_D^{25}$ = +11.5 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

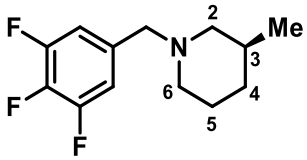


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	29.063	BV	4781.6	133.6	0.5575	50.028	0.848
2	30.67	VB	4776.2	124.1	0.5992	49.972	0.847



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	29.272	MF	885.4	28.9	0.5101	7.169	0
2	30.595	FM	11463.9	328.9	0.5809	92.831	0.849

(*S*)-3-Methyl-1-(3,4,5-trifluorobenzyl)piperidine, (+)-3ag



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), 3,4,5-trifluorobenzylnitrile (0.19 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine (+)-**3ag** (137 mg, 56%, 90:10 er) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.00-6.92 (2H, m, ArH), 3.47 (2H, s, NCH_2Ph), 2.75-2.66 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.88 (1H, td, *J* = 11.1, 3.2 Hz, CH_2-6_{ax}), 1.73-1.49 (5H, m, CH_2-2_b, CH-3, CH_2-4_a, CH_2-5), 0.92-0.83 (1H, m, CH_2-4_b), 0.84 (3H, d, *J* = 6.3 Hz, CH_3).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 151.2 (ddd, *J* = 249.4, 10.1, 4.0 Hz), 138.6 (dt, *J* = 249.6, 15.4 Hz), 135.9 (td, *J* = 6.8, 4.6 Hz), 112.4 (d, *J* = 20.8 Hz), 62.4, 62.0, 54.1, 33.0, 31.3, 25.6, 19.8.

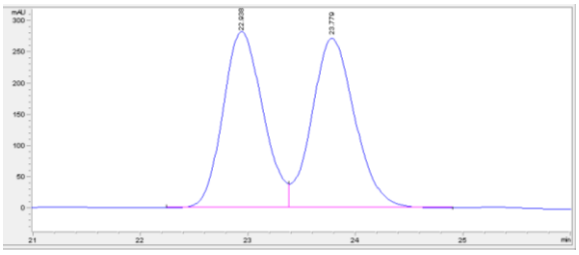
^{19}F NMR (376 MHz, $CDCl_3$) δ = –135.3, –163.6.

HRMS: ESI+ found $[M+H]^+$ = 244.1308, $C_{13}H_{17}F_3N$ requires 244.1308, Δ = 0.34 ppm.

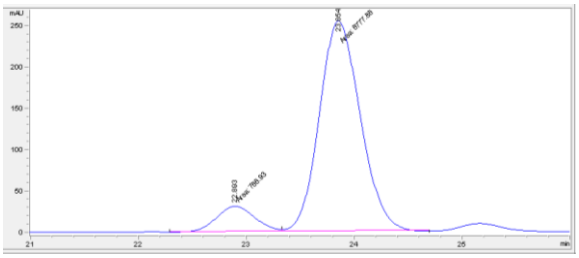
FTIR (film): ν_{max} = 2930, 1621, 1526, 1445, 1372, 1360, 1350, 1231, 1131, 1122, 1039, 980 cm^{-1}.

$[\alpha]_D^{25}$ = +10.4 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

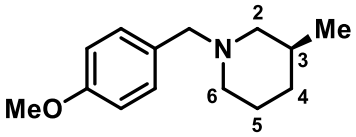


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	22.938	BV	7300.9	281.8	0.4022	49.195	0.837
2	23.779	VB	7539.8	271.5	0.4261	50.805	0.835



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	22.893	MF	766.9	30.8	0.4148	10.165	0.909
2	23.854	FM	6777.9	255.5	0.4421	89.835	0.849

(*S*)-1-(4-Methoxybenzyl)-3-methylpiperidine, (+)-3ah



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), *p*-methoxybenzylamine (0.20 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 75:25) afforded piperidine (+)-**3ah** (148 mg, 67%, 72:28 er) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.24-7.20 (2H, m, ArH), 6.87-6.83 (2H, m, ArH), 3.80 (3H, s, OCH_3), 3.42 (2H, s, NCH_2Ph), 2.82-2.74 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.83 (1H, td, *J* = 11.2, 3.5 Hz, CH_2-6_{ax}), 1.72-1.49 (5H, m, CH_2-2_b, CH-3, CH_2-4_a, CH_2-5), 0.89-0.80 (1H, m, CH_2-4_b), 0.83 (3H, d, *J* = 6.4 Hz, CH_3).

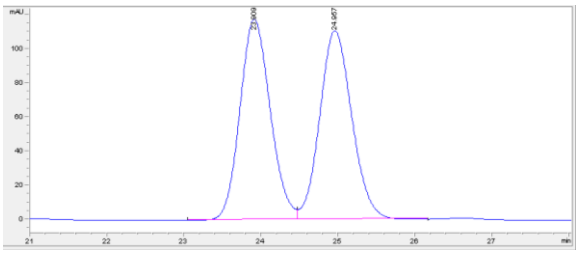
^{13}C NMR (101 MHz, $CDCl_3$) δ = 158.7, 130.8, 130.5, 113.6, 63.1, 62.0, 55.4, 54.0, 33.3, 31.3, 25.7, 19.9.

HRMS: ESI+ found $[M+H]^+$ = 220.1696, $C_{14}H_{22}NO$ requires 220.1696, Δ = 0.12 ppm.

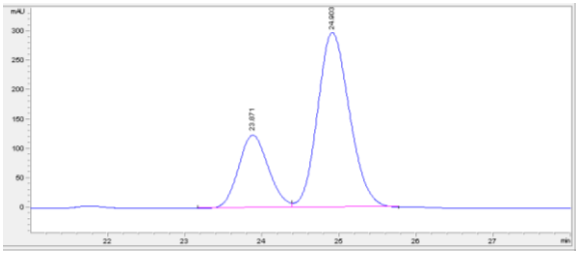
FTIR (film): ν_{max} = 2927, 1613, 1511, 1464, 1300, 1243, 1179, 1121, 1038, 830, 815 cm^{-1}.

$[\alpha]_D^{25}$ = +5.2 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

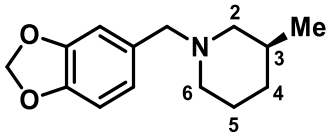


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	23.909	BV	3232.9	118	0.4238	50.056	0.858
2	24.957	VB	3225.7	110.9	0.4492	49.944	0.856



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	23.871	BV	3369.6	124.6	0.4216	28.138	0.87
2	24.903	VB	8605.5	298.8	0.446	71.862	0.824

(*S*)-1-(Benzo[*d*][1,3]dioxol-5-ylmethyl)-3-methylpiperidine, (+)-3ai



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), piperonylamine (0.19 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B**

at 80 °C. Purification by column chromatography (pentane:Et_2O 50:50) afforded piperidine (+)-**3ai** (68 mg, 29%, 64:36 er) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 6.85 (1H, t, *J* = 1.0 Hz, ArH), 6.74-6.72 (2H, m, ArH), 5.93 (2H, s, OCH_2O), 3.38 (2H, s, NCH_2Ph), 2.81-2.73 (2H, m, CH_2-2_a and CH_2-6_{eq}), 1.83 (1H, td, *J* = 11.2, 3.4 Hz, CH_2-6_{ax}), 1.72-1.49 (5H, m, CH_2-2_b, CH-3, CH_2-4_a, CH_2-5), 0.89-0.83 (1H, m, CH_2-4_b), 0.83 (3H, d, *J* = 6.4 Hz, CH_3).

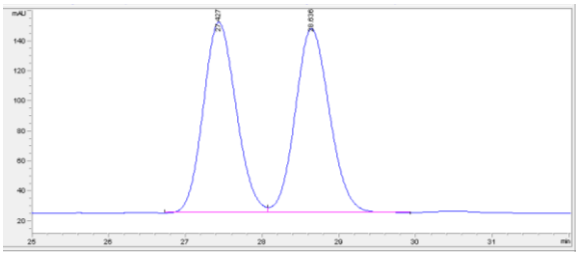
^{13}C NMR (101 MHz, $CDCl_3$) δ = 147.6, 146.5, 132.8, 122.3, 109.7, 107.9, 100.9, 63.5, 62.0, 54.0, 33.2, 31.3, 25.7, 19.9.

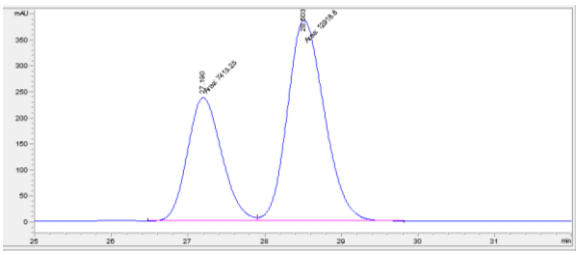
HRMS: ESI+ found $[M+H]^+$ = 234.1488, $C_{14}H_{20}NO_2$ requires 234.1489, Δ = –0.03 ppm.

FTIR (film): ν_{max} = 2927, 2762, 1502, 1488, 1440, 1369, 1339, 1240, 1181, 1159, 1112, 1039, 932 cm^{-1}.

$[\alpha]_D^{25}$ = +3.9 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

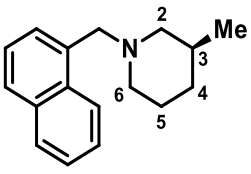




#	Time	Type	Area	Height	Width	Area%	Symmetry
1	27.427	BV	3793.2	127.4	0.4632	49.854	0.862
2	28.636	VB	3815.5	123	0.4818	50.146	0.863

#	Time	Type	Area	Height	Width	Area%	Symmetry
1	27.19	MF	7415.2	237.7	0.52	36.467	0
2	28.503	FM	12918.8	386.4	0.5572	63.533	0.796

(*S*)-3-Methyl-1-(naphthalen-1-ylmethyl)piperidine, (+)-3aj



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), naphthalene-1-ylmethanamine (0.22 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine (+)-**3aj** (82 mg, 34%, 73:27 er) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 8.35-8.32 (1H, m, ArH), 7.86-7.84 (1H, m, ArH), 7.77 (1H, dt, *J* = 7.9, 1.1 Hz, ArH), 7.54-7.39 (4H, m, ArH), 3.92-3.80 (2H, m, NCH_2Ph), 2.89-2.83 (2H, m, CH_2-2_a and CH_2-6_{eq}),

1.97 (1H, td, *J* = 11.1, 3.4 Hz, C$\underline{H_2}$-6$_{ax}$), 1.73-1.49 (5H, m, C$\underline{H_2}$-2$_b$, C$\underline{H}$-3, C$\underline{H_2}$-4$_a$, C$\underline{H_2}$-5), 0.96-0.82 (1H, m, C$\underline{H_2}$-4$_b$), 0.85 (3H, d, *J* = 6.1 Hz, C$\underline{H_3}$).

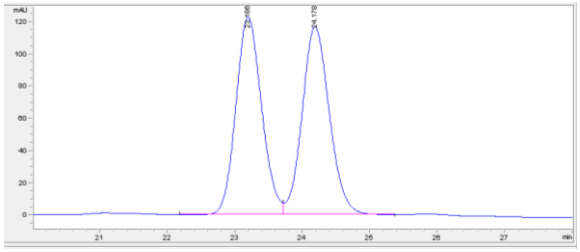
^{13}C NMR (101 MHz, $CDCl_3$) δ = 135.0, 134.0, 132.8, 128.5, 127.7, 127.2, 125.7, 125.6, 125.3, 125.0, 62.5, 61.8, 54.5, 33.3, 31.3, 25.8, 19.9.

HRMS: ESI+ found $[M+H]^+$ = 240.1746, $C_{17}H_{22}N$ requires 240.1747, Δ = 0.48 ppm.

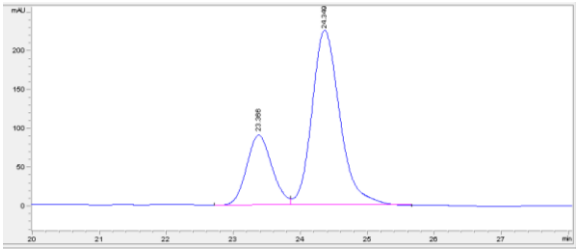
FTIR (film): ν_{max} = 2926, 2801, 2756, 1509, 1465, 1457, 1370, 1341, 1168, 1126, 1117, 975, 791, 783, 772 cm^{-1}.

$[\alpha]_D^{25}$ = +10.1 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

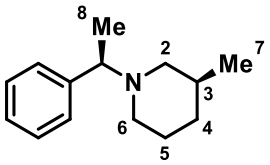


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	23.186	BV	3262.2	122.7	0.4101	49.837	0.862
2	24.178	VB	3283.5	116.8	0.434	50.163	0.851



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	23.366	BV	2387.1	90.4	0.4082	26.761	0.868
2	24.349	VB	6533	225.2	0.4445	73.239	0.784

(*S*)-3-Methyl-1-((*R*)-1-phenylethyl)piperidine, (+)-3ak



(*S*)-2-Methylhexane-1,5-diol[6] **2i** (118 mg, 1.0 mmol, >99:1 er), (*R*)-α-methylbenzylamine (0.19 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and deionised water (0.5 mL) were subjected to **general procedure B** at 80 °C. Analysis of the crude reaction mixture by ^{1}H NMR indicated a dr of 83:17. Purification by column chromatography (pentane:Et_2O 80:20) afforded piperidine (+)-**3ak** (161 mg, 79%, 76:24 er, 85:15 dr) as a colourless oil.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35-7.21 (5H, m, Ar$\underline{H}$), 3.41 (1H, q, *J* = 6.8 Hz, NC$\underline{H}$(CH_3)Ph), 2.98-2.88 (1H, m, C$\underline{H_2}$-6$_{eq}$), 2.76-2.70 (1H, m, C$\underline{H_2}$-2$_{eq}$), 1.85 (1H, td, *J* = 11.1, 3.3 Hz, C$\underline{H_2}$-6$_{ax}$), 1.70-1.51 (4H, m, C$\underline{H}$-3, C$\underline{H_2}$-4$_a$, C$\underline{H_2}$-5), 1.45 (1H, t, *J* = 10.6 Hz, C$\underline{H_2}$-2$_{ax}$), 1.37 (3H, d, *J* = 7.0 Hz, C$\underline{H_3}$-8), 0.87-0.74 (1H, m, C$\underline{H_2}$-4$_b$), 0.78 (3H, d, *J* = 6.4 Hz, C$\underline{H_3}$-7). The minor diastereomer displays diagnostic signals at δ = 3.50

(1H, q, *J* = 6.8 Hz, NC<u>H</u>(CH_3)Ph), 1.76 (1H, td, *J* = 11.3, 3.0 Hz, C<u>H_2-6$_{ax}$</u>), 1.27 (3H, d, *J* = 6.7 Hz, C<u>H_3-8</u>), 0.68 (3H, d, *J* = 6.3 Hz, C<u>H_3-7</u>).

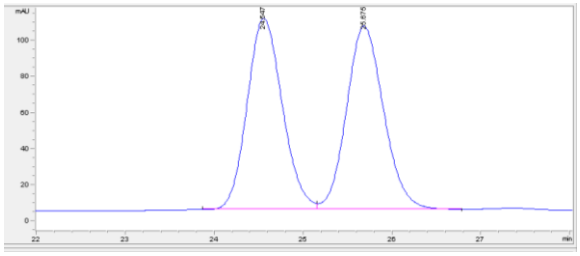
^{13}C NMR (101 MHz, $CDCl_3$) δ = 144.1, 128.1, 127.9, 126.8, 65.0, 59.0, 51.1, 33.4, 31.5, 26.0, 20.0, 19.5. Not all of the signals for the minor diastereoisomer could be distinguished, but peaks were observed at δ = 65.1, 59.2, 51.1, 33.4, 25.6, 19.5, 20.0.

HRMS: ESI+ found $[M+H]^+$ = 204.1748, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.78 ppm.

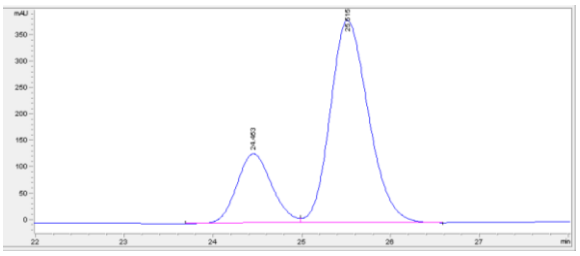
FTIR (film): ν_{max} = 2927, 1492, 1453, 1373, 1125, 1081, 760, 700 cm^{-1}.

$[\alpha]_D^{25}$ = +38.9 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by chiral HPLC analysis of the corresponding *N*-Cbz compound **S4** (synthesised using **general procedure C**, analytic sample isolated by preparative TLC. For full characterisation data for this compound, see **S4**, page S31). Chiralpak® IC column (99:1 hexane:IPA, 0.7 mL min^{-1}, 210 nm, room temperature):

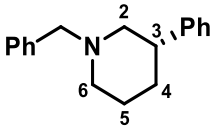


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	24.547	BV	2925.2	106.1	0.4256	49.756	0.856
2	25.675	VB	2953.9	101.6	0.4491	50.244	0.852



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	24.453	BV	3620.4	131.9	0.4262	23.901	0.857
2	25.515	VB	11527.1	384.8	0.4615	76.099	0.787

(*S*)-*N*-Benzyl-3-phenylpiperidine, (–)-3j

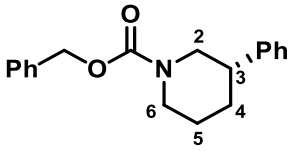


(*S*)-2-Phenylpentane-1,5-diol (+)-**2j** (144 mg, 0.8 mmol, >99:1 er), anhydrous benzylamine (0.13 mL, 1.2 mmol), $[IrCp^*Cl_2]_2$ (6.3 mg, 1 mol%) and water (0.4 mL) were subjected to **general procedure B** at 80 °C. Purification by column chromatography (pentane:Et_2O 90:10) afforded piperidine (–)-**3j** (107 mg, 43%, 67:33 er) as a colourless solid. The spectral data was identical to that of the corresponding racemate described above.

$[\alpha]_D^{25}$ = –10.6 (*c* = 1.0, $CHCl_3$).

The enantiomeric purity was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

Benzyl (*S*)-3-phenylpiperidine-1-carboxylate, S5



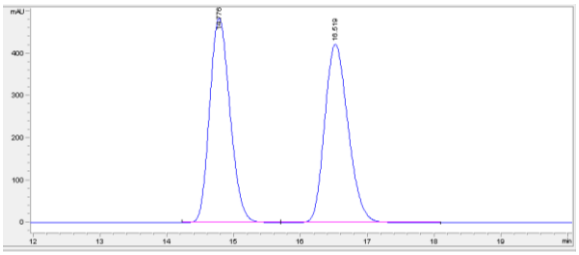
(*S*)-*N*-Benzyl-3-phenylpiperidine (–)-**3j** (30 mg, 0.12 mmol) and benzyl chloroformate (3M in toluene, 0.5 mL, 1.5 mmol) were subjected to **general procedure C**. Purification by column chromatography (pentane:Et_2O 75:25) afforded piperidine **S5** (36 mg, 99%, 67:33 er) as a colourless oil. The corresponding racemic piperidine *rac*-**S5** was prepared by an identical procedure starting from *rac*-**3j**. *The data is consistent with the literature.*[19]

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.37-7.21 (10H, m, ArH), 5.16 (2H, s, OCH_2Ph), 4.38-4.20 (2H, br. m, CH_2-2_a and CH_2-6_a), 2.89-2.66 (3H, br. m, CH_2-2_b, CH-3 and CH_2-6_b), 2.07-2.02 (1H, m, CH_2-4_a), 1.84-1.55 (3H, m, CH_2-4_b and CH_2-5). *Some of the signals appear broad due to the rotameric nature of the carbamate.*

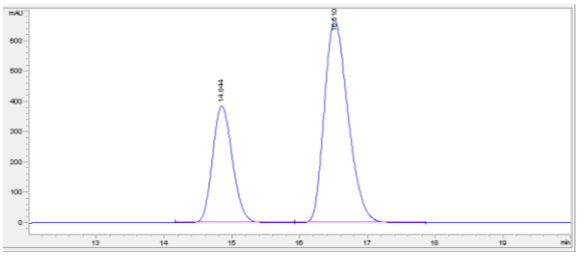
^{13}C NMR (101 MHz, $CDCl_3$) δ = 155.4, 143.4, 137.1, 128.7, 128.6, 128.1, 128.0, 127.2, 126.8, 67.2, 50.8, 44.5, 42.8, 31.9, 25.6. *Some of the signals appear broad due to the rotameric nature of the carbamate.*

$[\alpha]_D^{25}$ = –18.8 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IB-N column (99:1 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature):

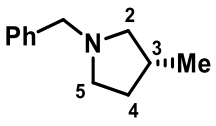


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	14.776	BB	10215.3	482.9	0.3328	49.899	0.823
2	16.519	BB	10256.5	420.6	0.3825	50.101	0.794



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	14.844	BB	7853.8	384.5	0.3203	32.585	0.842
2	16.51	BB	16249.1	667.1	0.3802	67.415	0.737

(*R*)-*N*-Benzyl-3-methylpyrrolidine, (–)-3l



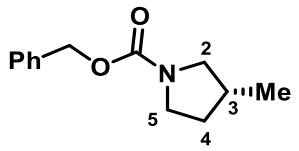
To a 2-5 mL Biotage® microwave vial equipped with a stirrer bar was added (*R*)-2-methylpentane-1,4-diol[20] (*R*)-**2l** (104 mg, 1.0 mmol, >99:1 er), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and $CsHCO_3$ (3.9 mg, 2.0 mol%). The vial was sealed with a microwave vial crimp cap (containing a Reseal® septum), evacuated under vacuum and refilled with argon three times. Cyclopentyl methyl ether (0.5 mL) was

added *via* syringe, followed by anhydrous benzylamine (0.16 mL, 1.5 mmol). The vial was sealed with Parafilm®, placed in a preheated oil bath and stirred at 110 °C for 24 hours. The reaction mixture was cooled to room temperature and concentrated under a flow of nitrogen. Purification by column chromatography (pentane:Et_2O 80:20, SiO_2 was basified with Et_3N prior to use, see General Information for details) afforded pyrrolidine (–)-**3l** (126 mg, 72%, 94:6 er) as a colourless oil. The spectral data was identical to that of the corresponding racemate described above.

$[\alpha]_D^{25}$ = –5.2 (*c* = 1.0, $CHCl_3$).

The enantiomeric purity was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

Benzyl (*R*)-3-methylpyrrolidine-1-carboxylate, S6



(*R*)-*N*-benzyl-3-methylpyrrolidine (–)-**3l** (19 mg, 0.08 mmol) and benzyl chloroformate (3 M in toluene, 0.5 mL, 1.5 mmol) were subjected to **general procedure C**. Purification by column chromatography (pentane:Et_2O 80:20) afforded pyrrolidine **S6** (28 mg, 38%, 94:6 er) as a colourless oil. The corresponding racemic Cbz-pyrrolidine *rac*-**S6** was prepared by an identical procedure starting from *rac*-**3l**. *The data are consistent with the literature.*[21]

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.39-7.26 (5H, m, ArH), 5.13 (2H, s, OCH_2Ph), 3.63-3.50 (2H, m, CH_2-2_a and CH_2-5_a), 3.40-3.30 (1H, m, CH_2-5_b), 2.98-2.85 (1H, m, CH_2-2_b), 2.31-2.17 (1H, m, CH-3), 2.02-1.94 (1H, m, CH_2-4_a), 1.55-1.45 (1H, m, CH_2-4_b), 1.05 (3H, m, CH_3).

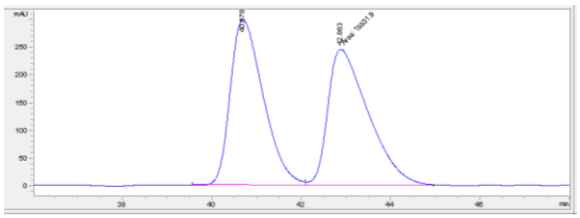
^{13}C NMR (101 MHz, $CDCl_3$) δ = 155.0, 137.3, 128.6, 128.0, 127.9, 66.72, 66.69, 53.4, 53.0, 46.2, 45.8, 33.8, 33.7, 33.0, 32.9, 17.8. *N.B. The majority of the signals are doubled due to the rotameric nature of the carbamate.*

HRMS: ESI+ found $[M+Na]^+$ = 242.1153, $C_{13}H_{17}NO_2Na$ requires 242.1152, Δ = 0.54 ppm.

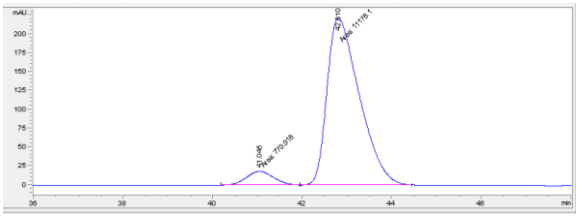
FTIR (film): ν_{max} = 2959, 2874, 1702, 1419, 1358, 1216, 1177, 1149, 1133, 1103, 1074 cm^{-1}.

$[\alpha]_D^{25}$ = +18.5 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IB-N column (99:1 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature):

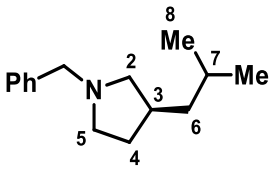


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	40.678	BV	15420.7	299.4	0.7928	49.820	0.589
2	42.863	MF	15531.9	246.4	1.0507	50.180	0.458



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	41.045	MF	770	18.2	0.7043	6.446	0.914
2	42.81	FM	11176.1	221.9	0.8395	93.554	0.528

(*S*)-1-Benzyl-3-isobutylpyrrolidine, (+)-3al



To a 2-5 mL Biotage® microwave vial equipped with a stirrer bar was added (*S*)-2-isobutylbutane-1,4-diol (–)-**2al** (146 mg, 1.0 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and $CsHCO_3$ (3.9 mg, 2.0 mol%). The vial was sealed with a microwave vial crimp cap (containing a Reseal® septum), evacuated under vacuum and refilled with argon three times. Cyclopentyl methyl ether (0.5 mL) was added *via* syringe, followed by anhydrous benzylamine (0.16 mL, 1.5 mmol). The vial was sealed with Parafilm®, placed in a preheated oil bath and stirred at 110 °C for 24 hours. The reaction mixture was cooled to room temperature and concentrated under a flow of nitrogen. Purification by column chromatography (pentane:Et_2O 75:25, SiO_2 was basified with Et_3N prior to use, see General Information for details) afforded pyrrolidine (+)-**3al** (169 mg, 78%, 89:11 er) as a colourless oil. The corresponding racemic pyrrolidine *rac*-**3al** was prepared by an identical procedure starting from *rac*-**2al**.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.35 – 7.21 (5H, m, ArH), 3.61 (1H, d, *J* = 12.8 Hz, $NCH_{2a}Ph$), 3.57 (1H, d, *J* = 12.8 Hz, $NCH_{2b}Ph$), 2.84 (1H, dd, *J* = 9.0, 7.4 Hz, CH_2-2_a), 2.72 (1H, ddd, *J* = 9.2, 8.0, 5.2 Hz, CH_2-5_a), 2.39 (1H, td, *J* = 8.9, 6.5 Hz, CH_2-5_b), 2.31 – 2.18 (1H, m, CH-3), 2.04 – 1.94 (2H, m, CH_2-2_b and CH_2-4_a), 1.60 – 1.45 (1H, nonet, *J* = 6.7 Hz, CH-7), 1.36 (1H, dddd, *J* = 12.2, 8.6, 6.7, 5.3 Hz, CH_2-4_b), 1.24 (2H, t, *J* = 7.2 Hz, CH_2-6), 0.87 (3H, d, *J* = 6.6 Hz, CH_3-8a), 0.85 (3H, d, *J* = 6.6 Hz, CH_3-8b).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.6, 129.0, 128.3, 126.9, 61.1, 61.0, 54.1, 45.2, 35.5, 31.1, 26.9, 22.9, 22.9.

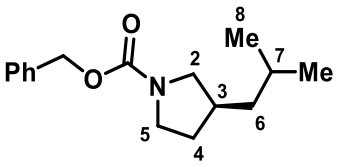
HRMS: ESI+ found $[M+H]^+$ = 218.1904, $C_{15}H_{24}N$ requires 218.1903, Δ = 0.26 ppm.

FTIR (film): ν_{max} = 2954, 2783, 1467, 1454, 1382, 1351, 1155, 1132, 738, 698 cm^{-1}.

$[\alpha]_D^{25}$ = +10.2 (*c* = 1.0, $CHCl_3$).

The enantiomeric purity was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

Benzyl (*S*)-3-isobutylpyrrolidine-1-carboxylate, S7



(*S*)-1-Benzyl-3-isobutylpyrrolidine (+)-**3al** (30 mg, 0.14 mmol) and benzyl chloroformate (3 M in toluene, 0.28 mL, 0.83 mmol) were subjected to **general procedure C**. Purification by column chromatography afforded piperidine **S7** (19 mg, 53%, 89:11 e.r.). The corresponding racemic Cbz-pyrrolidine *rac*-**S7** was prepared by an identical procedure starting from *rac*-**3al**.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.40 – 7.27 (5H, m, ArH), 5.13 (2H, s, OCH_2Ph), 3.67 – 3.47 (2H, m, CH_2-2_a and CH_2-5_a), 3.37-3.26 (1H, m, CH_2-5_b), 2.96 – 2.83 (1H, m, CH_2-2_b), 2.29 – 2.12 (1H, m, CH-3), 2.06 – 1.93 (1H, m, CH_2-4_a), 1.64 – 1.39 (2H, m, CH-7 and CH_2-4_b), 1.31 – 1.21 (2H, m, CH_2-6), 0.95 – 0.86 (6H, m, 2 x CH_3-8).

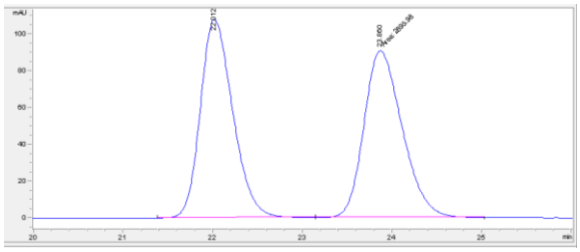
^{13}C NMR (101 MHz, $CDCl_3$) δ = 155.0, 137.3, 128.6, 128.0, 128.0, 128.0, 127.9, 66.7, 66.7, 52.1, 51.7, 46.2, 45.7, 42.6, 42.6, 37.2, 36.3, 32.3, 31.5, 26.9, 26.8, 23.0, 22.9, 22.8, 22.8. *N.B. The majority of the signals are doubled due to the rotameric nature of the carbamate.*

HRMS: ESI+ found $[M+Na]^+$ = 284.1621, $C_{16}H_{23}O_2NNa$ requires 284.1621, Δ = –0.08 ppm.

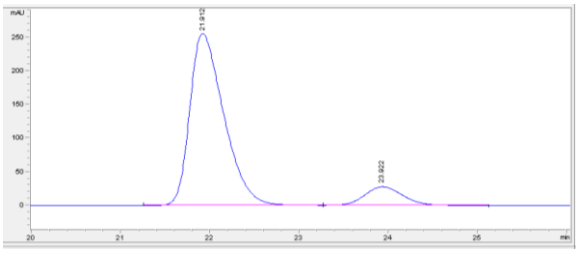
FTIR (film): ν_{max} = 2955, 1704, 1418, 1359, 1109, 768, 697 cm^{-1}.

$[\alpha]_D^{25}$ = –21.4 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IA column (99:1 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature):

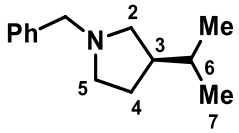


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	22.012	BB	2707.9	107.8	0.3872	50.111	0.729
2	23.86	MF	2696	90.6	0.4961	49.889	0.728



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	21.912	BB	6768.1	256.1	0.4043	89.309	0.577
2	23.922	BB	810.2	27.6	0.4544	10.691	0.842

(*R*)-1-Benzyl-3-isopropylpyrrolidine, (+)-3am



To a 2-5 mL Biotage® microwave vial equipped with a stirrer bar was added (*R*)-2-isopropylbutane-1,4-diol (–)-**2am** (132 mg, 1.0 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and $CsHCO_3$ (3.9 mg, 2.0 mol%). The vial was sealed with a microwave vial crimp cap (containing a Reseal® septum), evacuated under vacuum and refilled with argon three times. Cyclopentyl methyl ether (0.5 mL) was added *via* syringe, followed by anhydrous benzylamine (0.16 mL, 1.5 mmol). The vial was sealed with Parafilm®, placed in a preheated oil bath and stirred at 110 °C for 24 hours. The reaction mixture was cooled to room temperature and concentrated under a flow of nitrogen. Purification by column chromatography (pentane:Et_2O 75:25, SiO_2 was basified with Et_3N prior to use, see General Information for details) afforded pyrrolidine (+)-**3am** (155 mg, 76%, 92:8 er) as a colourless oil. The corresponding racemic pyrrolidine *rac*-**3am** was prepared by an identical procedure starting from *rac*-**2am**.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.29 – 7.13 (5H, m, ArH), 3.54 (1H, d, *J* = 12.8 Hz, NCH_{2a}Ph), 3.49 (1H, d, *J* = 12.8 Hz, NCH_{2b}Ph), 2.74 (1H, dd, *J* = 9.0, 7.4 Hz, CH_2-2$_a$), 2.71 – 2.63 (1H, m, CH_2-5$_a$), 2.28 (1H, td, *J* = 8.9, 6.2 Hz, CH_2-5$_b$), 1.98 (1H, t, *J* = 8.6 Hz, CH_2-2$_b$), 1.92 – 1.72 (2H, m, CH_2-4$_a$ and CH-3), 1.45 – 1.31 (2H, m, CH_2-4$_b$ and CH-6), 0.81 (3H, d, *J* = 6.6 Hz, CH_3-7a), 0.77 (3H, d, *J* = 6.6 Hz, CH_3-7b).

^{13}C NMR (101 MHz, $CDCl_3$) δ = 139.6, 129.0, 128.3, 126.9, 61.2, 59.2, 54.4, 45.6, 33.2, 29.2, 21.5, 21.3.

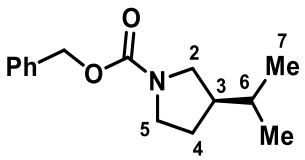
HRMS: ESI+ found $[M+H]^+$ = 204.1747, $C_{14}H_{22}N$ requires 204.1747, Δ = 0.33 ppm.

FTIR (film): ν_{max} = 2956, 2784, 1453, 1377, 1154, 737, 698 cm^{-1}.

$[\alpha]_D^{25}$ = +5.5 (*c* = 1.0, $CHCl_3$).

The enantiomeric purity was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

Benzyl (*R*)-3-isopropylpyrrolidine-1-carboxylate, S8



(*R*)-1-Benzyl-3-isopropylpyrrolidine (+)-**3am** (30 mg, 0.15 mmol) and benzyl chloroformate (3 M in toluene, 0.29 mL, 0.89 mmol) were subjected to **general procedure C**. Purification by column

chromatography afforded piperidine **S8** (13 mg, 36%, 92:8 e.r.). The corresponding racemic Cbz-pyrrolidine *rac*-**S8** was prepared by an identical procedure starting from *rac*-**3am**.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.41 – 7.27 (5H, m, ArH), 5.13 (2H, s, OCH_2Ph), 3.70 – 3.52 (2H, m, CH_2-2_a and CH_2-5_a), 3.34 – 3.24 (1H, m, CH_2-5_b), 2.99 – 2.89 (1H, m, CH_2-2_b), 2.06 – 1.95 (1H, m, CH_2-4_a), 1.90 – 1.74 (1H, m, CH-3), 1.57 – 1.41 (2H, m, CH-6 and CH_2-4_b), 0.95 – 0.89 (6H, m, 2 x CH_3-7).

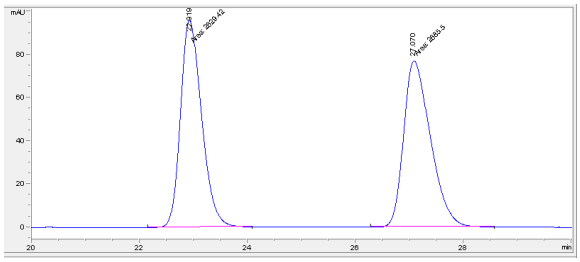
^{13}C NMR (101 MHz, $CDCl_3$) δ = 155.0, 137.3, 128.6, 128.1, 128.0, 128.0, 66.7, 66.7, 50.9, 50.4, 46.9, 46.7, 46.3, 46.1, 32.1, 30.6, 29.8, 21.6, 21.3, 21.3. *N.B. The majority of the signals are doubled due to the rotameric nature of the carbamate.*

HRMS: ESI+ found $[M+H]^+$ = 248.1646, $C_{15}H_{22}O_2N$ requires 248.1645, Δ = 0.55 ppm.

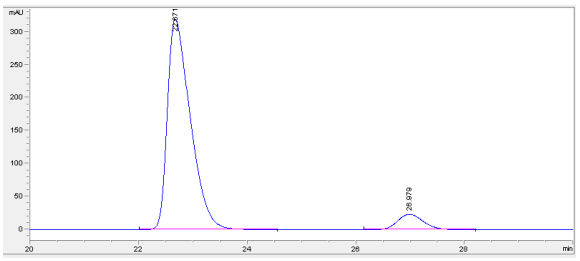
FTIR (film): ν_{max} = 2959, 1703, 1418, 1359, 1106, 798, 697 cm^{-1}.

$[\alpha]_D^{25}$ = –32.4 (*c* = 1.0, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IA column (99:1 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature):

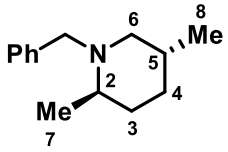


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	22.919	MF	2629.4	96.4	0.4544	49.473	0.722
2	27.07	MF	2685.5	77.5	0.5775	50.527	0.618



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	22.671	BB	9385.3	318.8	0.4475	92.375	0.501
2	26.979	BB	774.7	23.5	0.5112	7.625	0.801

(2*R*,5*R*)-1-Benzyl-2,5-dimethylpiperidine, 3o



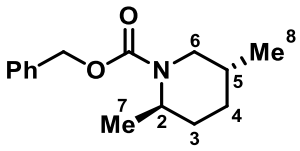
(2*R*,5*R*)-2-Methylhexane-1,5-diol (+)-**2o** (132 mg, 1.0 mmol, ~53:47 dr, 94:6 er), anhydrous benzylamine (0.16 mL, 1.5 mmol), $[IrCp^*Cl_2]_2$ (8.0 mg, 1.0 mol%) and water (0.5 mL) were subjected to **general procedure B** at 110 °C. ^{1}H NMR analysis of the crude reaction mixture indicated the presence of two diastereomers in 63:37 dr. Purification by column chromatography (pentane:Et_2O 95:5) afforded piperidine (–)-**3o$_{major}$** (105 mg, 52%, >95:5 dr, 75:25 er) as a colourless oil and piperidine (+)-**3o$_{minor}$** (50 mg, 25%, >95:5 dr, 75:25 er) as a colourless oil. The spectral data for both diastereoisomers was identical to that of the corresponding racemate described above.

(–)-**3o$_{major}$**: $[\alpha]_D^{25}$ = –65.2 (*c* = 2.1, $CHCl_3$).

(+)-**3o$_{minor}$**: $[\alpha]_D^{25}$ = +2.4 (*c* = 0.7, $CHCl_3$).

The enantiomeric purity of each diastereoisomer was determined by chiral HPLC analysis after conversion to the corresponding benzyl carbamate (see below).

Benzyl (2*R*,5*R*)-2,5-dimethylpiperidine-1-carboxylate, S9



N-benzyl-(2*R*,5*R*)-2,5-dimethylpiperidine (–)-**3o**$_{major}$ (26 mg, 0.13 mmol) and benzyl chloroformate (3 M in toluene, 0.5 mL, 1.5 mmol) were subjected to **general procedure C**. Purification by column chromatography afforded piperidine **S9** (31 mg, 98%, 75:25 er, >95:5 dr). The corresponding racemic piperidine *rac*-**S9** was prepared by an identical procedure starting from *rac*-**3o**$_{major}$.

^{1}H NMR (400 MHz, $CDCl_3$) δ = 7.37-7.28 (5H, m, ArH), 5.16-5.10 (2H, m, OCH_2Ph), 4.46-4.39 (1H, m, CH-2), 3.73 (1H, dt, *J* = 13.6, 2.3 Hz, CH_2-6$_a$), 3.13 (1H, dd, *J* = 13.5, 3.4 Hz, CH_2-6$_b$), 1.96-1.78 (3H, m, CH_2-3$_a$, CH_2-4$_a$ and CH-5), 1.32-1.25 (2H, m, CH_2-3$_b$ and CH_2-4$_b$), 1.13 (3H, d, *J* = 6.9 Hz, CH_3-7), 0.98 (3H, d, *J* = 6.9 Hz, CH_3-8).

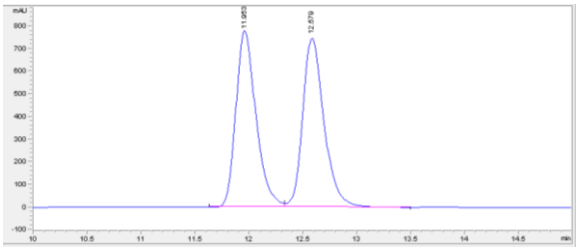
^{13}C NMR (101 MHz, $CDCl_3$) δ = 156.1, 137.3, 128.6, 127.9, 127.8, 66.9, 46.8, 44.0, 27.8, 24.9, 24.8, 16.7, 16.3.

HRMS: ESI+ found $[M+H]^+$ = 248.1646, $C_{15}H_{22}O_2N$ requires 248.1645, Δ = 0.24 ppm.

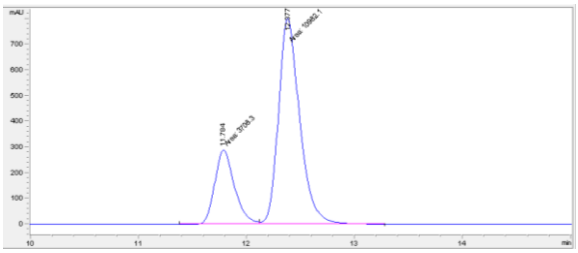
FTIR (film): ν_{max} = 2936, 1693, 1423, 1355, 1336, 1308, 1260, 1244, 1159, 1076, 1029, 697 cm^{-1}.

$[\alpha]_D^{25}$ = –14.2 (*c* = 1.4, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IA column (99:1 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature):

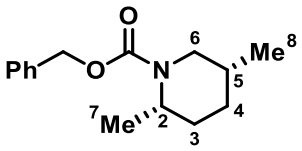


#	Time	Type	Area	Height	Width	Area%	Symmetry
1	11.953	BV	10199.6	783.4	0.1979	49.627	0.717
2	12.579	VB	10352.8	749.9	0.2091	50.373	0.722



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	11.784	MF	3708.3	289.3	0.2137	25.243	0.764
2	12.377	FM	10982.1	800.2	0.2287	74.757	0.728

Benzyl (2*S*,5*R*)-2,5-dimethylpiperidine-1-carboxylate, S10



N-benzyl-(2*S*,5*R*)-2,5-dimethylpiperidine (+)-**3o$_{minor}$** (25 mg, 0.12 mmol) and benzyl chloroformate (3M in toluene, 0.5 mL, 1.5 mmol) were subjected to **general procedure C**. Purification by column chromatography afforded piperidine **S10** (29 mg, 95%, 75:25 er, >95:5 dr). The corresponding racemic piperidine *rac*-**S10** was prepared by an identical procedure starting from *rac*-**3o$_{minor}$**.

^{1}H NMR (400 MHz, $CDCl_3$,) δ = 7.39-7.28 (5H, m, ArH), 5.13 (2H, s, OCH_2Ph), 4.53-4.40 (1H, m, CH-2), 4.02-3.86 (1H, m, CH_2-6$_a$), 2.53-2.43 (1H, m, CH_2-6$_b$), 1.74-1.63 (1H, m, CH_2-3$_a$), 1.60-1.44 (3H, m, CH_2-3$_b$, CH_2-4$_a$ and CH-5), 1.30-1.19 (1H, m, CH_2-4$_b$), 1.13 (3H, d, *J* = 7.0 Hz, CH_3-7), 0.89 (3H, d, *J* = 6.3 Hz, CH_3-8).

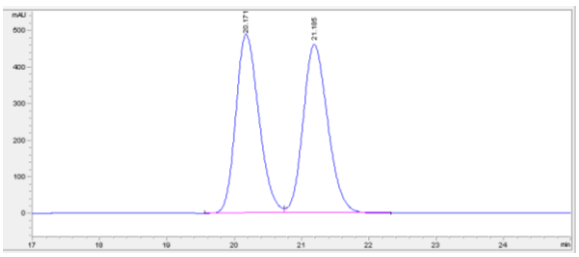
^{13}C NMR (101 MHz, $CDCl_3$) δ = 156.1, 137.3, 128.6, 128.0, 127.9, 67.0, 45.8, 31.5, 30.2, 27.6, 19.4, 16.2. N.B. the carbonyl peak was not observed presumably due to restricted N-CO bond rotation on the NMR timescale.

HRMS: ESI+ found $[M+H]^+$ = 248.1646, $C_{15}H_{22}O_2N$ requires 248.1645, Δ = 0.55 ppm.

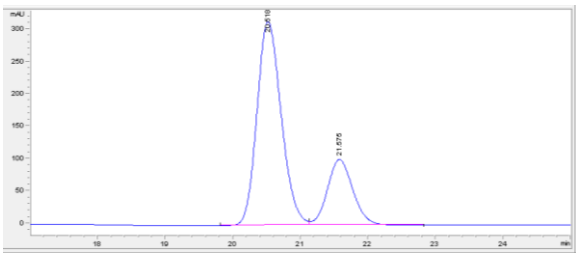
FTIR (film): ν_{max} = 2936, 1693, 1423, 1336, 1308, 1260, 1244, 1159, 1146, 1076, 1029, 697 cm^{-1}.

$[\alpha]_D^{25}$ = +5.0 (*c* = 1.6, $CHCl_3$).

HPLC: Enantiomeric excess was determined by HPLC with a Chiralpak® IA column (99:1 hexane:IPA, 1.0 mL min^{-1}, 210 nm, room temperature):



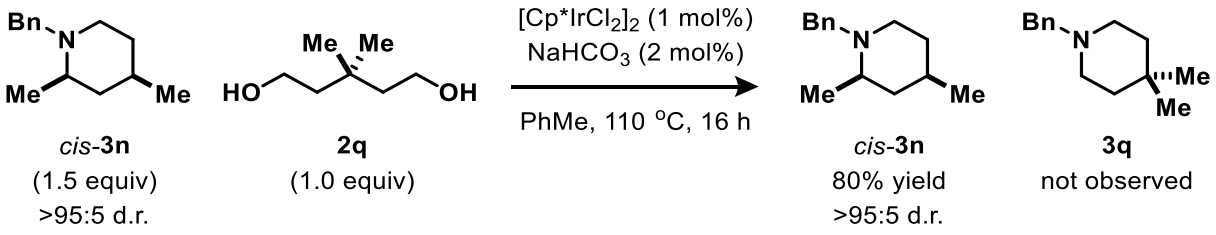
#	Time	Type	Area	Height	Width	Area%	Symmetry
1	20.171	BV	11669.3	489.1	0.3704	49.751	0.773
2	21.185	VB	11786.3	461.8	0.3938	50.249	0.785



#	Time	Type	Area	Height	Width	Area%	Symmetry
1	20.518	BV	7882.2	315.8	0.3852	74.707	0.8
2	21.575	VB	2668.6	101.7	0.4042	25.293	0.853

4.3 Resubjection Experiment

To test whether the saturated aza-heterocycle products can undergo epimerization under the reaction conditions, isomerically pure *cis*-**3n** was resubjected to the optimized reaction conditions:



cis-**3n** (1.5 equiv) >95:5 d.r.

2q (1.0 equiv)

cis-**3n** 80% yield >95:5 d.r.

3q not observed

Procedure: 3,3-Dimethylpentane-1,5-diol[6] **2q** (15 mg, 0.12 mmol), *cis*-**3n** (35 mg, 0.17 mmol, >95:5 d.r.), $[IrCp^*Cl_2]_2$ (0.9 mg, 1.0 mol%), $NaHCO_3$ (0.2 mg, 2.0 mol%) and anhydrous toluene (0.06 mL) were subjected to **general procedure A** at 110 °C. Purification by column chromatography (pentane:Et_2O 75:25) afforded piperidine *cis*-**3n** (28 mg, 80%, >95:5 d.r.) as a colourless oil. The spectral data of *cis*-**3n** (>95:5 d.r.) was identical to that described above. No signals corresponding to the minor diastereoisomer were observed in the ^{1}H-NMR spectra of either the purified material or the crude reaction mixture. Additionally, no formation of crossover product **3q** was observed. These results imply that epimerization of the products does not occur under the reaction conditions via reversible amine dehydrogenation.

5. References

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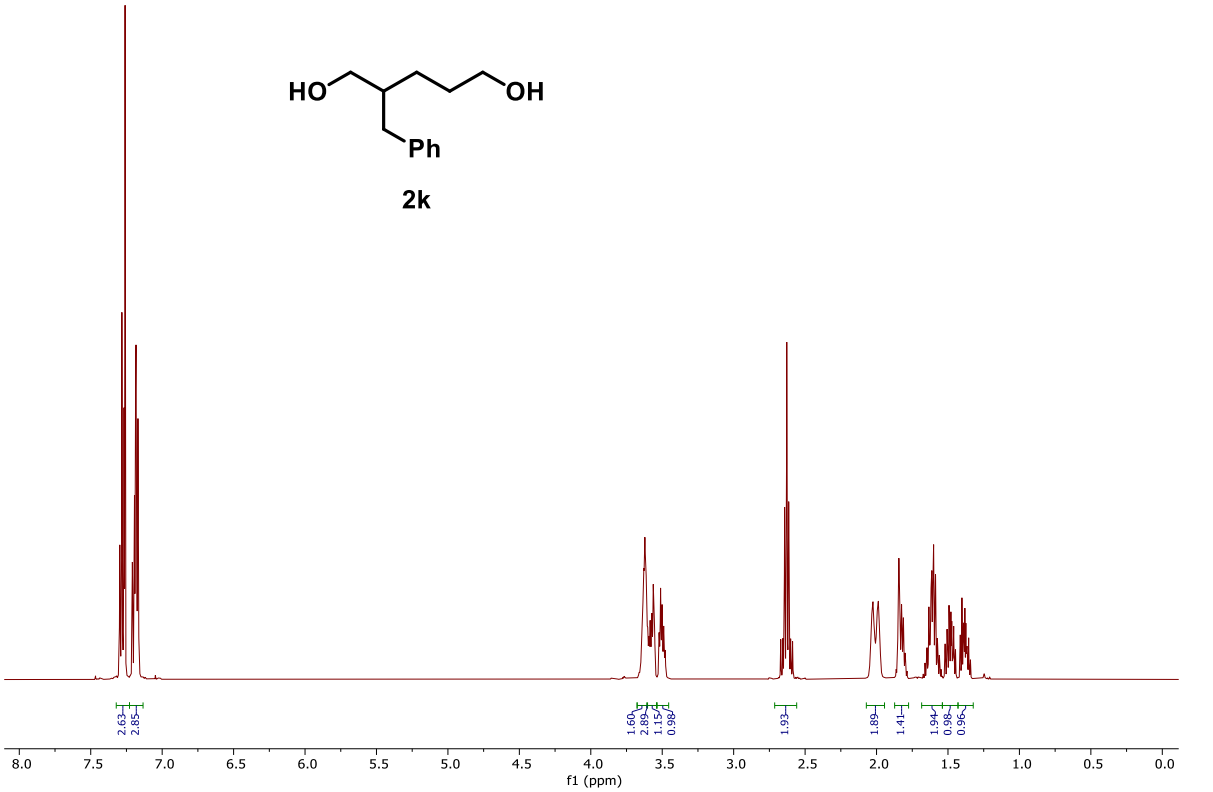
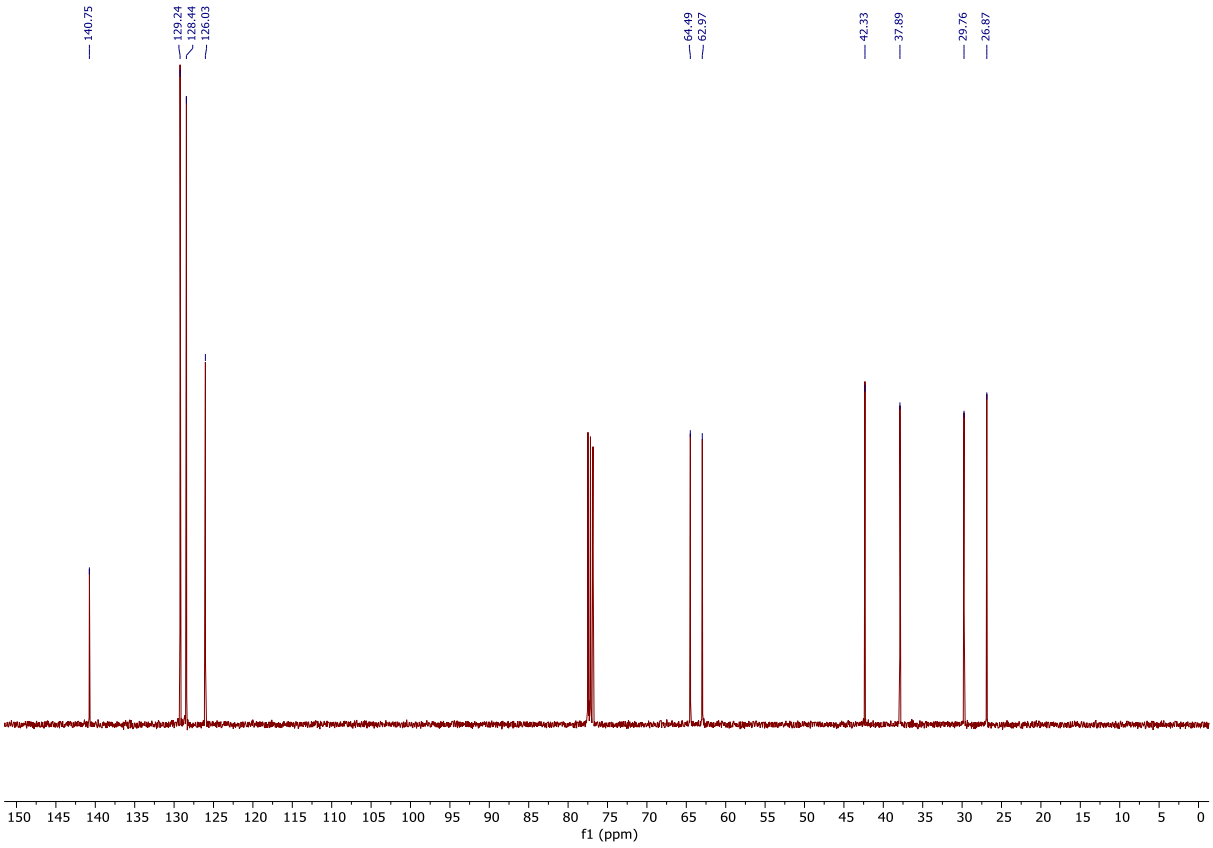
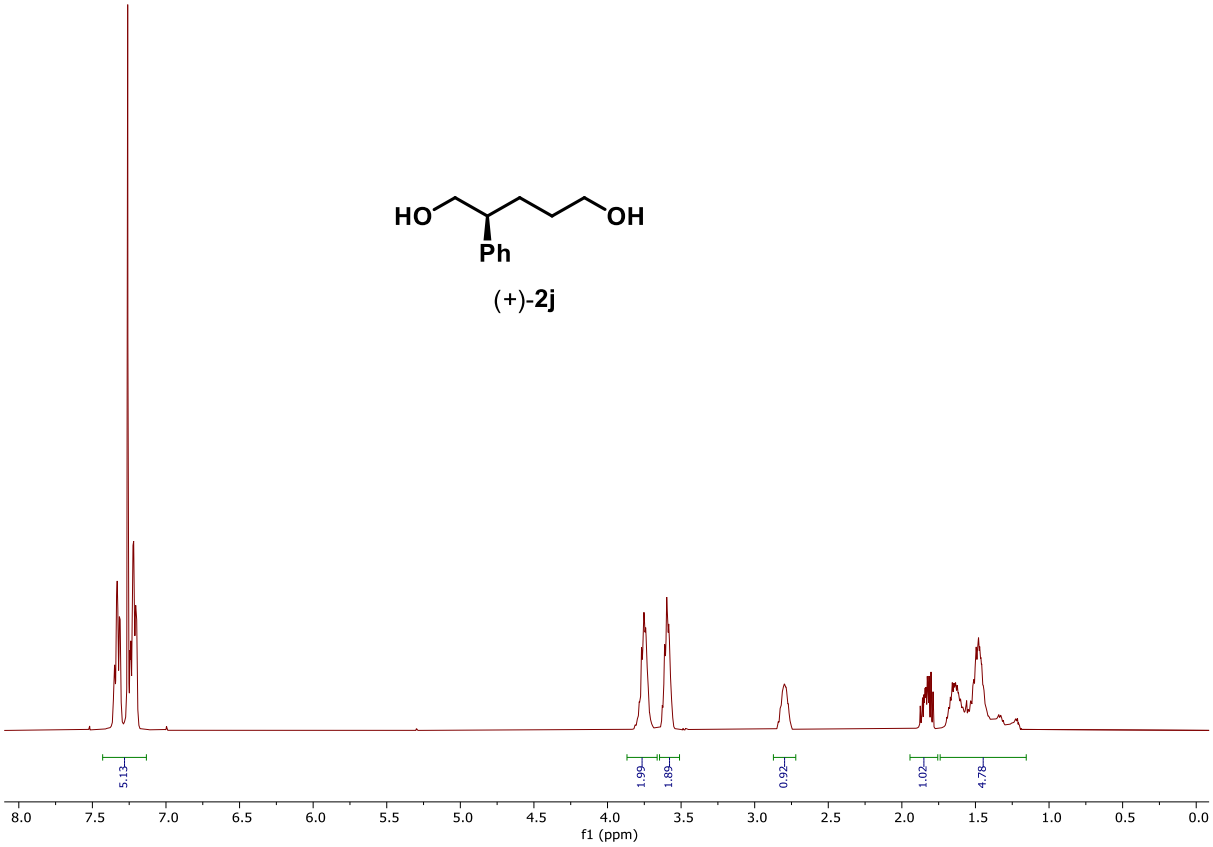
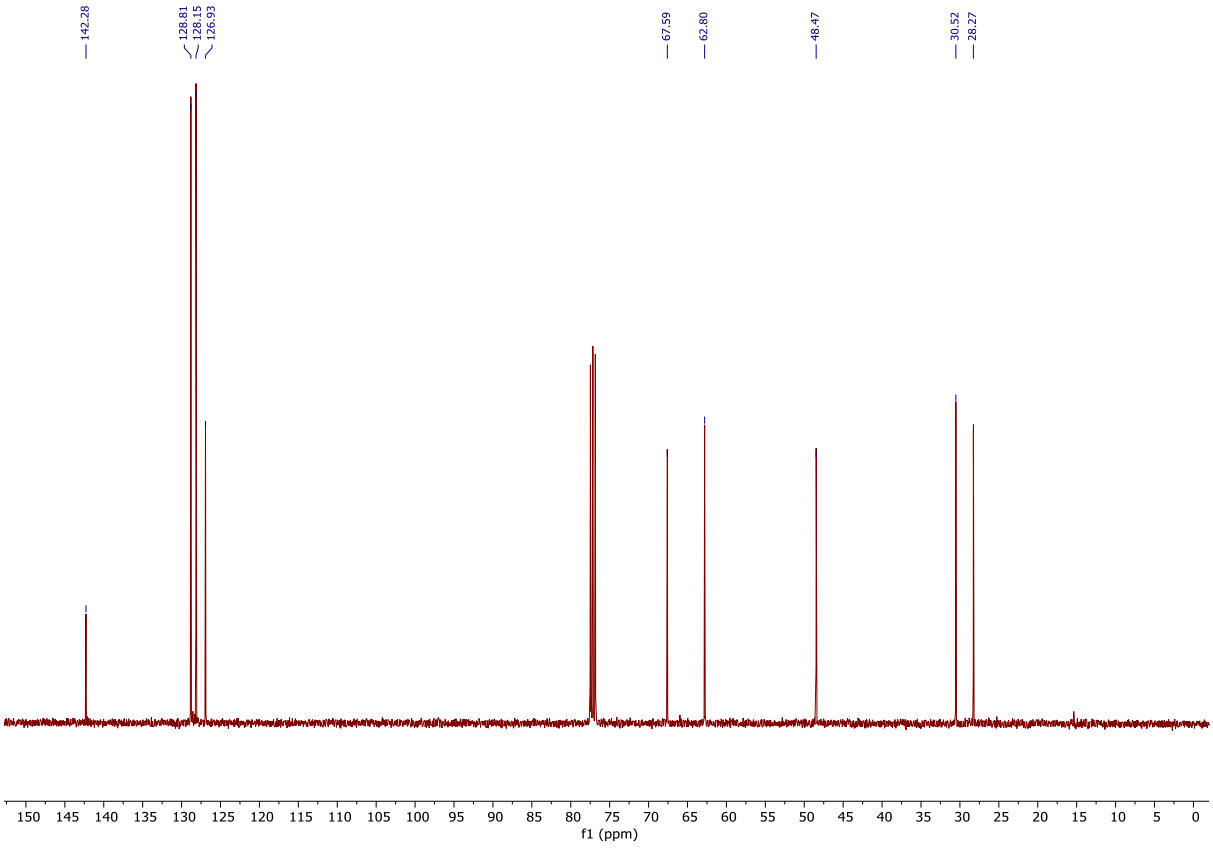
6. NMR Spectra

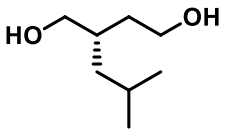





HO
OH
Ph
5.13
1.99
1.89
0.92
1.02
4.78
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

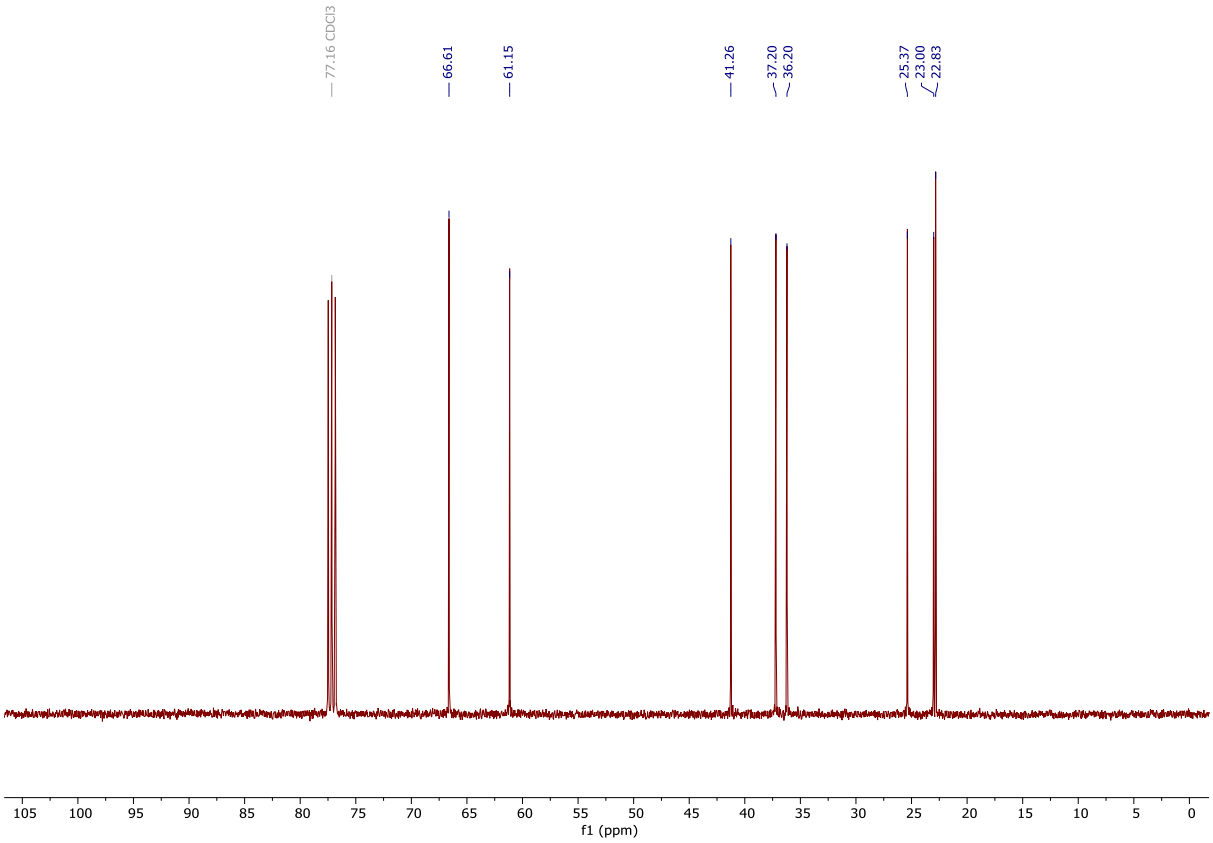
(+)-**2j**

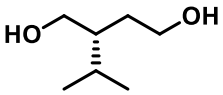

142.28
128.81
128.15
126.93
67.59
62.80
48.47
30.52
28.27
150 145 140 135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


HO
OH

(–)-**2al**

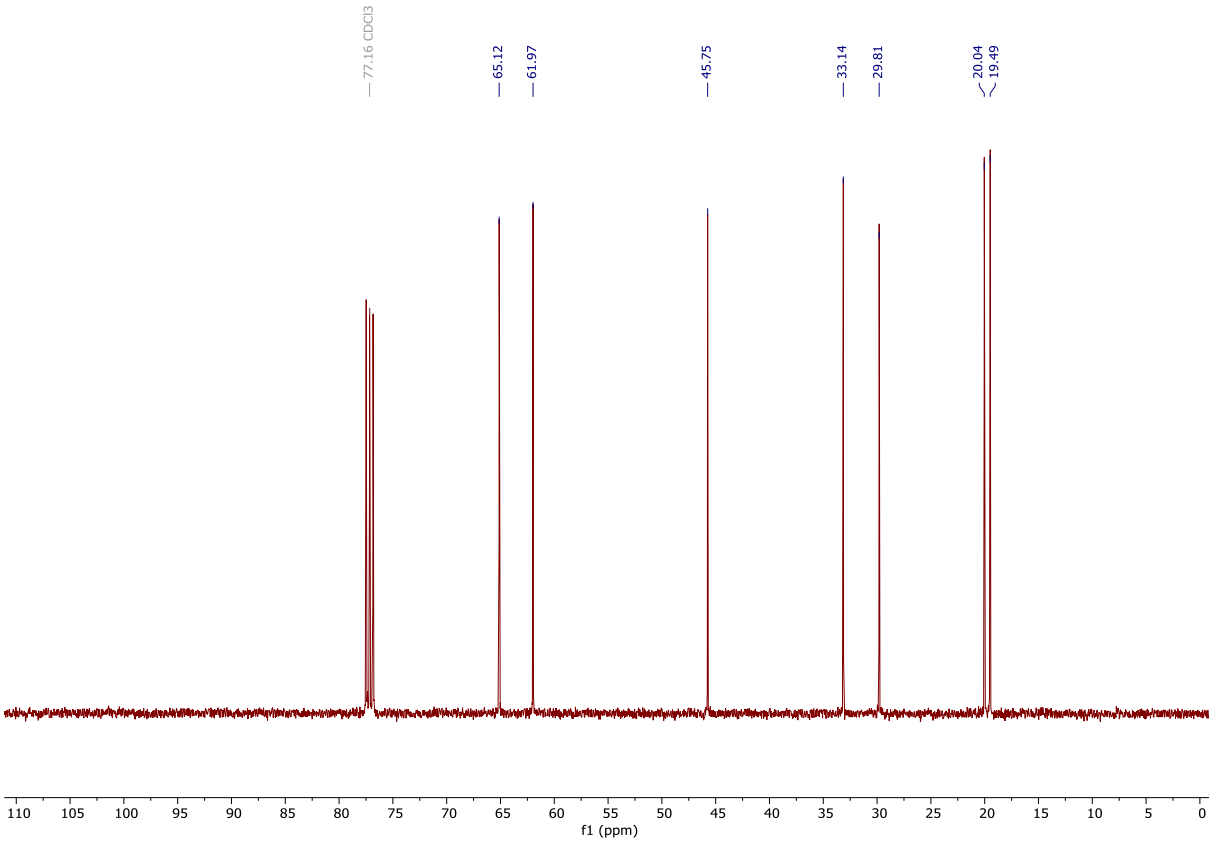
1.01
3.99
1.04
4.06
1.02
1.05
6.05
f1 (ppm)


77.16 CDCl3
66.61
61.15
41.26
37.20
36.20
25.37
23.00
22.83
f1 (ppm)


HO
OH

(–)-**2am**

1.02
2.85
1.14
1.02
1.99
1.03
0.97
6.00
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5
f1 (ppm)


77.16 CDCl3
65.12
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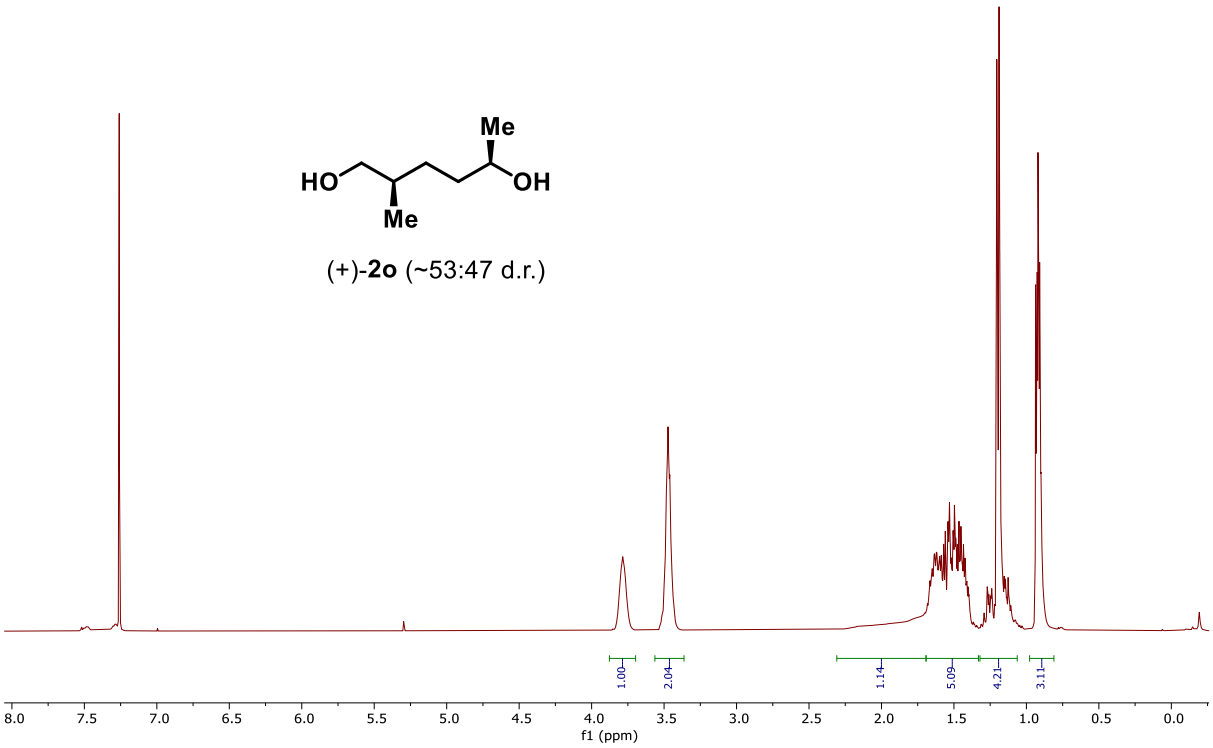
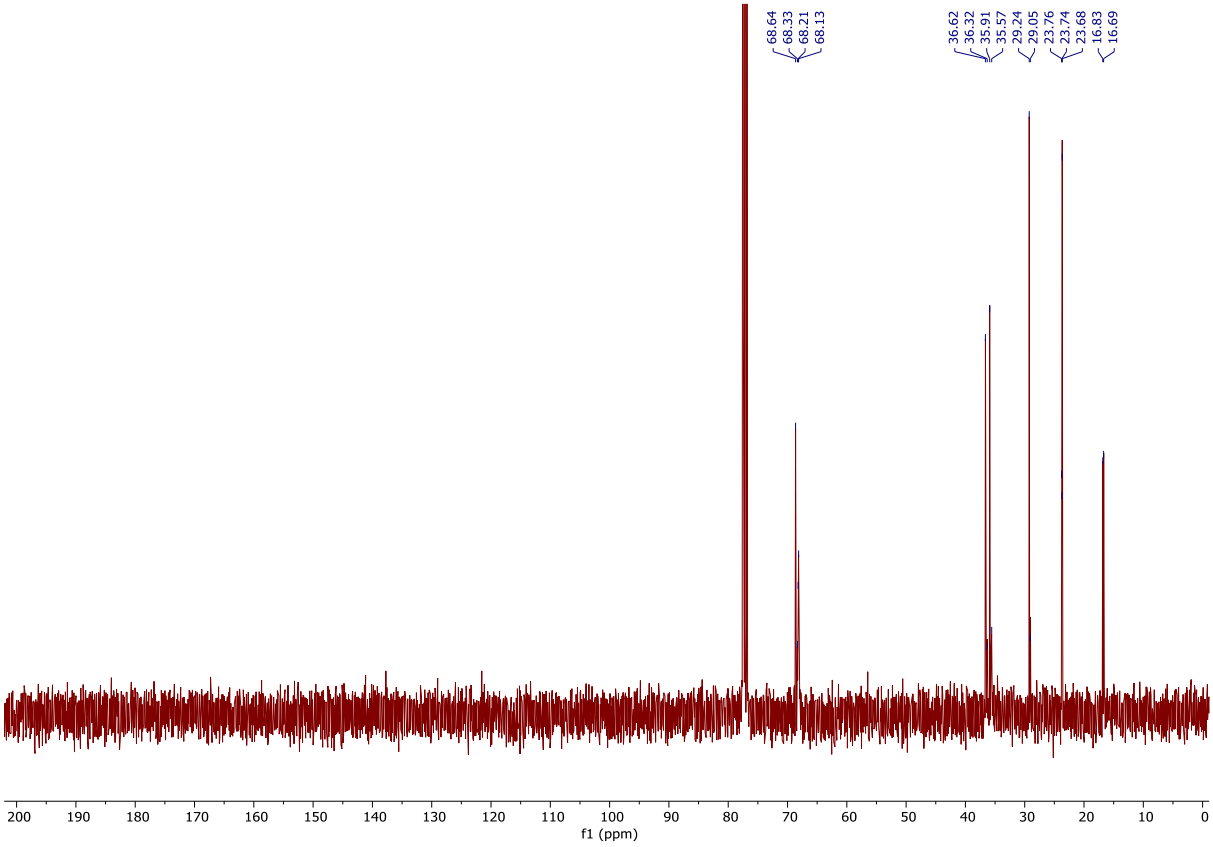
45.75
33.14
29.81
20.04
19.49
110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)


Me
HO
OH
Me
1.00
2.04
1.14
5.09
4.21
3.11
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

(+)-**2o** (~53:47 d.r.)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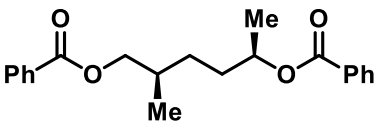
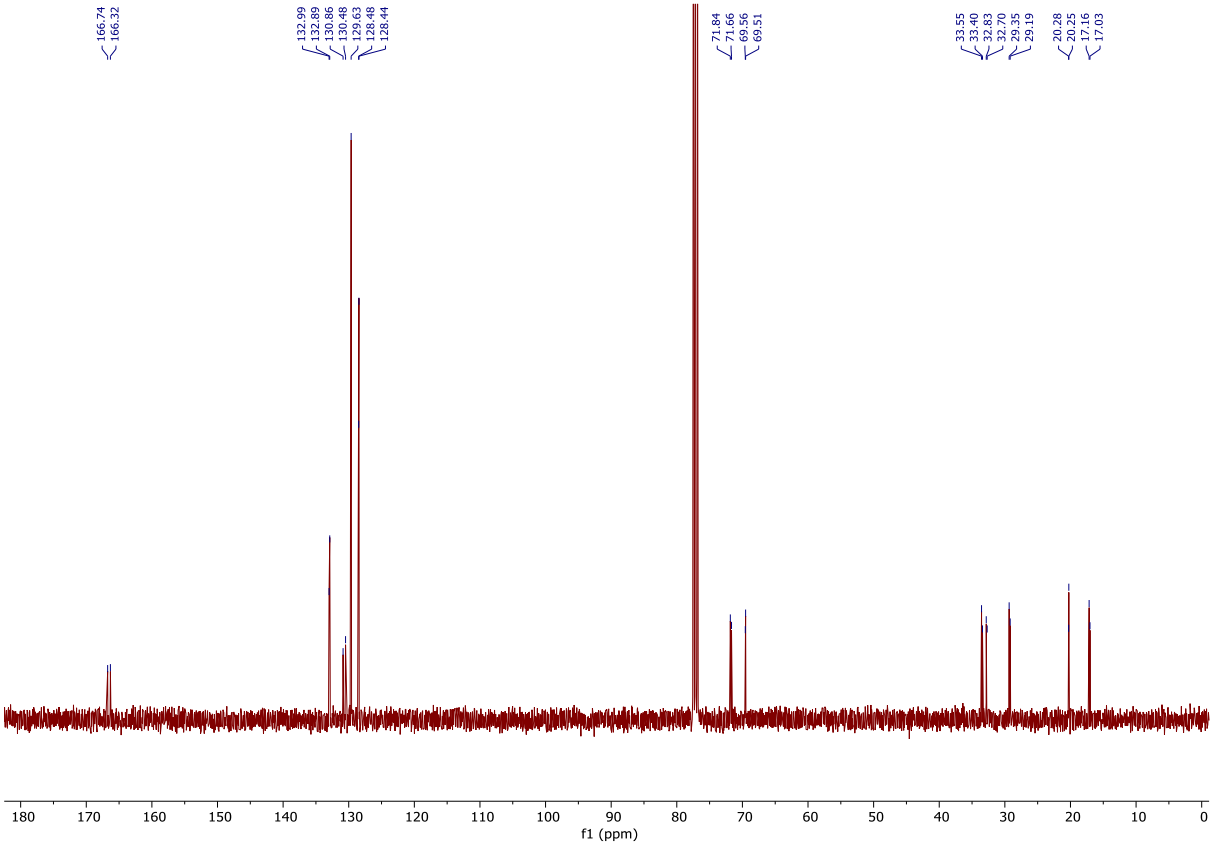
68.33
68.21
68.13
36.62
36.32
35.91
35.57
29.24
29.05
23.76
23.74
23.68
16.83
16.69
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Ph
O
Me
Me
O
O
Ph

S1 (~53:47 d.r.)

3.75
1.92
3.92
1.00
2.07
1.02
3.55
4.31
3.14
9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)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166.32
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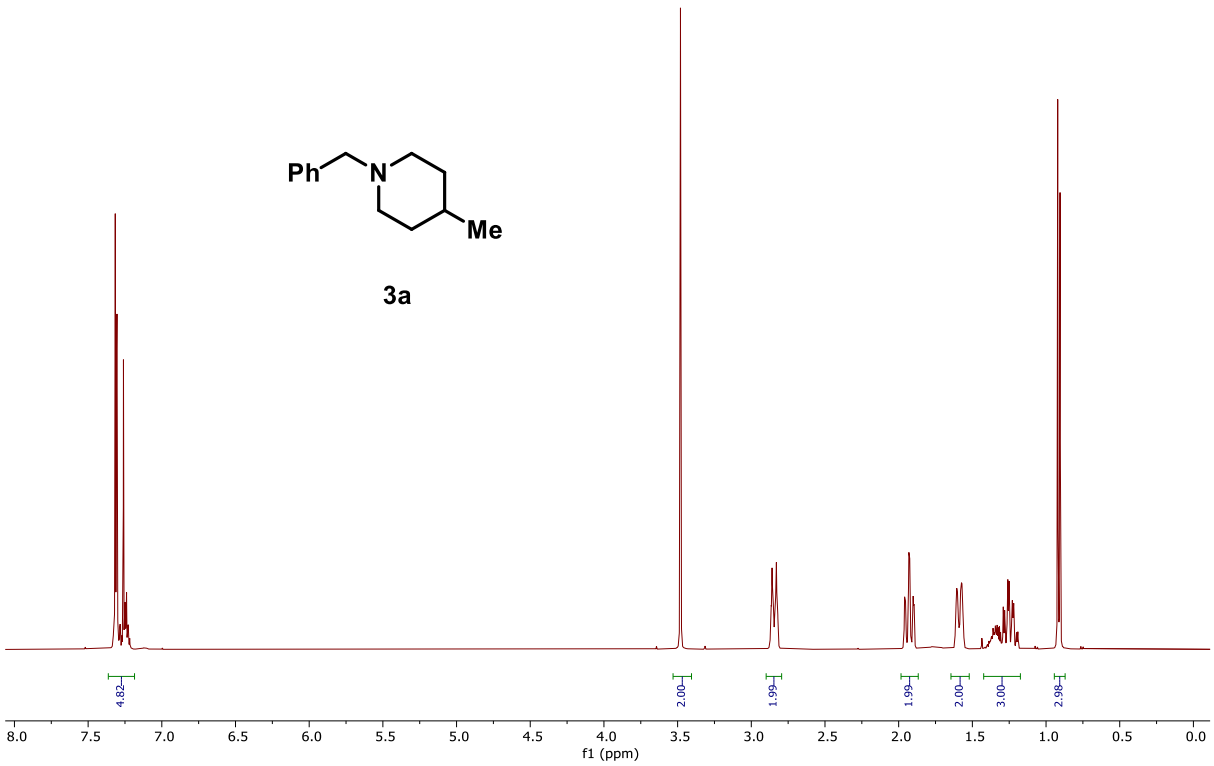
128.48
128.44
71.84
71.66
69.56
69.51
33.55
33.40
32.93
32.70
29.35
29.19
20.28
20.25
17.16
17.03
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)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Me
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1.99
1.99
2.00
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2.98
8.0
7.5
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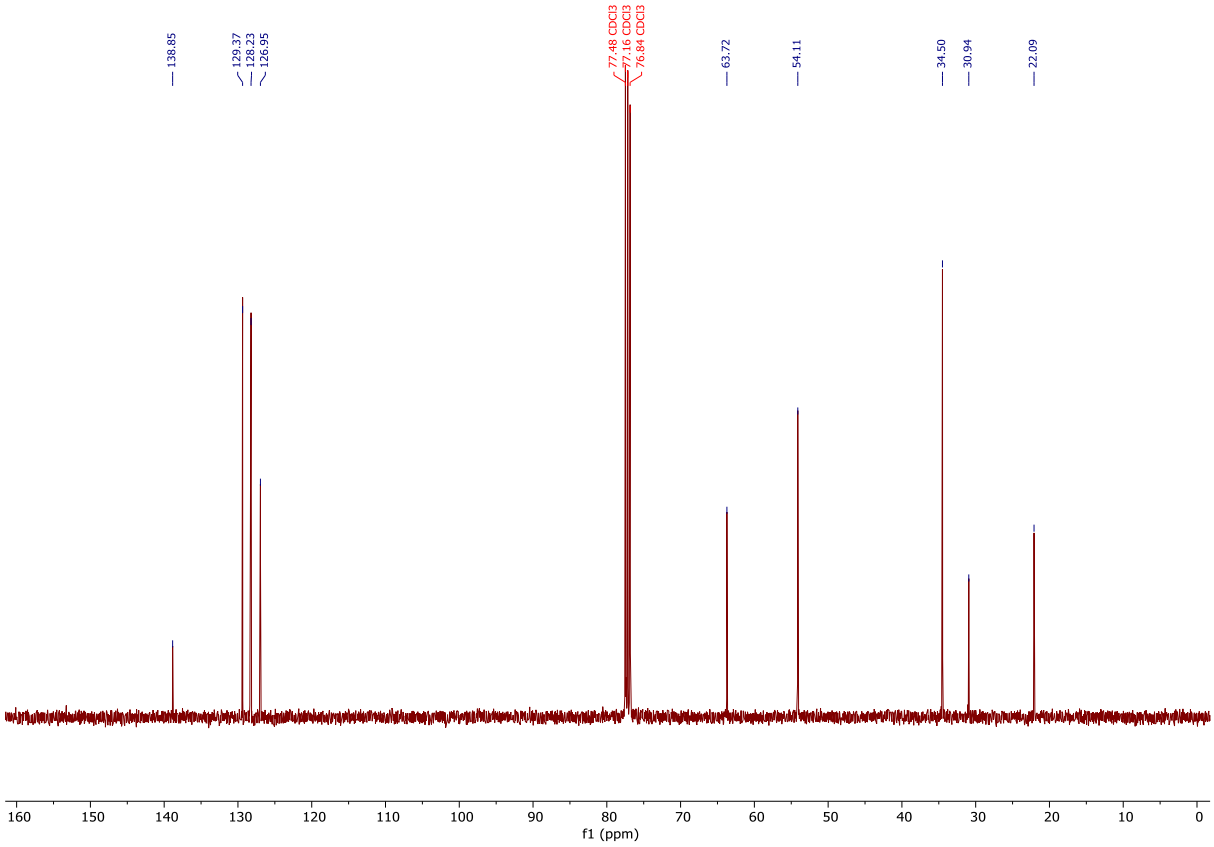
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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77.16 CDCl3
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54.11
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30.94
22.09
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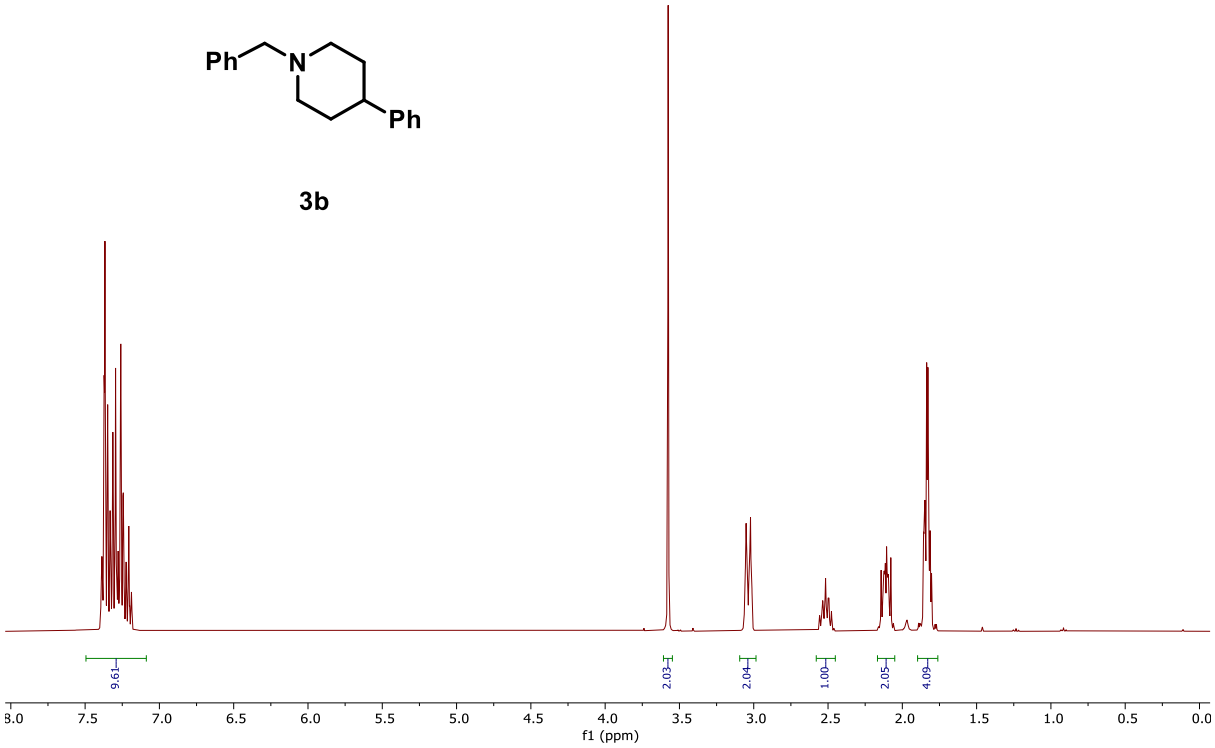
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)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Ph
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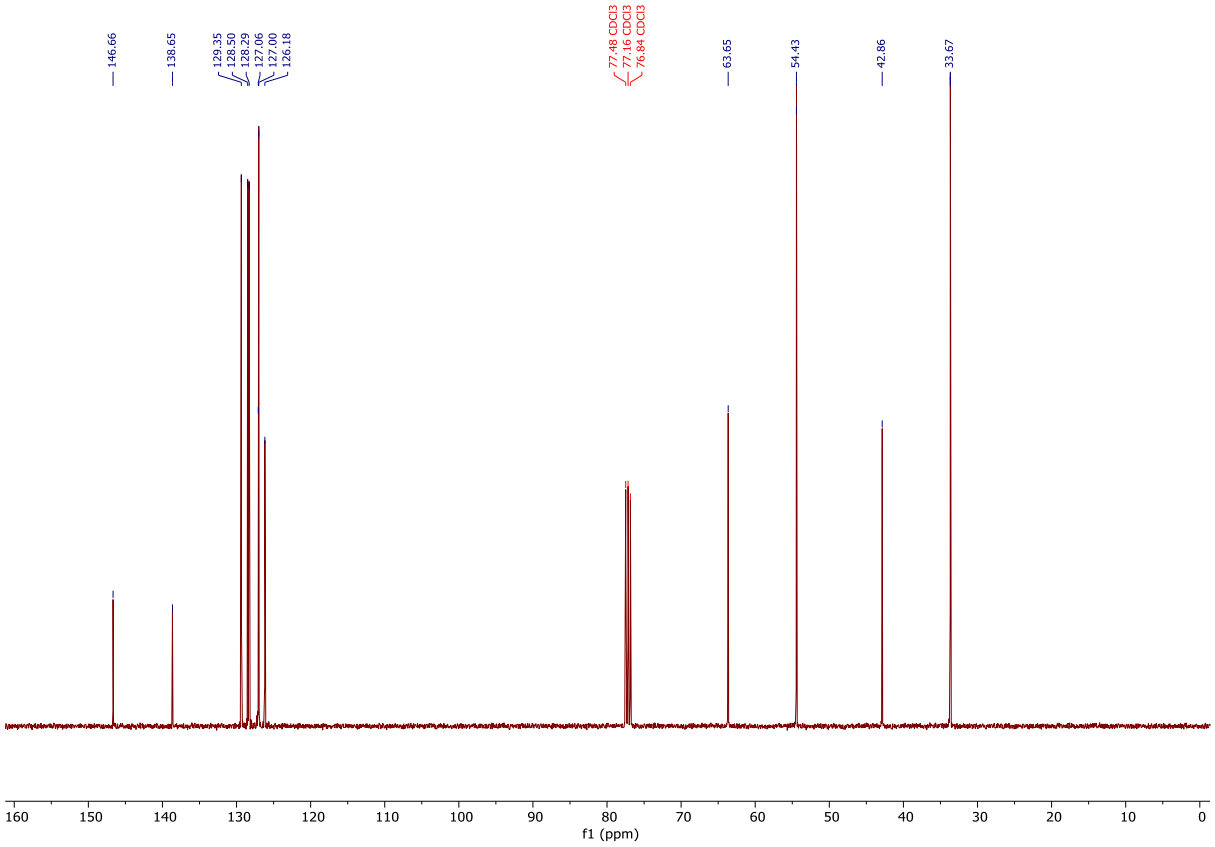
4.09
f1 (ppm)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128.50
128.29
127.06
127.00
126.18
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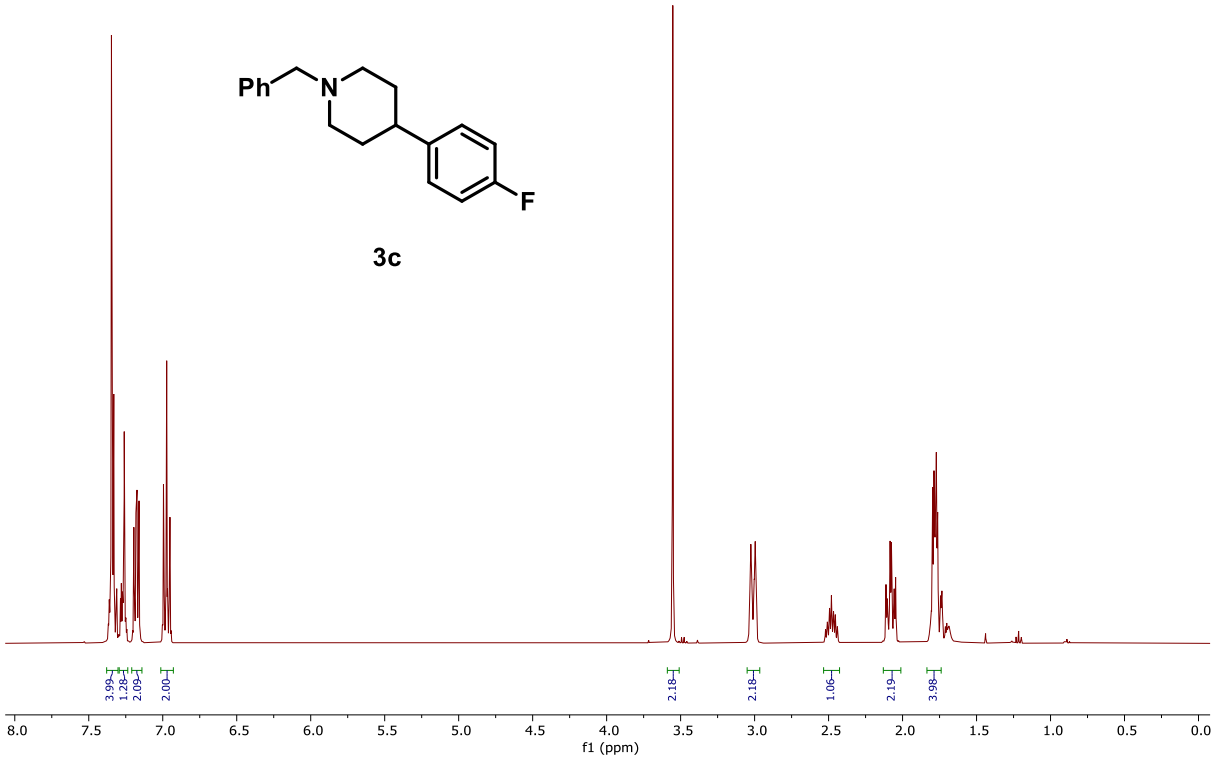
63.65
54.43
42.86
33.67
f1 (ppm)


Ph
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F
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2.09
2.00
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2.18
1.06
2.19
3.98
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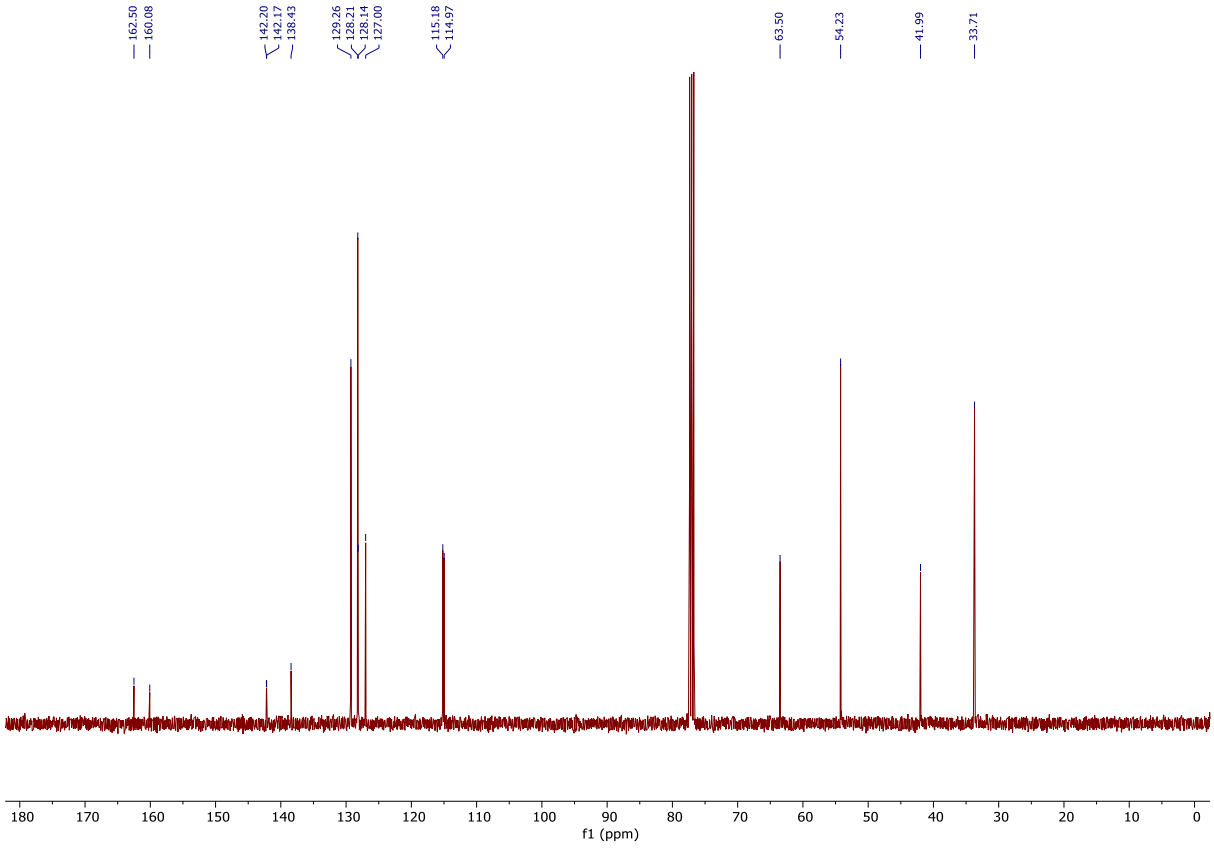
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)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128.14
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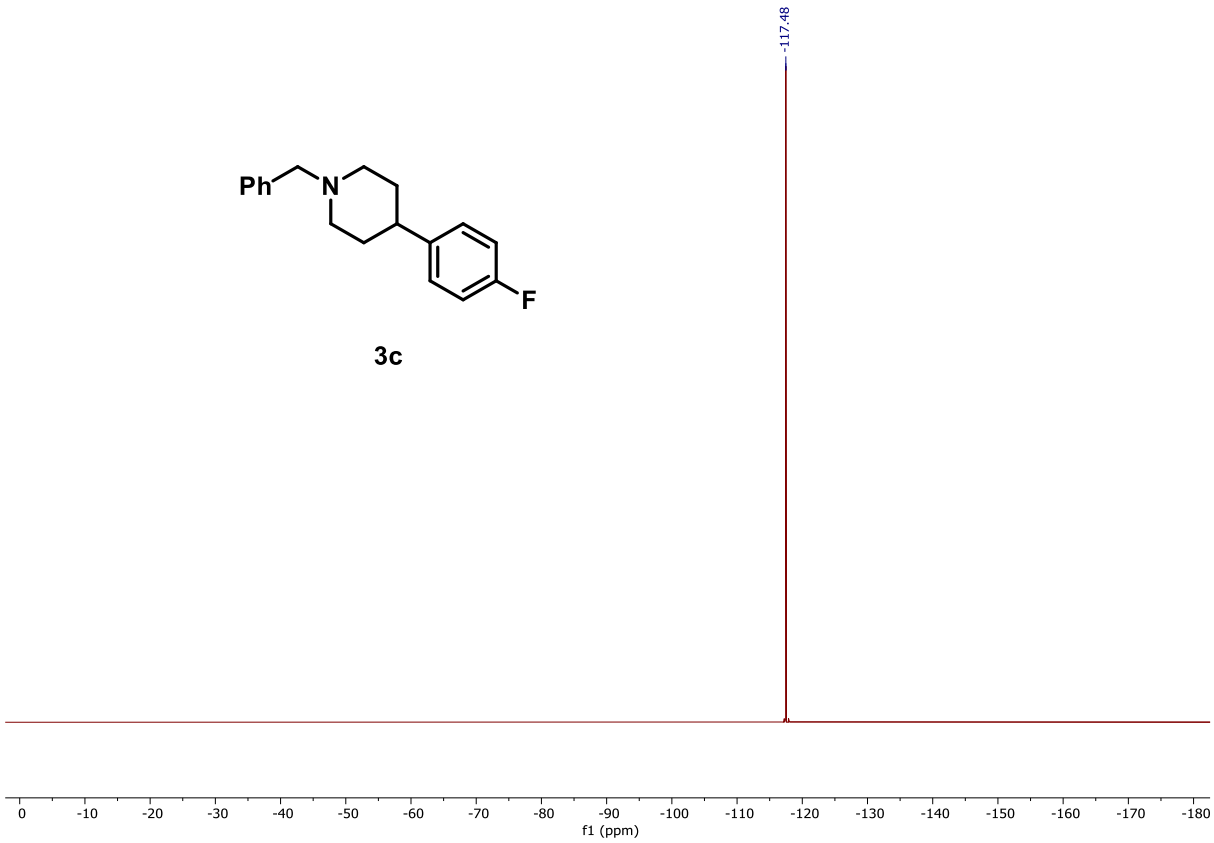
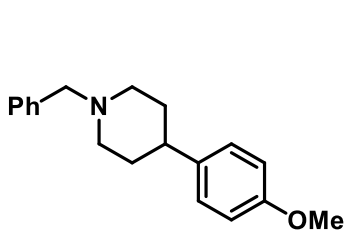
54.23
41.99
33.71
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

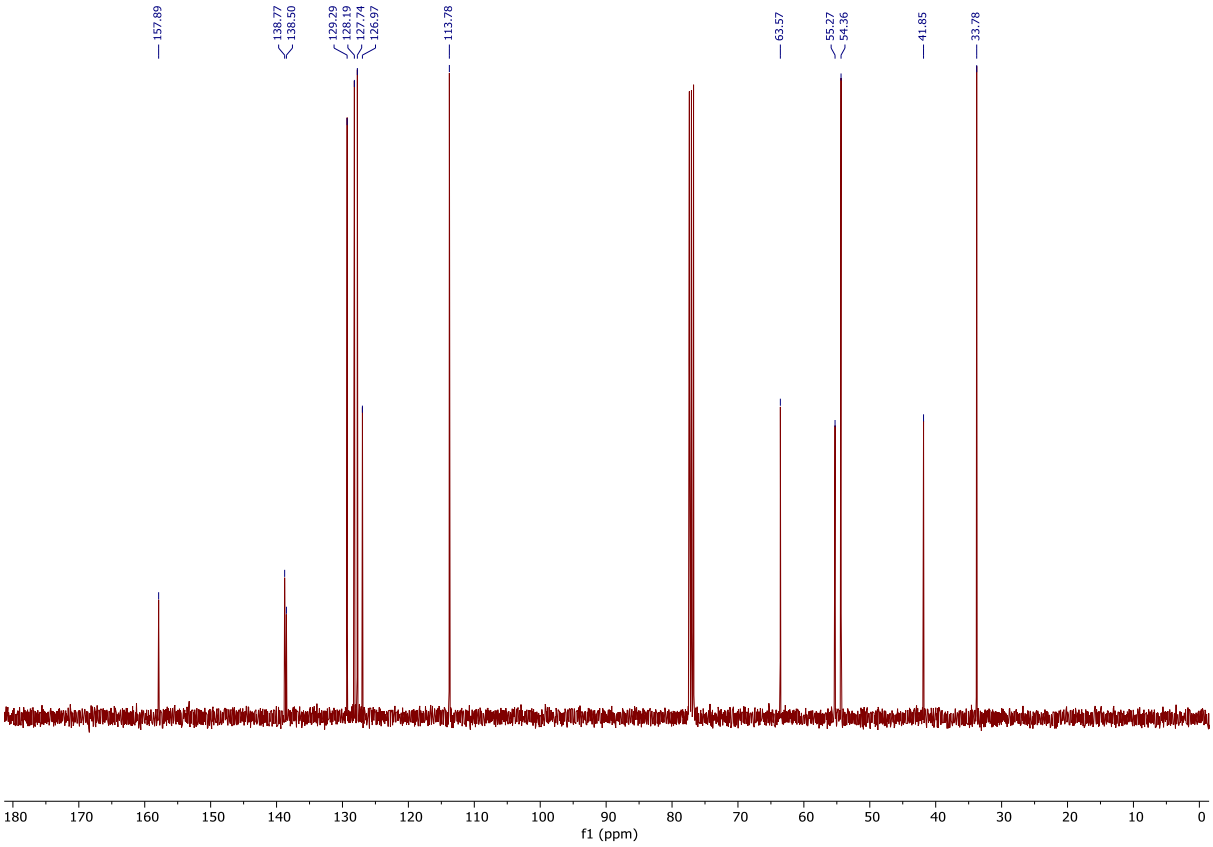

-117.48
Ph
N
F
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
f1 (ppm)

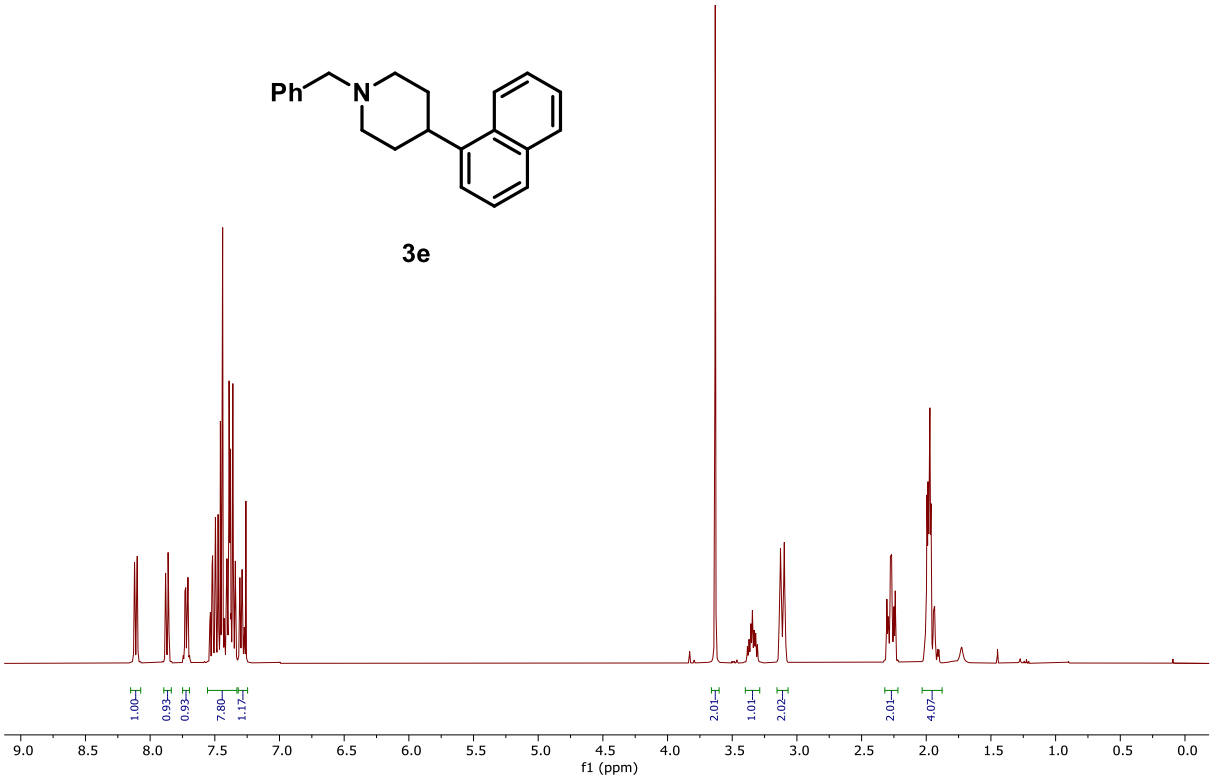
3c


Ph
N
OMe

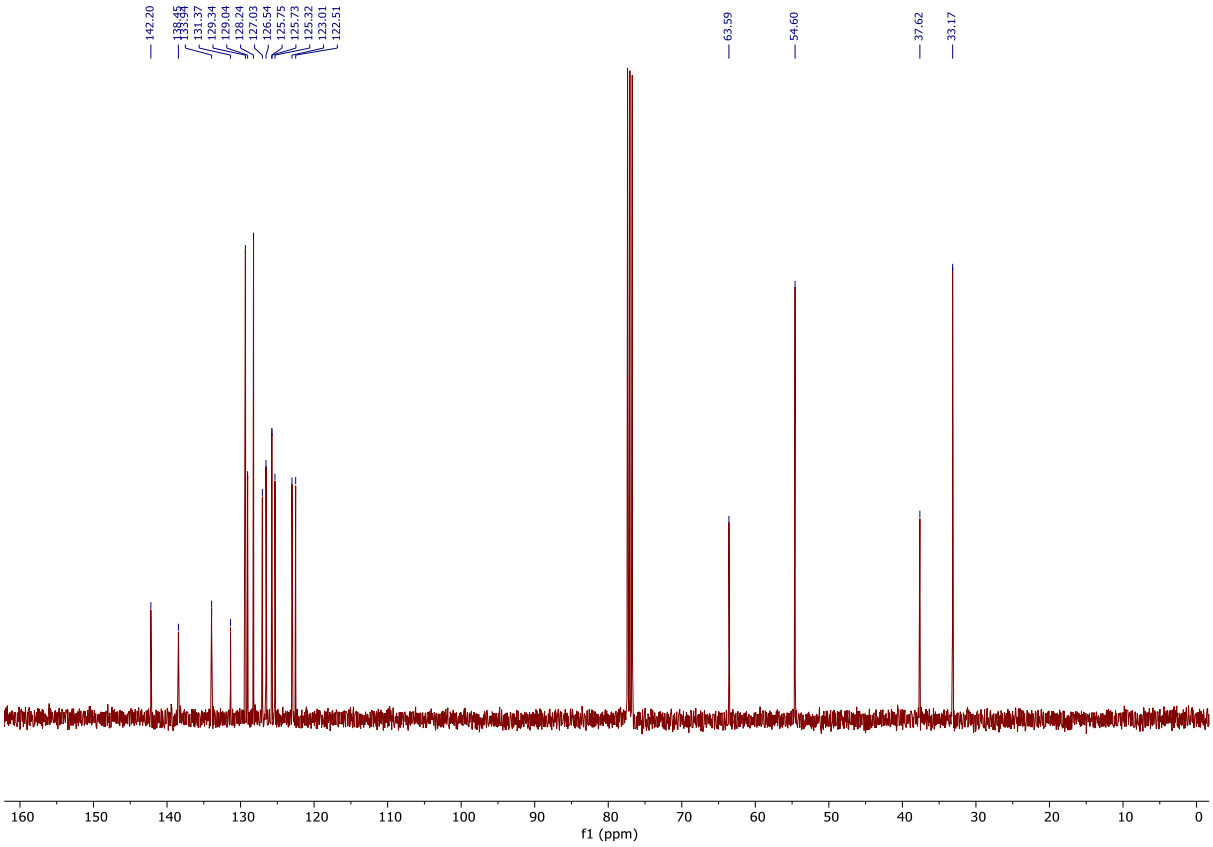
3d

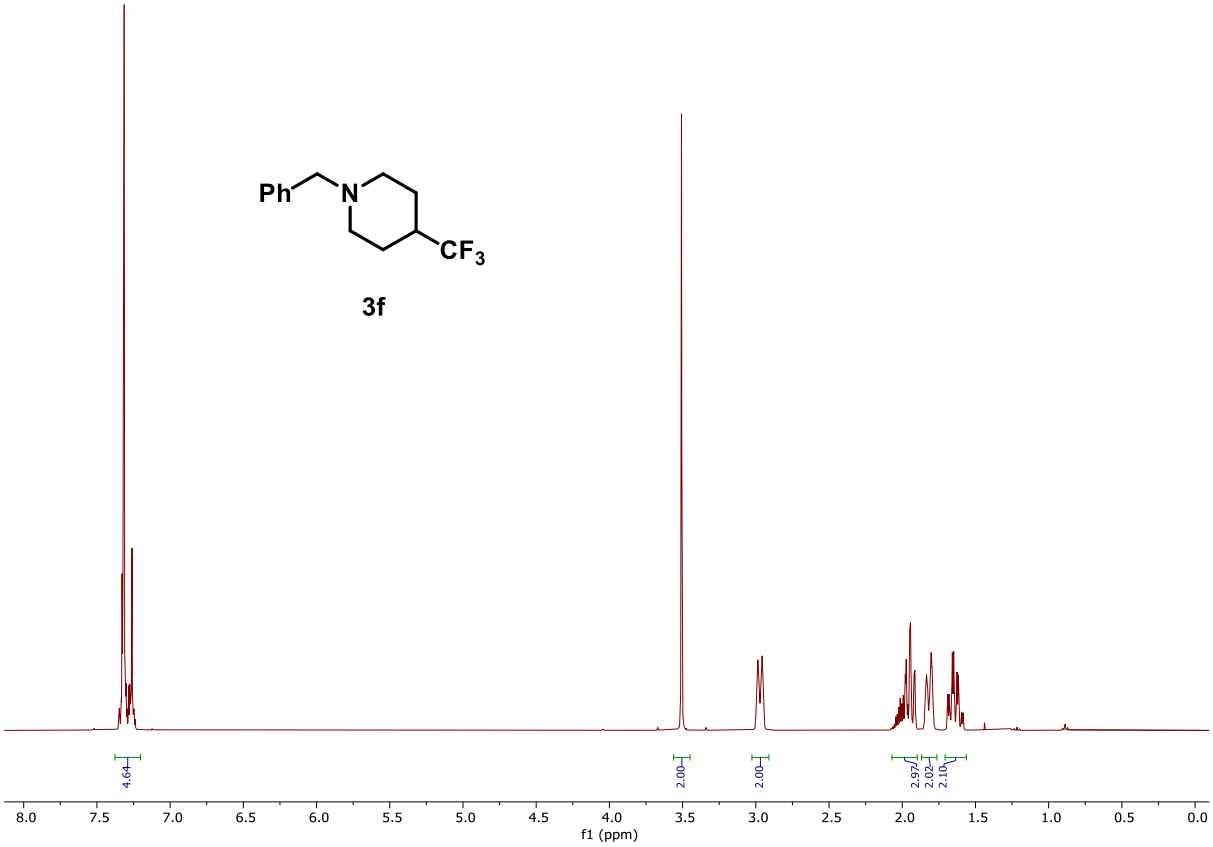
3.80
1.08
1.98
1.93
3.00
2.03
2.03
1.00
2.06
4.40
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

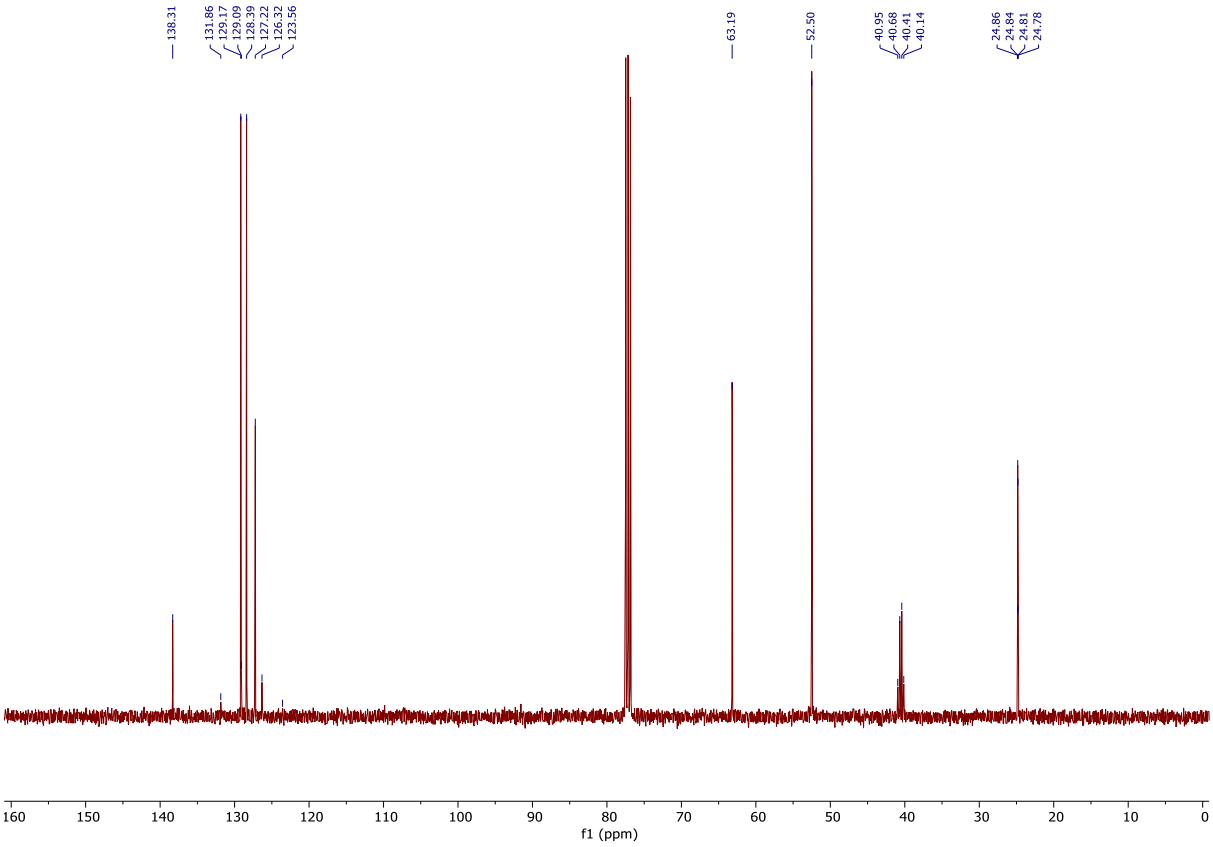

157.89
138.77
138.50
129.29
128.19
127.74
126.97
113.78
63.57
55.27
54.36
41.85
33.78
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

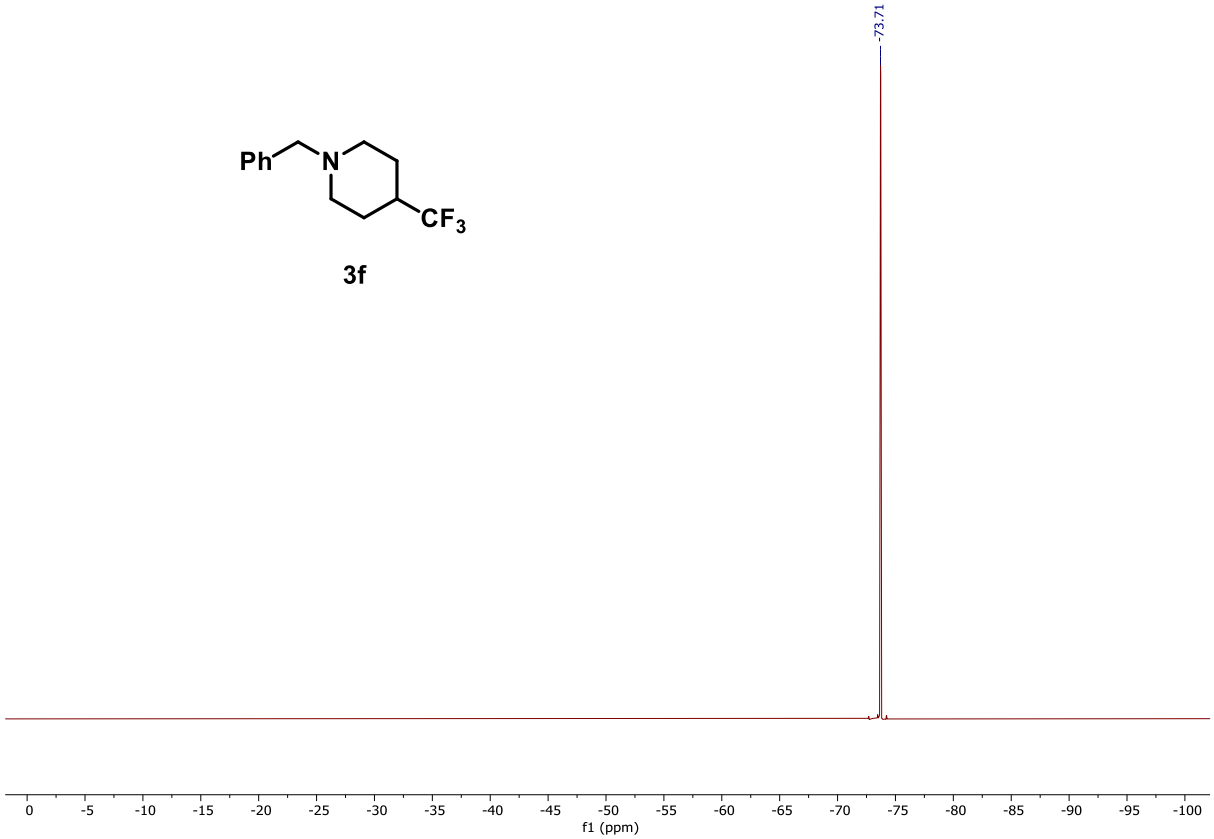

Ph
N
1.00
0.93
0.93
7.80
1.17
2.01
1.01
2.02
2.01
4.07
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

3e

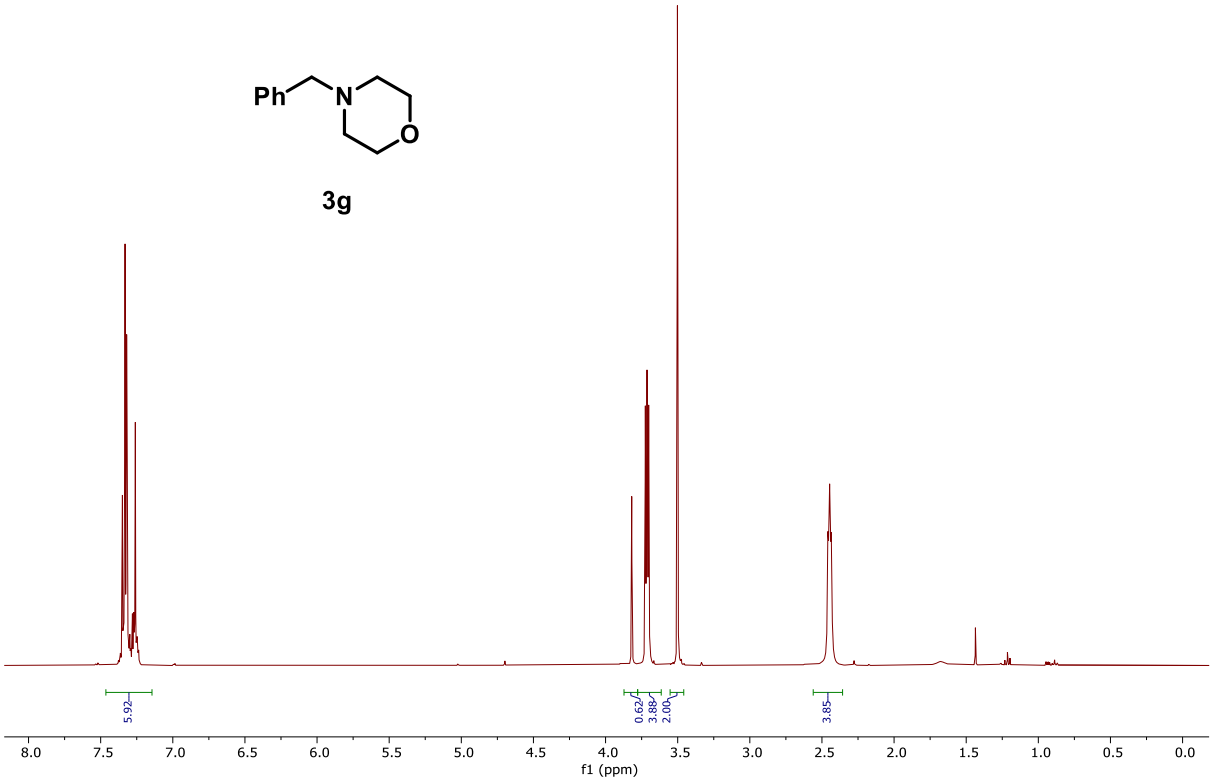

142.20
138.45
133.94
131.37
129.34
129.04
128.24
127.03
126.54
125.75
125.73
125.32
123.01
122.51
63.59
54.60
37.62
33.17
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

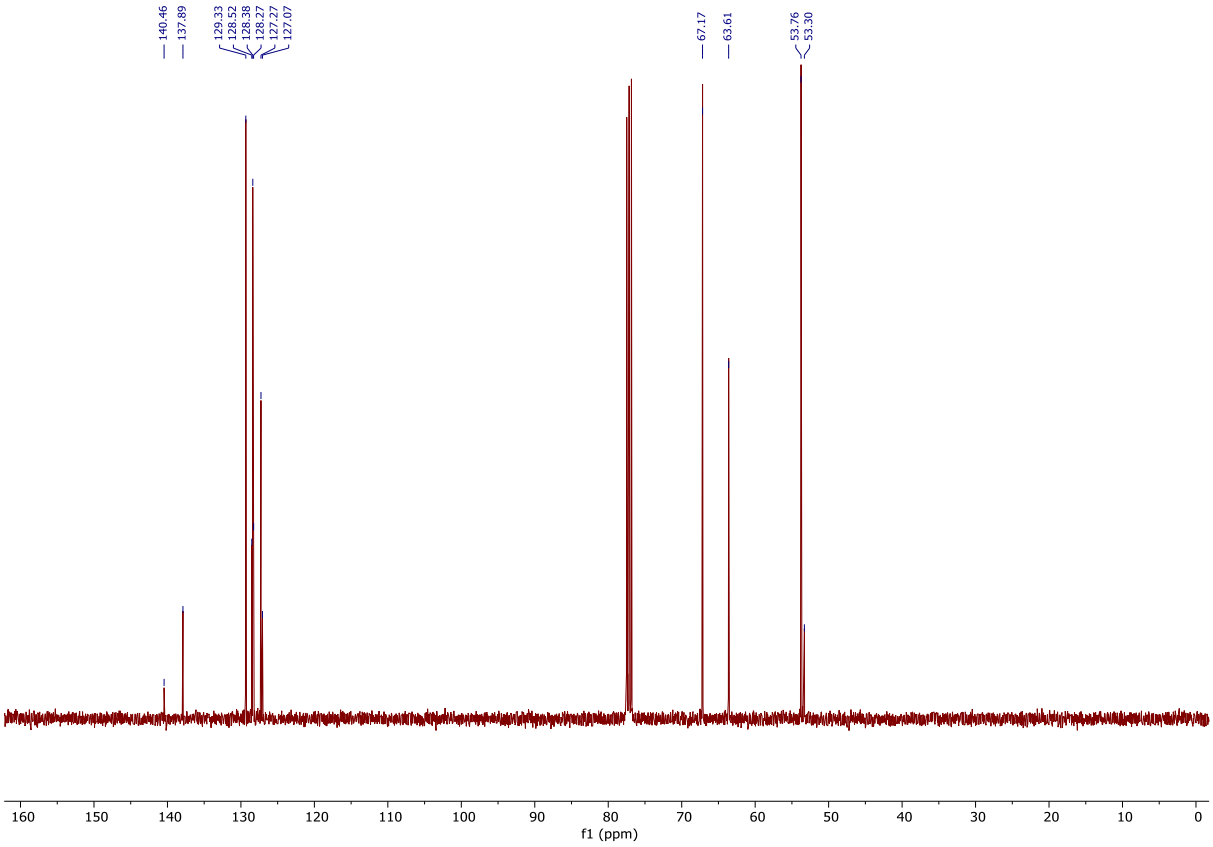

Ph
N
CF3
3f
4.64
2.00
2.00
2.97
2.02
2.10
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

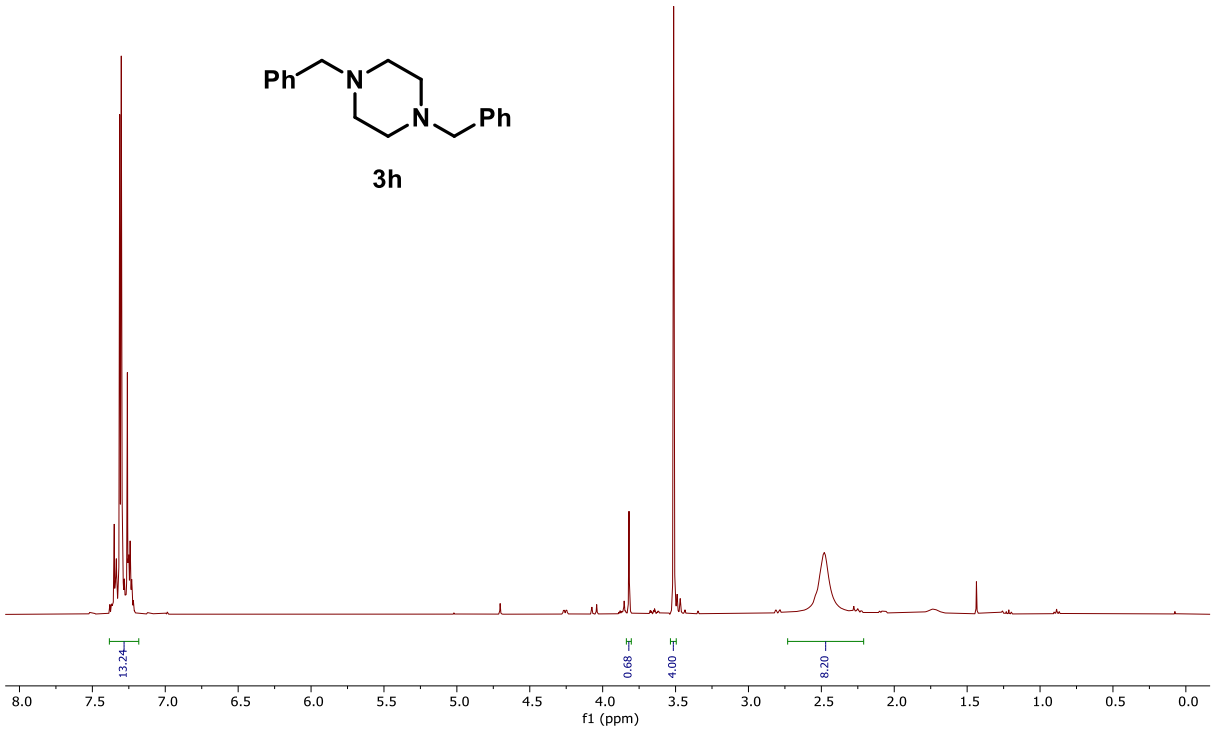

138.31
131.86
129.17
129.09
128.39
127.22
126.32
123.56
63.19
52.50
40.95
40.68
40.41
40.14
24.86
24.84
24.81
24.78
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

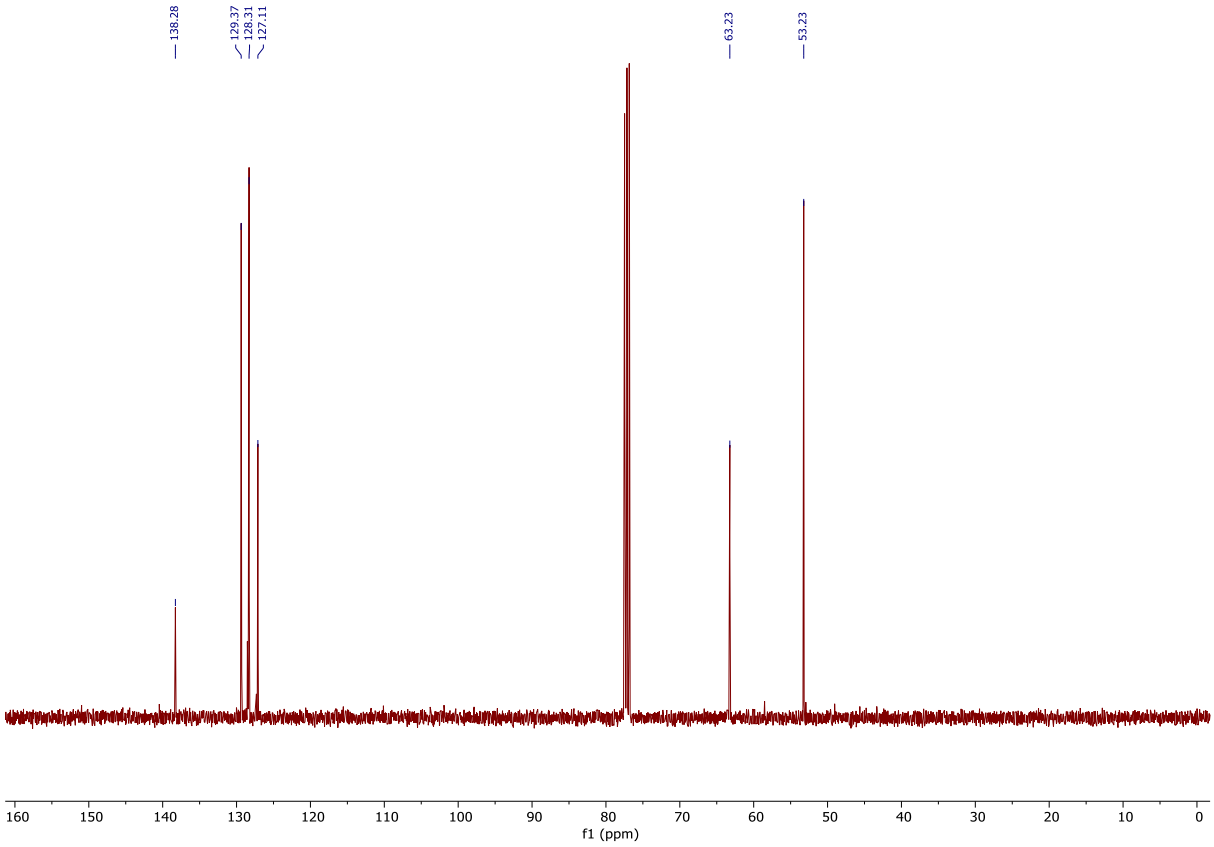

-73.71
Ph
N
CF3
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
f1 (ppm)

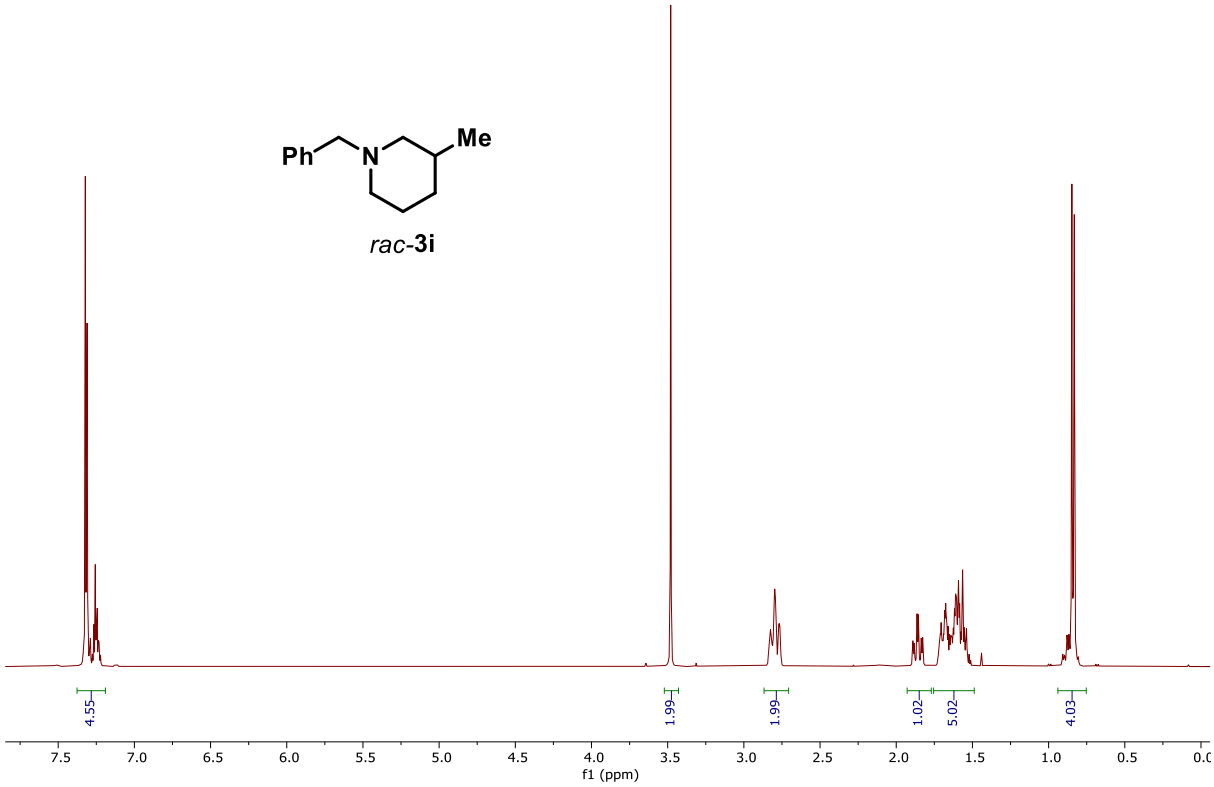
3f

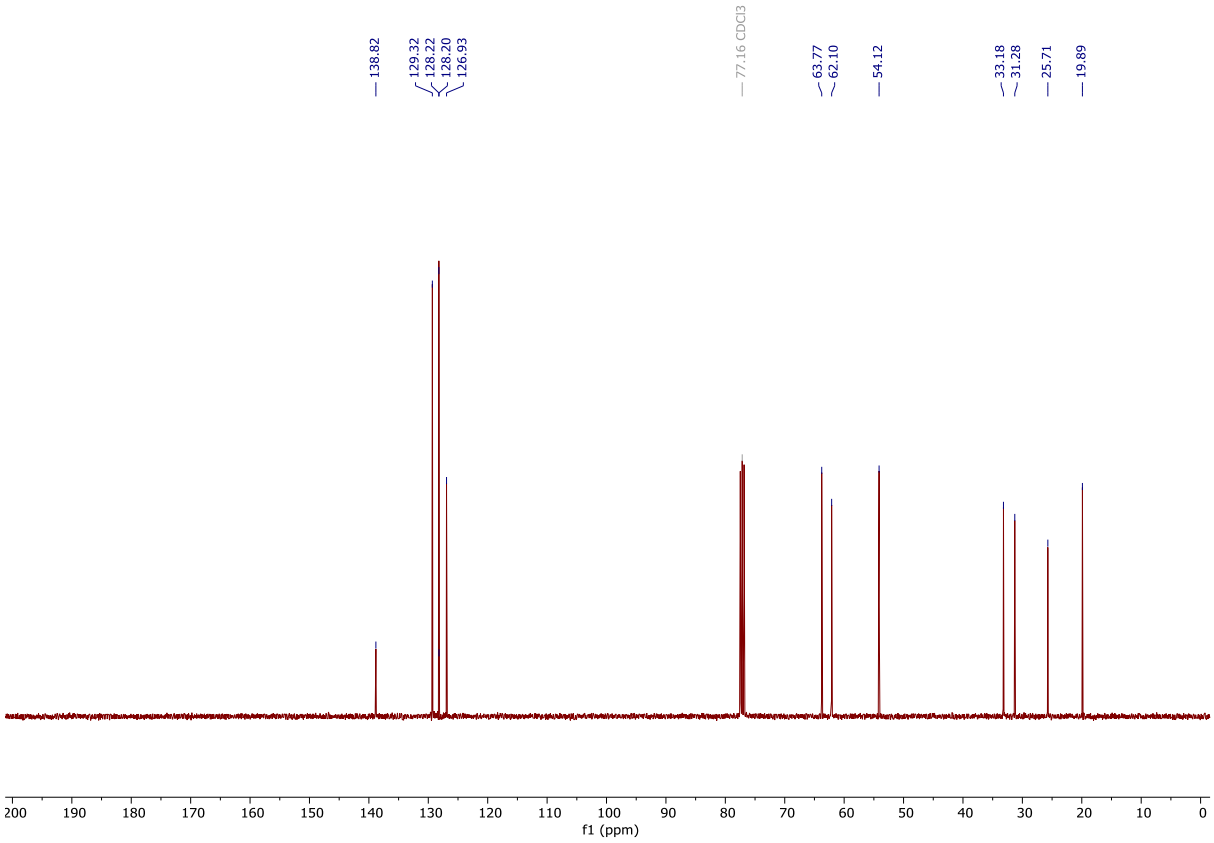

Ph
N
O
3g
5.92
0.62
3.88
2.00
3.85
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

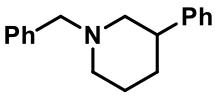

140.46
137.89
129.33
128.52
128.38
127.27
127.07
67.17
63.61
53.76
53.30
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Ph
N
N
Ph
3h
13.24
0.68
4.00
8.20
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

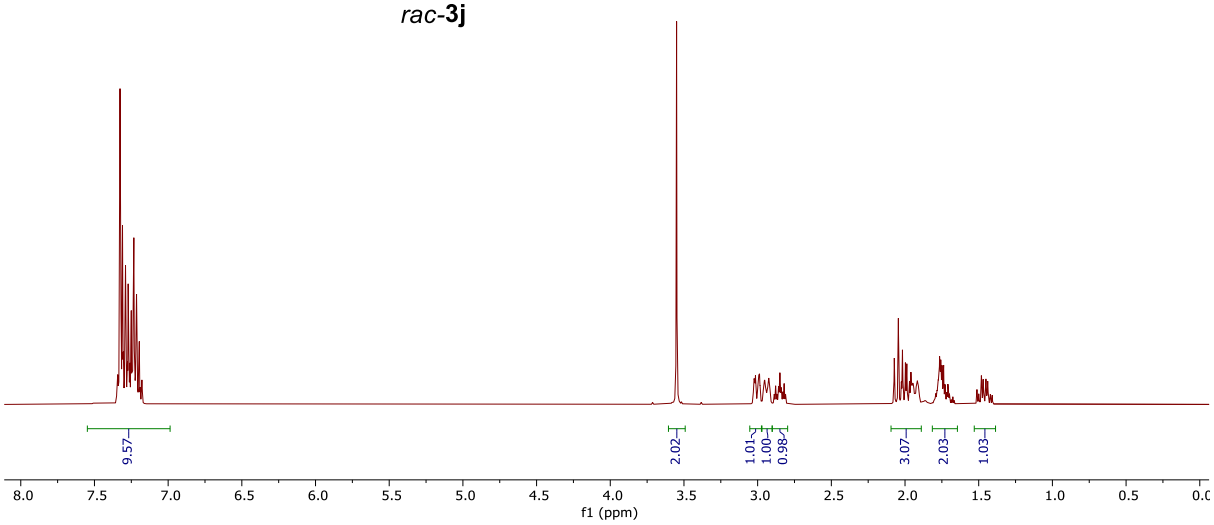

138.28
129.37
128.31
127.11
63.23
53.23
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

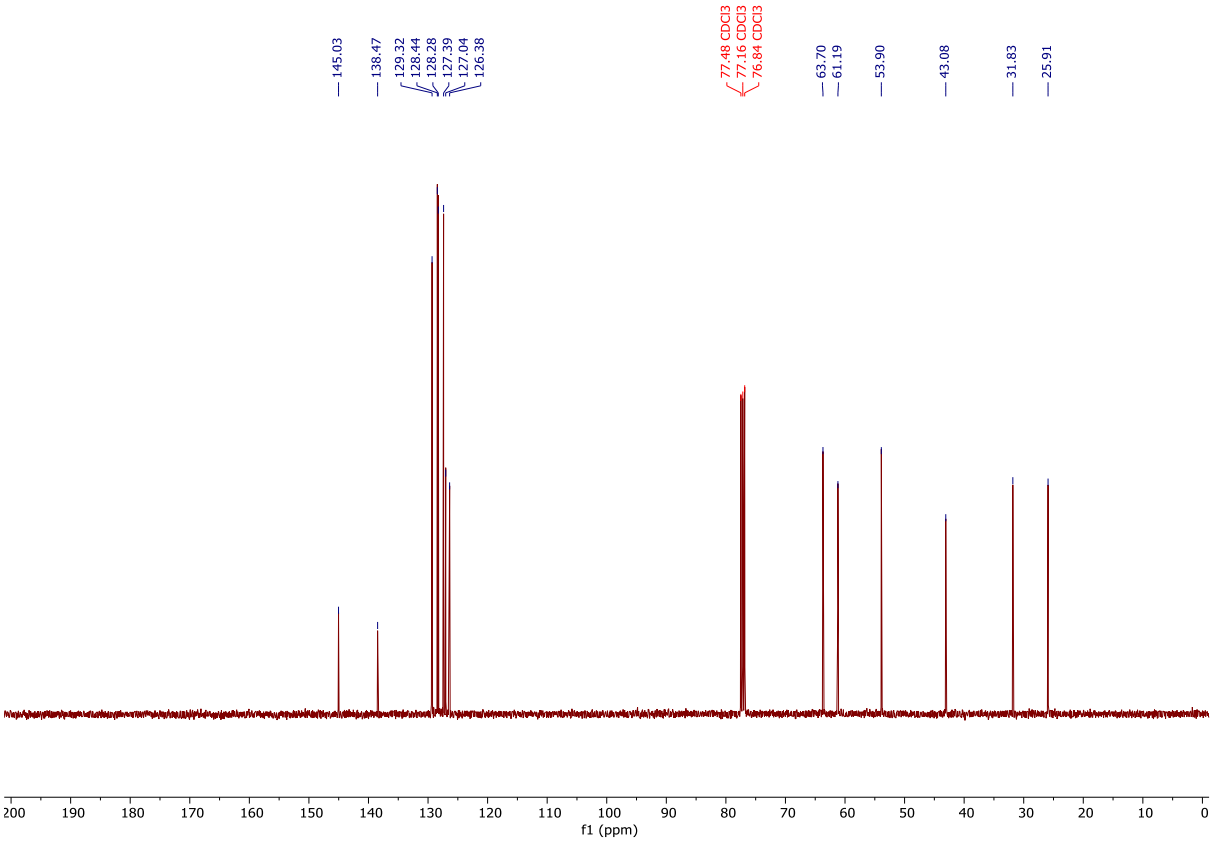

Ph
N
Me
rac-3i
4.55
1.99
1.99
1.02
5.02
4.03
f1 (ppm)

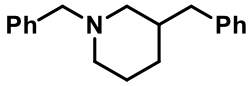

138.82
129.32
128.22
128.20
126.93
77.16 CDCl3
63.77
62.10
54.12
33.18
31.28
25.71
19.89
f1 (ppm)


Ph
N
Ph

rac-**3j**

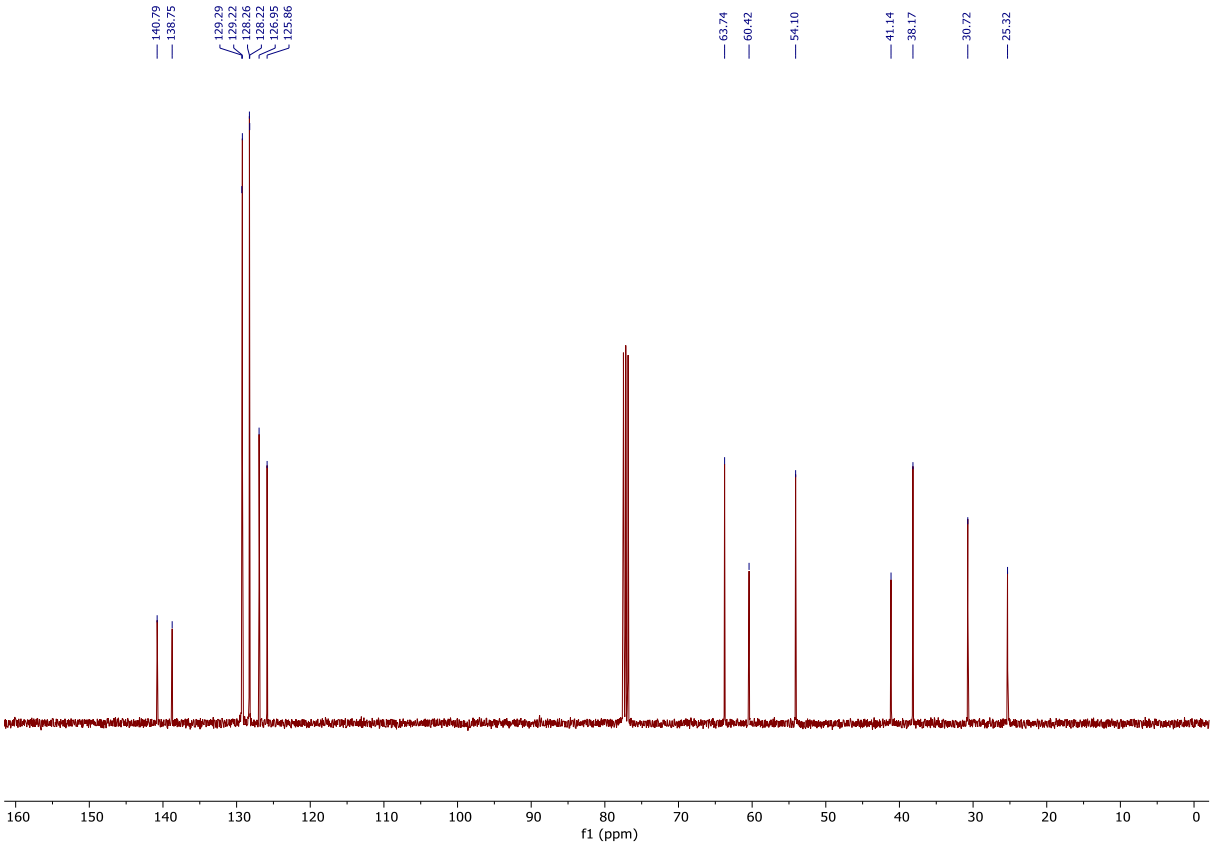

9.57
2.02
1.01
1.00
0.98
3.07
2.03
1.03
f1 (ppm)

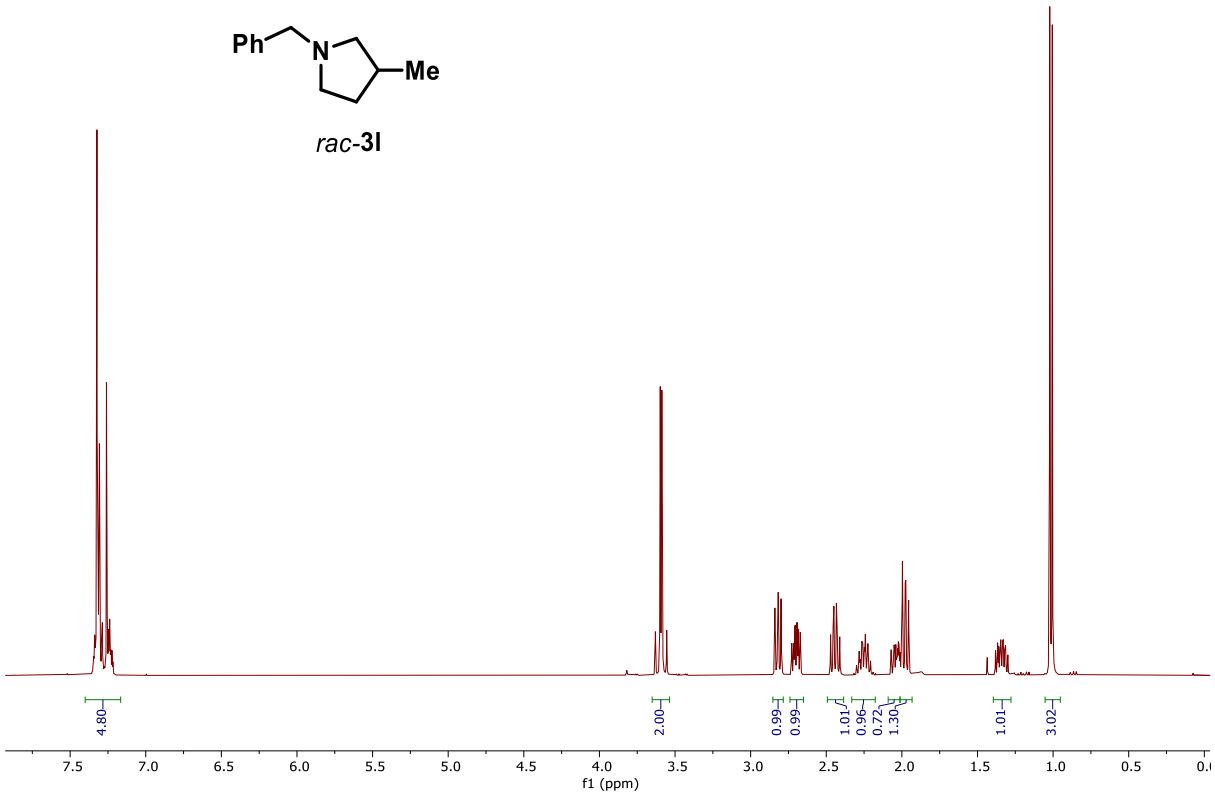

145.03
138.47
129.32
128.44
128.28
127.39
127.04
126.38
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
63.70
61.19
53.90
43.08
31.83
25.91
f1 (ppm)

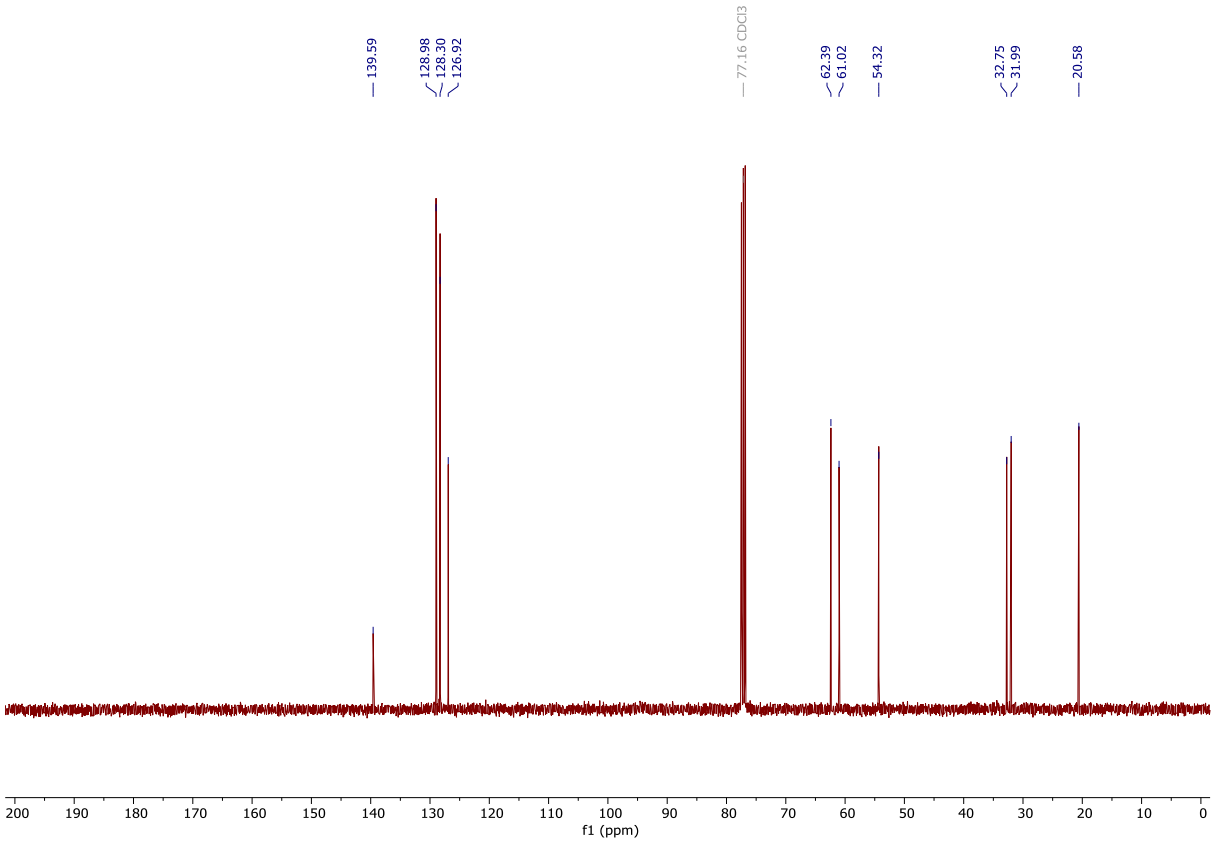

Ph
N
Ph

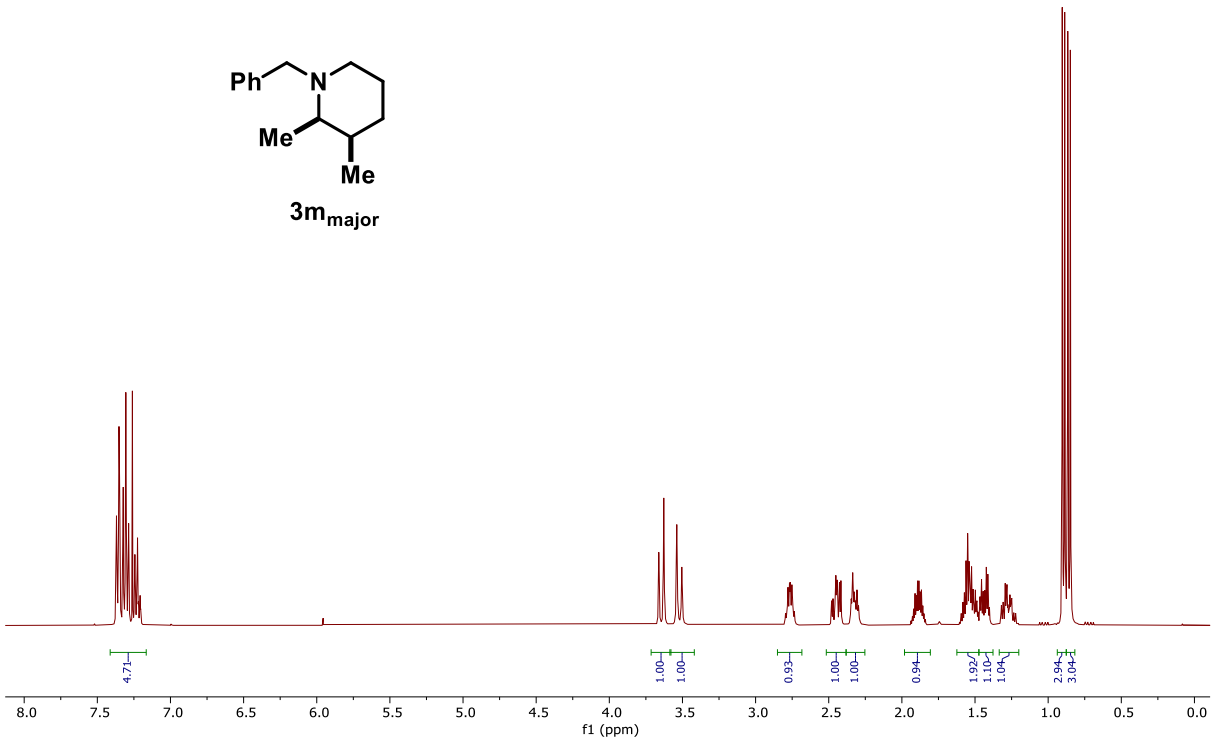
3k

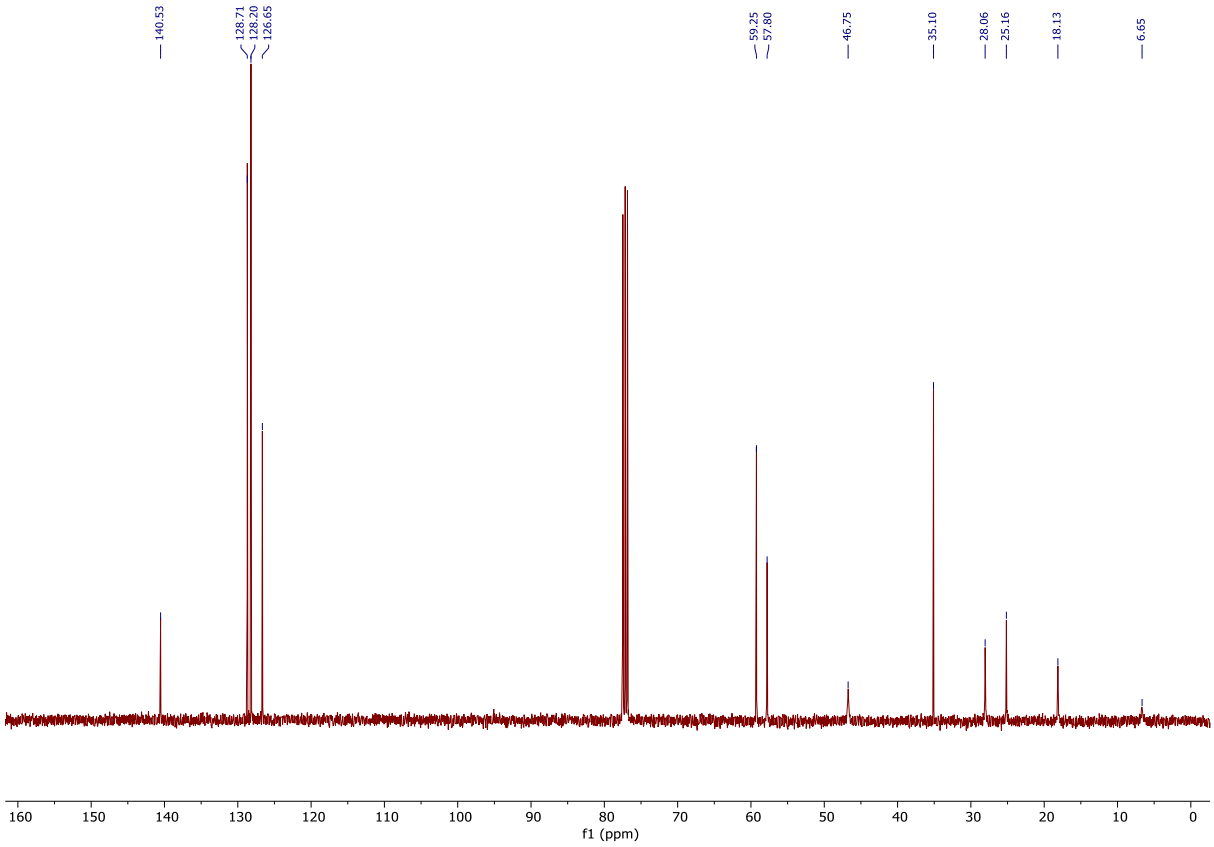
9.61
1.00
0.99
1.01
0.94
1.01
0.99
2.03
1.02
2.03
1.04
1.00
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

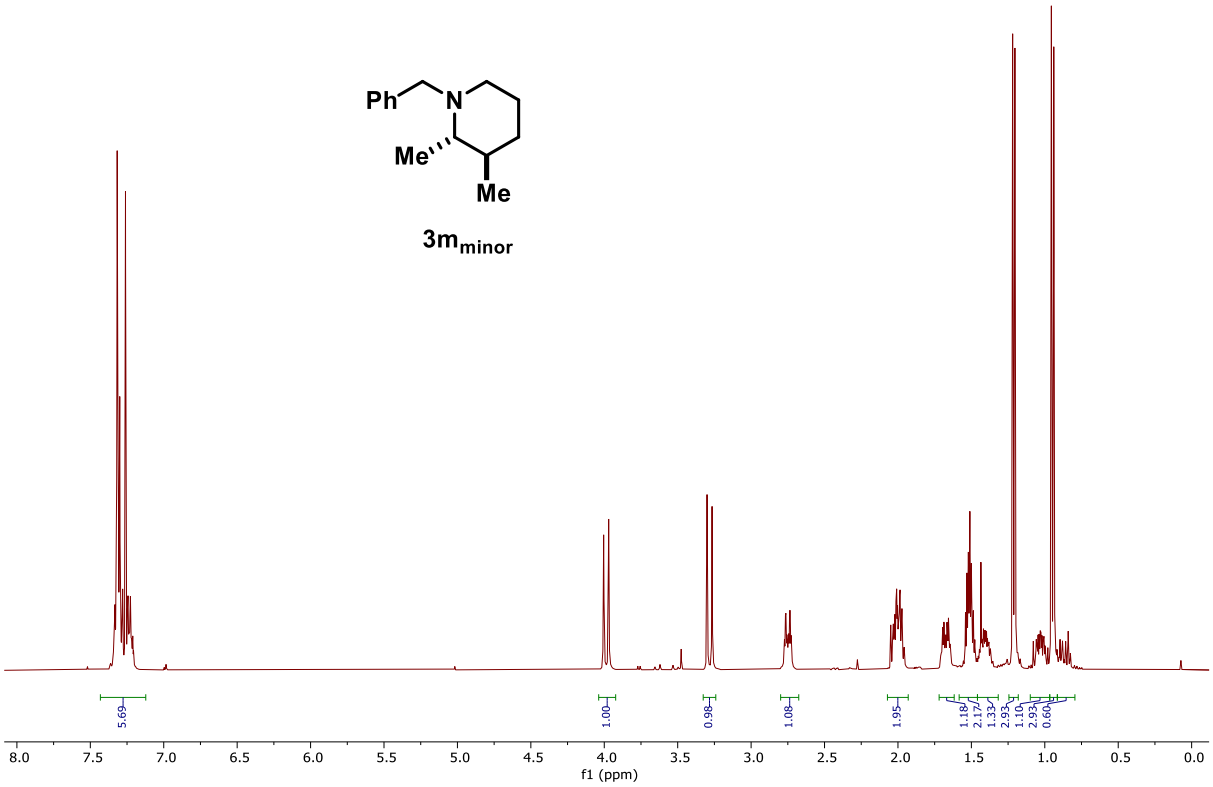

140.79
138.75
129.29
129.22
128.26
128.22
126.95
125.86
63.74
60.42
54.10
41.14
38.17
30.72
25.32
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

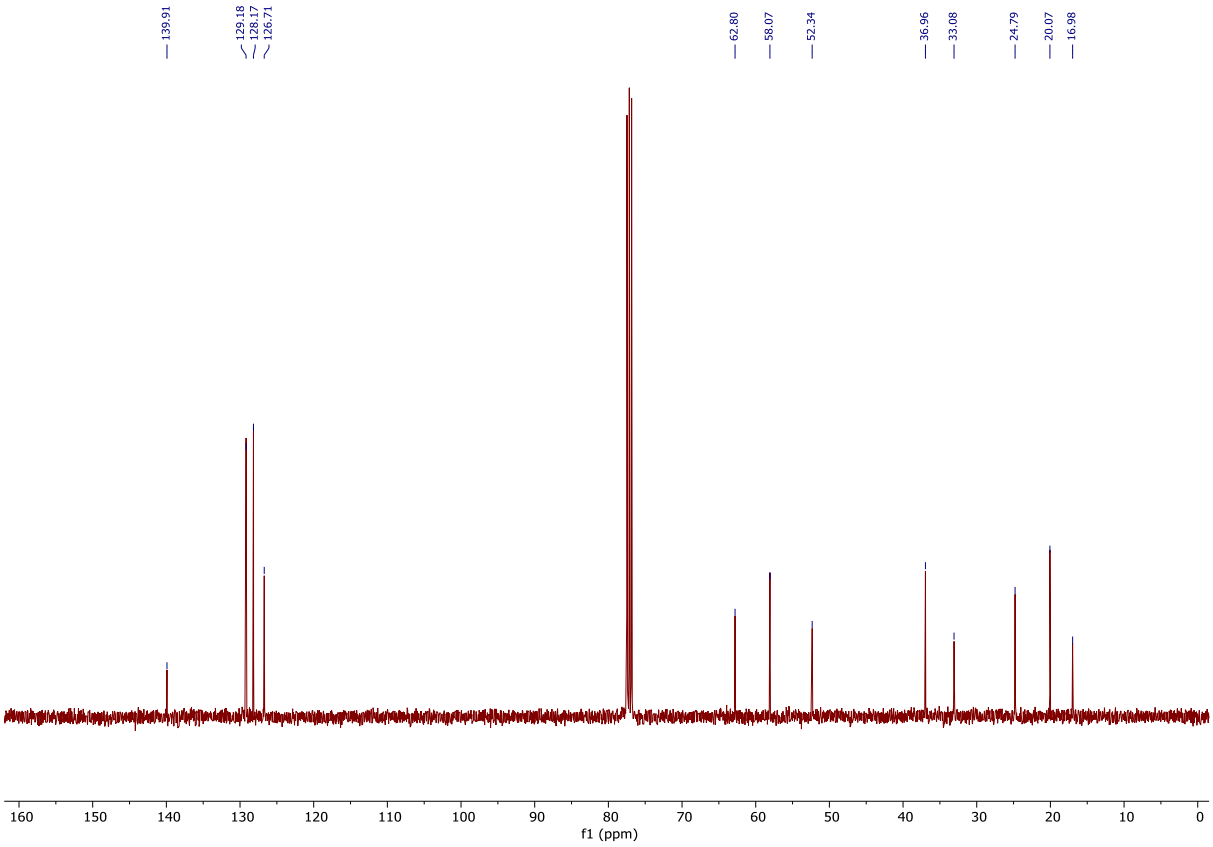

Ph
N
Me
rac-3l
4.80
2.00
0.99
0.99
1.01
0.96
0.72
1.30
1.01
3.02
f1 (ppm)

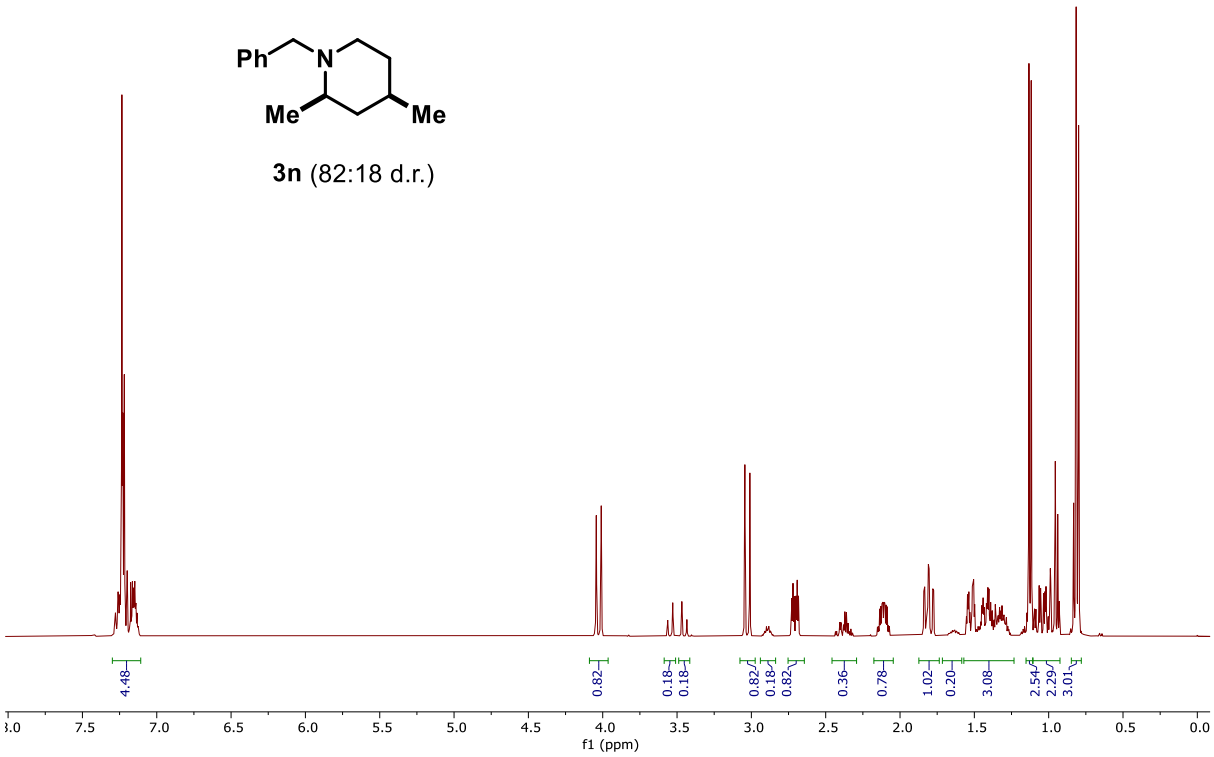

139.59
128.98
128.30
126.92
77.16 CDCl3
62.39
61.02
54.32
32.75
31.99
20.58
f1 (ppm)

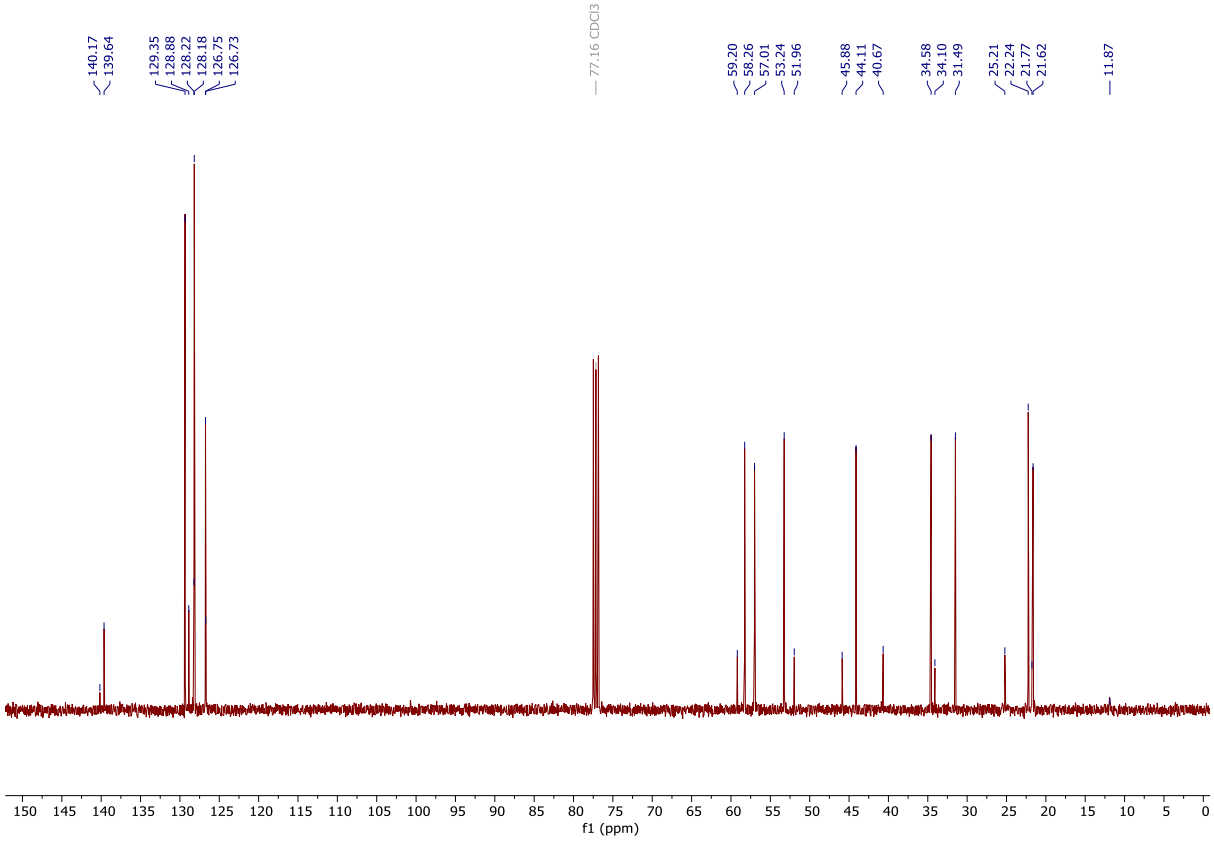

Ph
N
Me
Me
3m major
4.71
1.00
1.00
0.93
1.00
1.00
0.94
1.92
1.10
1.04
2.94
3.04
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

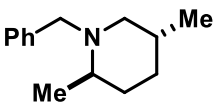

140.53
128.71
128.20
126.65
59.25
57.80
46.75
35.10
28.06
25.16
18.13
6.65
160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


Ph
N
Me
Me
3m minor
5.69
1.00
0.98
1.08
1.95
1.18
2.17
1.33
2.93
1.10
2.93
0.60
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


139.91
129.18
128.17
126.71
62.80
58.07
52.34
36.96
33.08
24.79
20.07
16.98
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

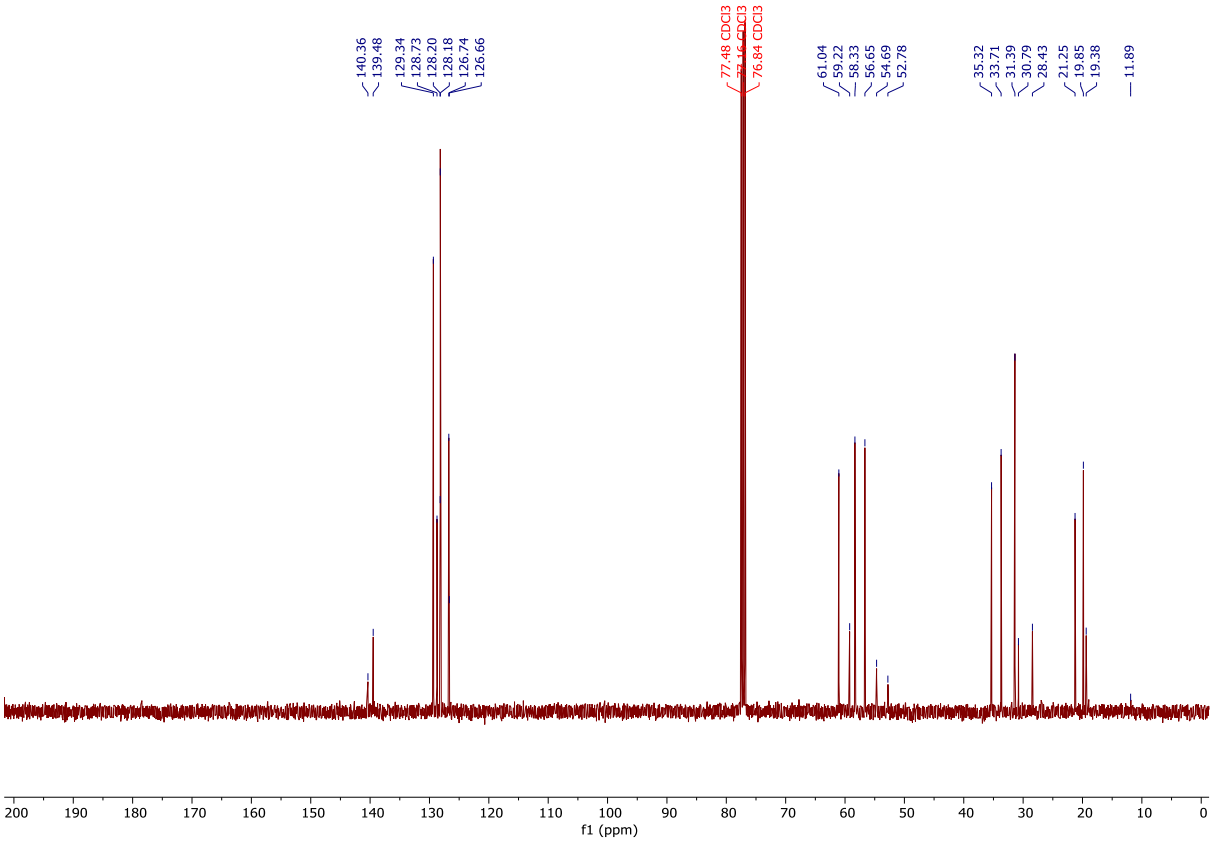

Ph
N
Me
Me
3n (82:18 d.r.)
4.48
0.82
0.18
0.18
0.82
0.18
0.82
0.36
0.78
1.02
0.20
3.08
2.54
2.29
3.01
f1 (ppm)

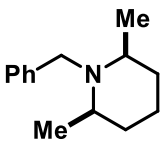

140.17
139.64
129.35
128.88
128.22
128.18
126.75
126.73
77.16 CDCl3
59.20
58.26
57.01
53.24
51.96
45.88
44.11
40.67
34.58
34.10
31.49
25.21
22.24
21.77
21.62
11.87
f1 (ppm)


Ph
N
Me
Me

3o (72:28 d.r.)

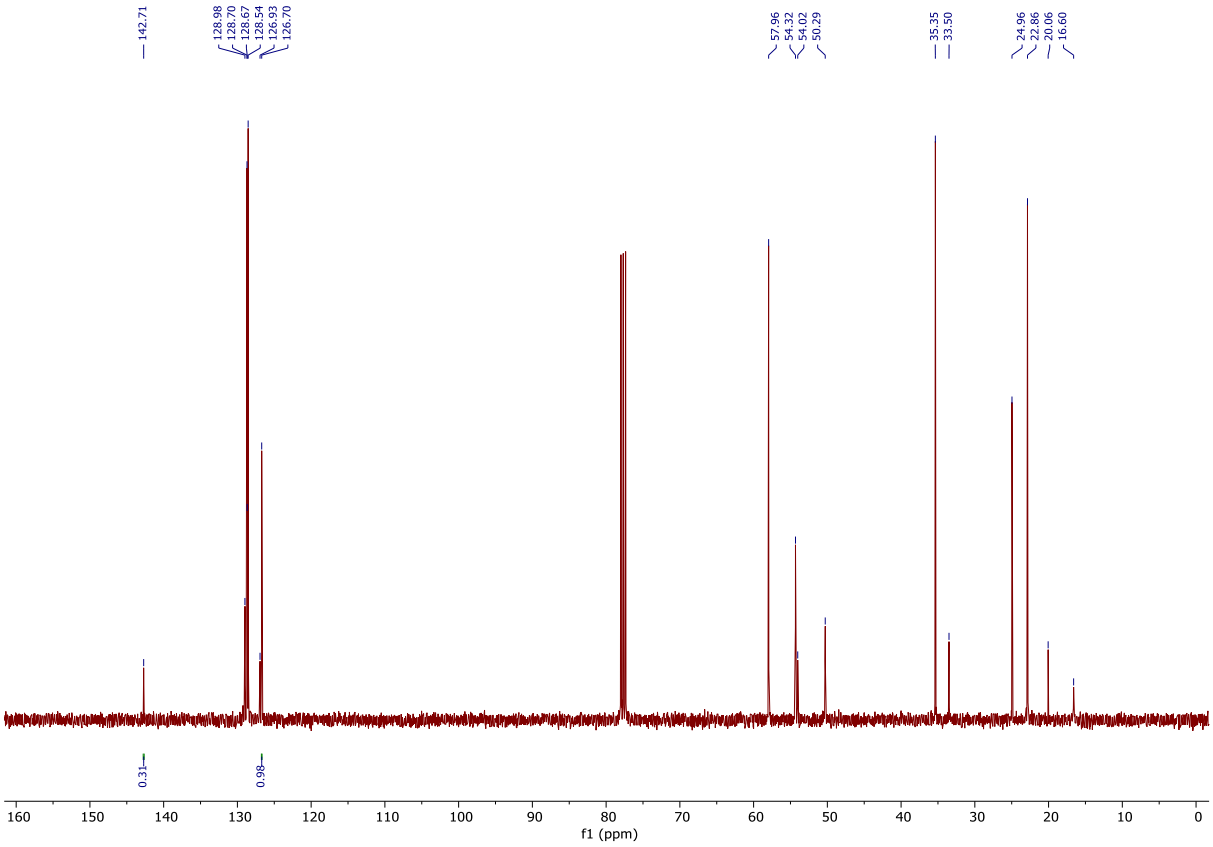
4.69
0.72
0.28
0.28
0.72
0.25
0.71
0.27
0.34
0.62
0.47
0.49
0.79
0.52
1.95
0.81
2.52
0.81
0.71
0.92
2.13
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

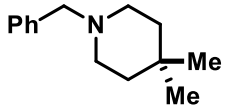

140.36
139.48
129.34
128.73
128.20
128.18
126.74
126.66
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
61.04
59.22
58.33
56.65
54.69
52.78
35.32
33.71
31.39
30.79
28.43
21.25
19.85
19.38
11.89
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Me
Ph
N
Me

3p (80:20 dr)

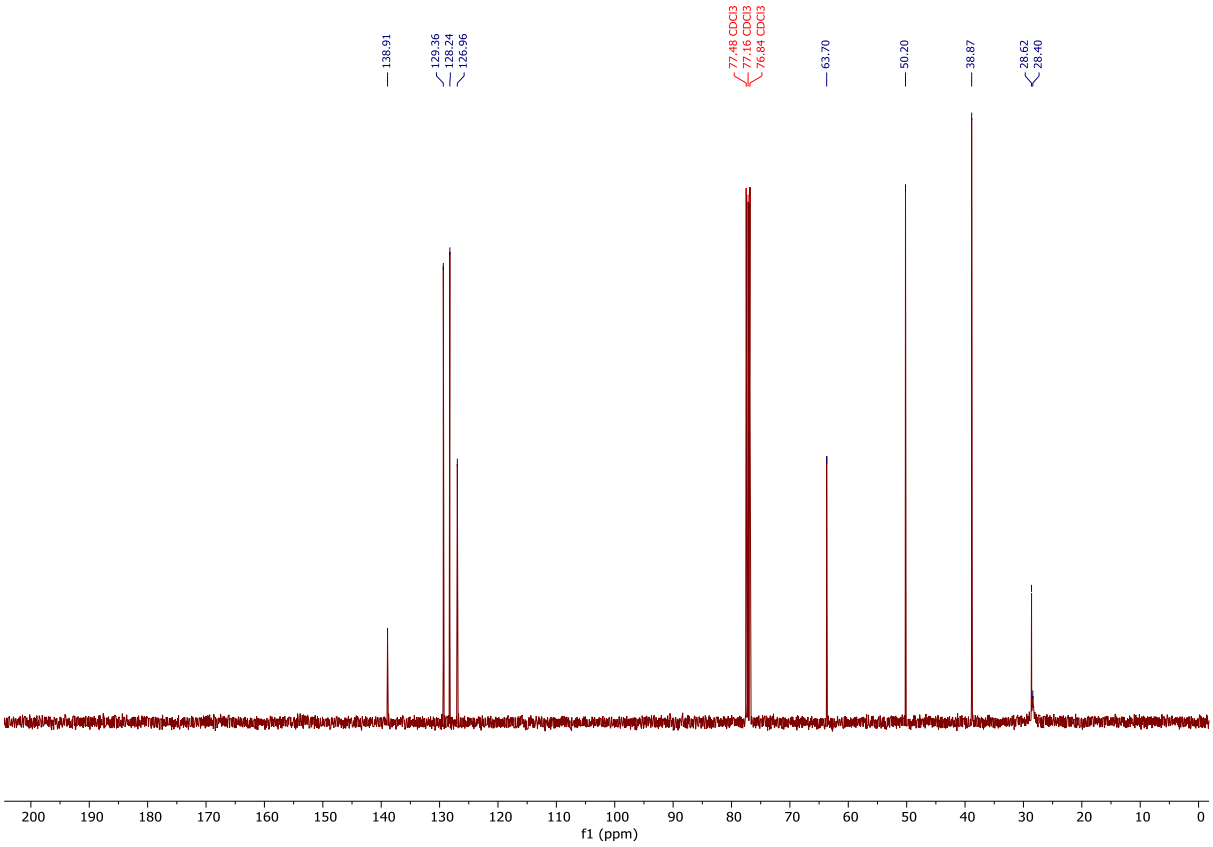
4.93
0.20
1.60
0.20
0.38
1.56
3.39
2.89
4.93
1.24
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

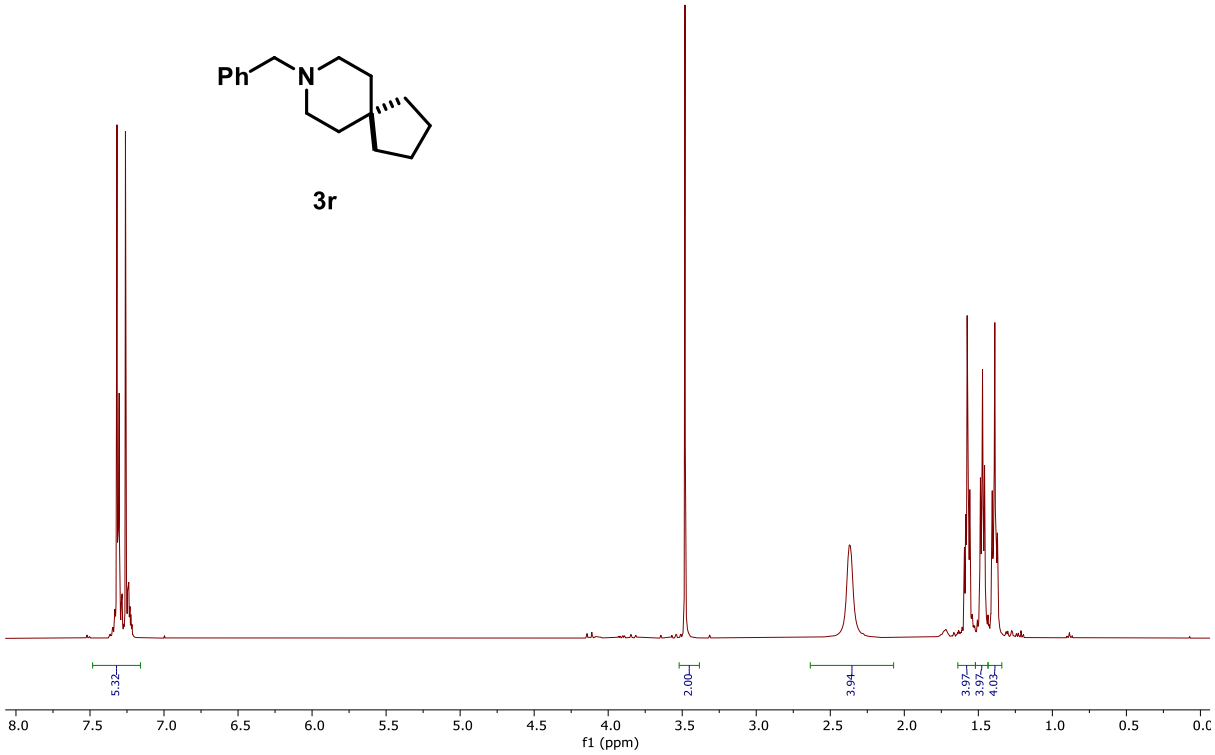

142.71
128.98
128.70
128.67
128.54
126.93
126.70
57.96
54.32
54.02
50.29
35.35
33.50
24.96
22.86
20.06
16.60
0.31
0.98
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

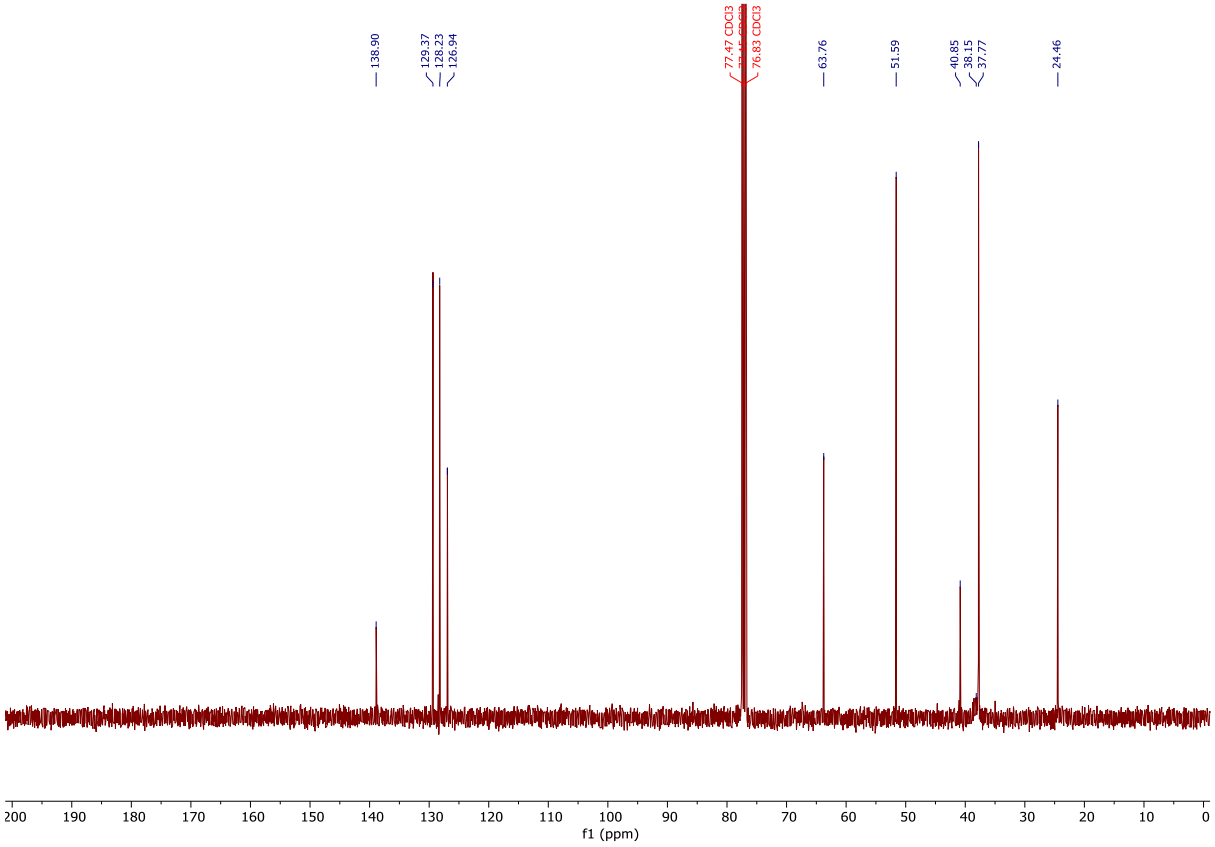

Ph
N
Me
Me

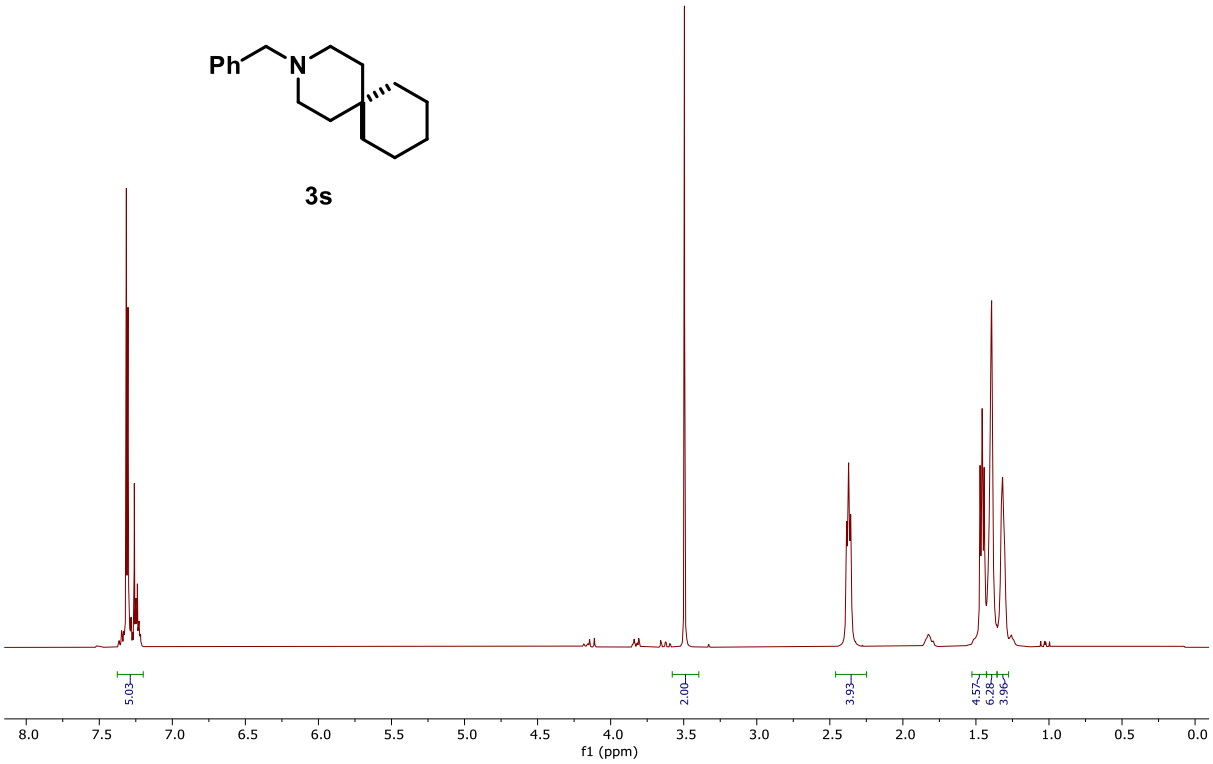
3q

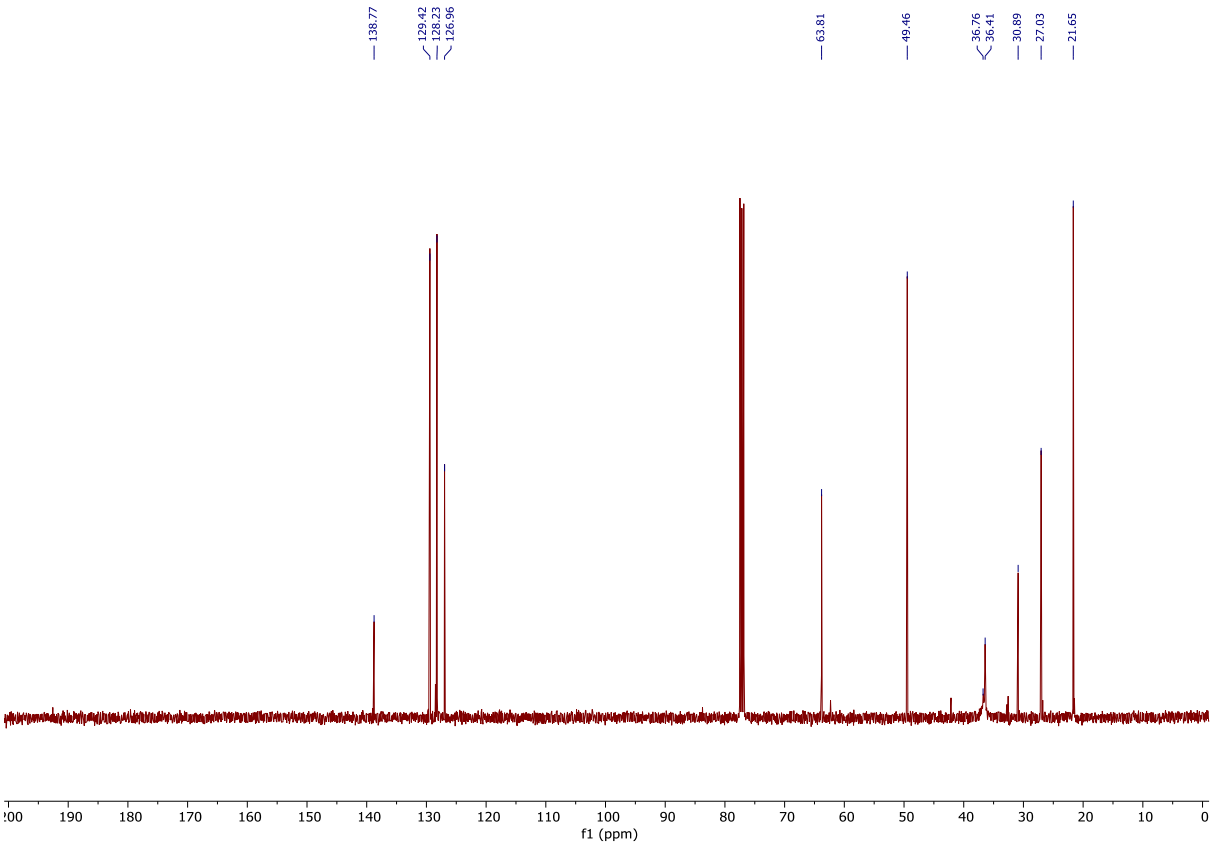
4.61
2.00
3.87
3.97
6.07
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

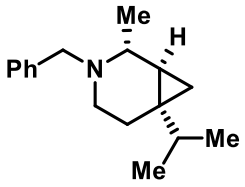

138.91
129.36
128.24
126.96
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
63.70
50.20
38.87
28.62
28.40
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Ph
N
3r
5.32
2.00
3.94
3.97
3.97
4.03
f1 (ppm)


138.90
129.37
128.23
126.94
77.47 CDCl3
76.83 CDCl3
63.76
51.59
40.85
38.15
37.77
24.46
f1 (ppm)

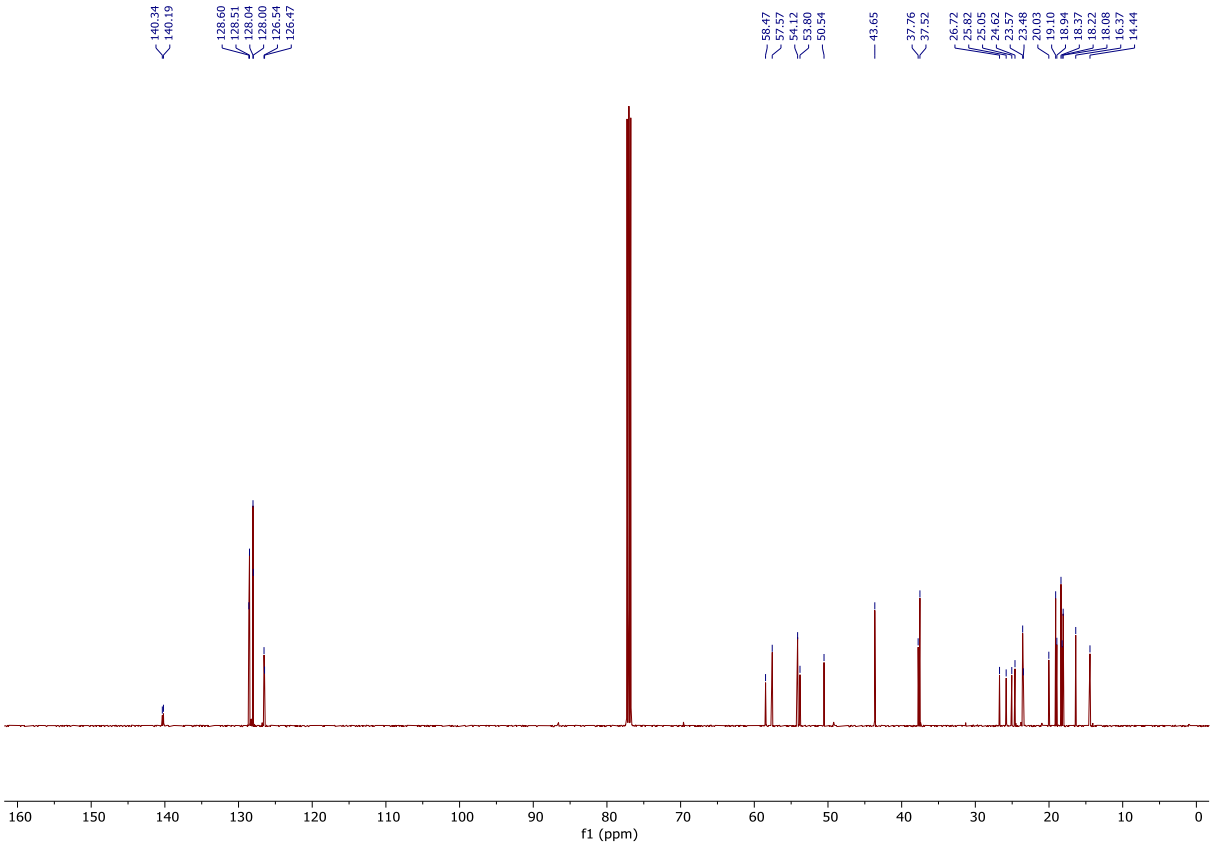

Ph
N
3s
5.03
2.00
3.93
4.57
6.28
3.96
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

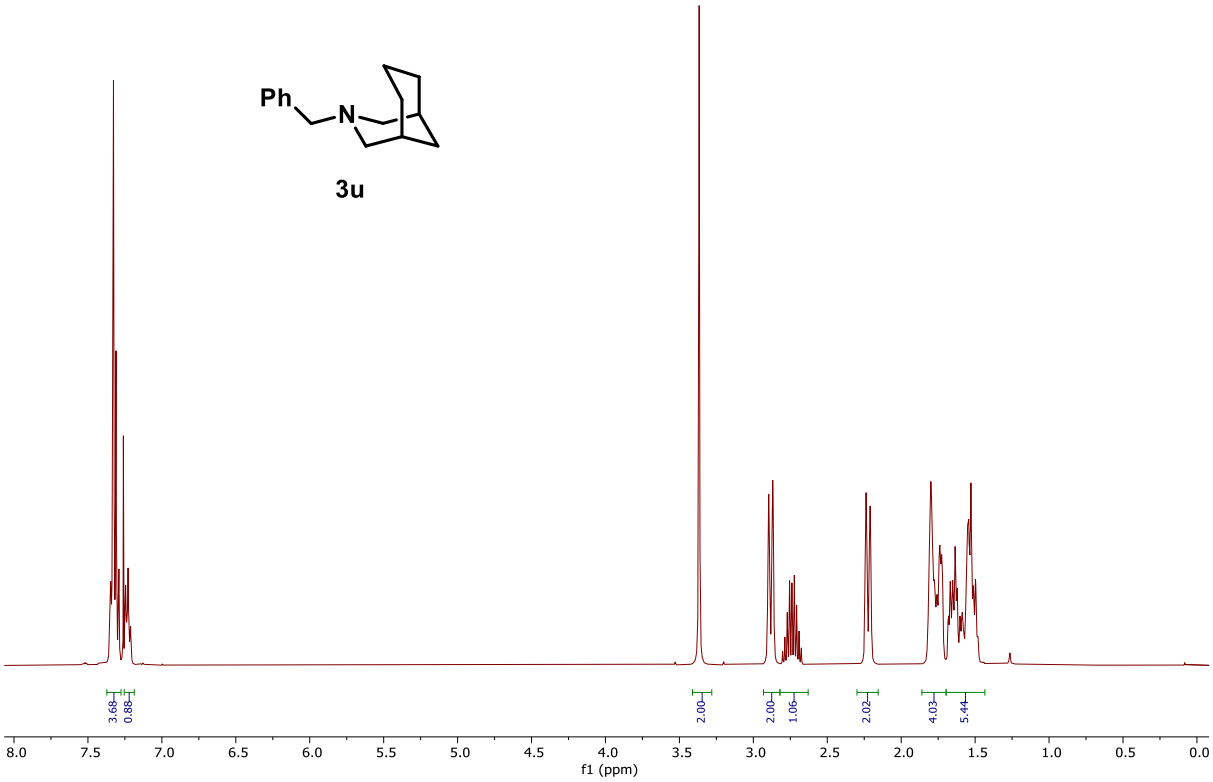

138.77
129.42
128.23
126.96
63.81
49.46
36.76
36.41
30.89
27.03
21.65
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

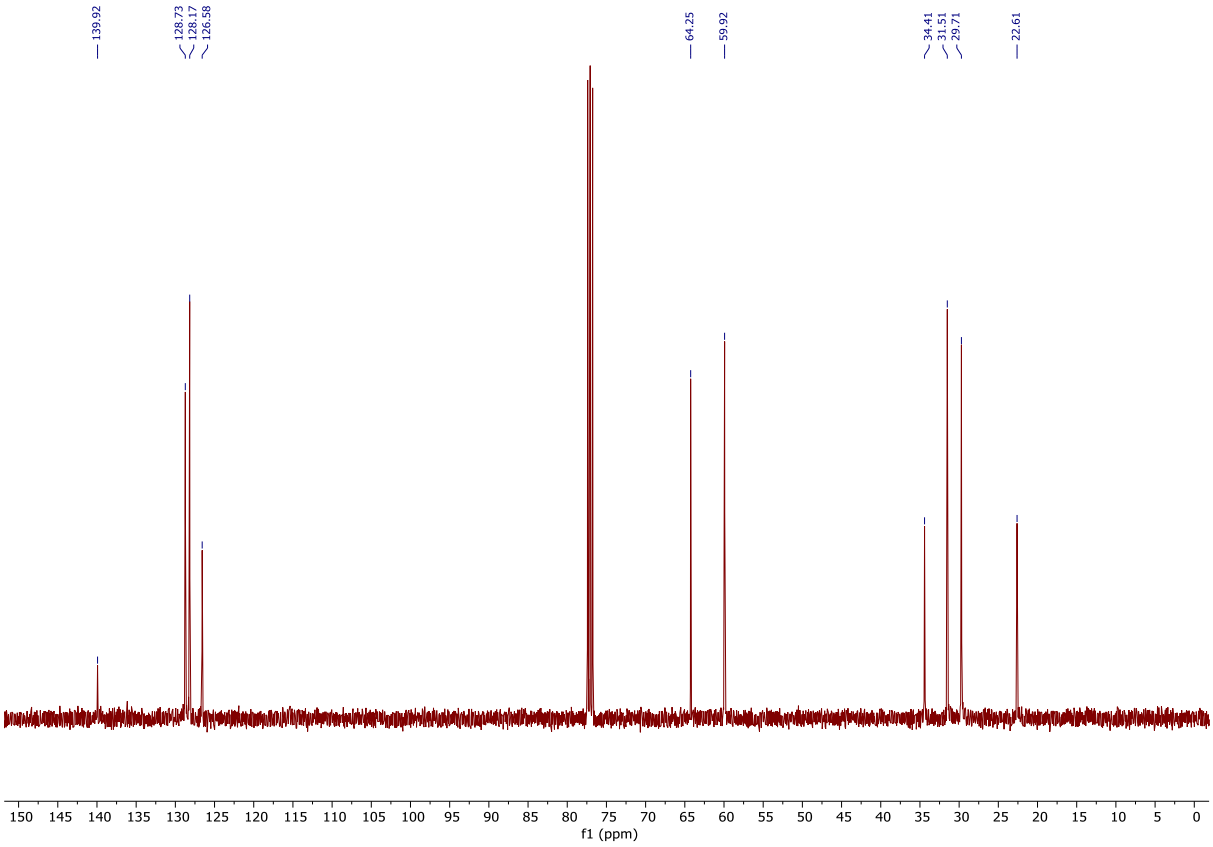

Me
H
Ph
N
Me
Me

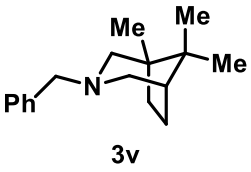
3t (62:38 d.r.)

5.11
0.38
0.62
0.62
0.38
0.61
0.38
0.99
0.62
0.44
1.12
0.65
0.41
3.06
7.11
0.43
1.62
0.70
0.39
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


140.34
140.19
128.60
128.51
128.04
128.00
126.54
126.47
58.47
57.57
54.12
53.80
50.54
43.65
37.76
37.52
26.72
25.82
25.05
24.62
23.57
23.48
20.03
19.10
18.94
18.37
18.22
18.08
16.37
14.44
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

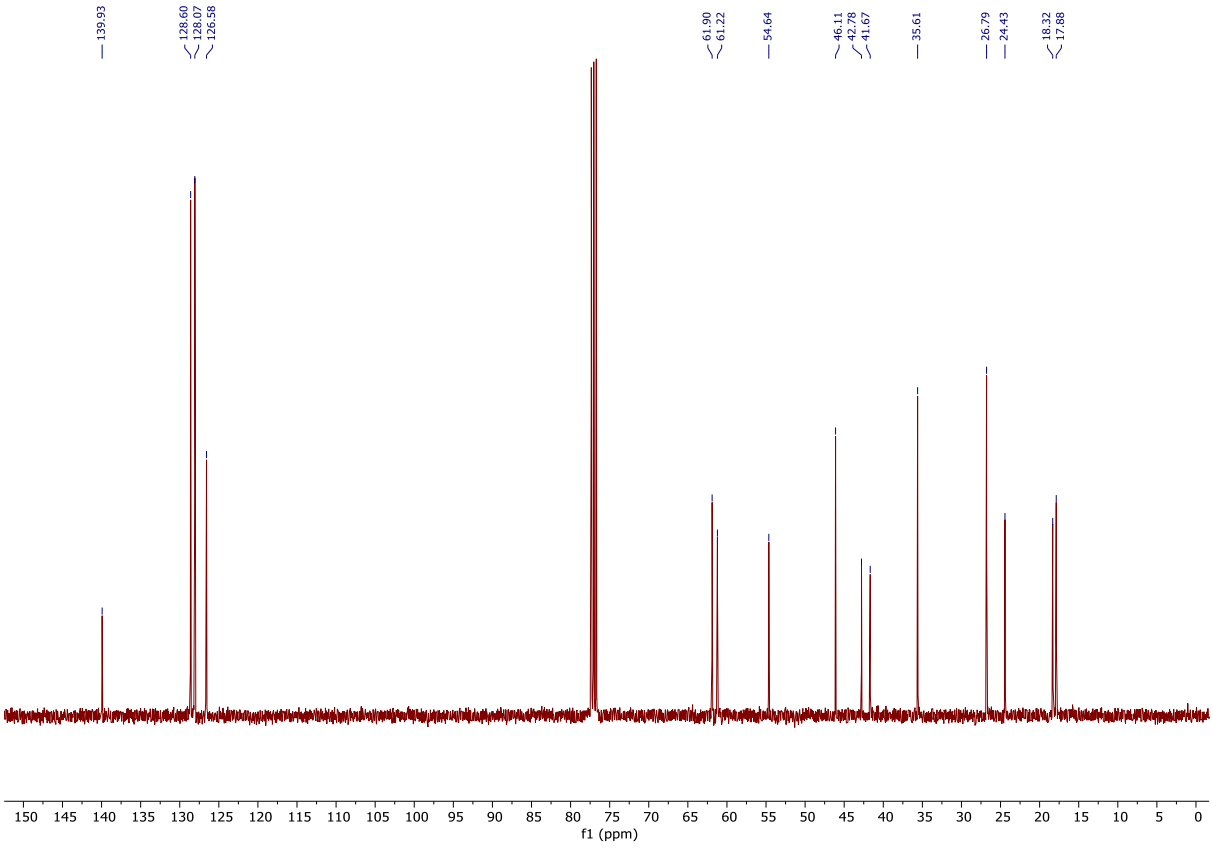

Ph
N
3u
3.68
0.88
2.00
2.00
1.06
2.02
4.03
5.44
f1 (ppm)

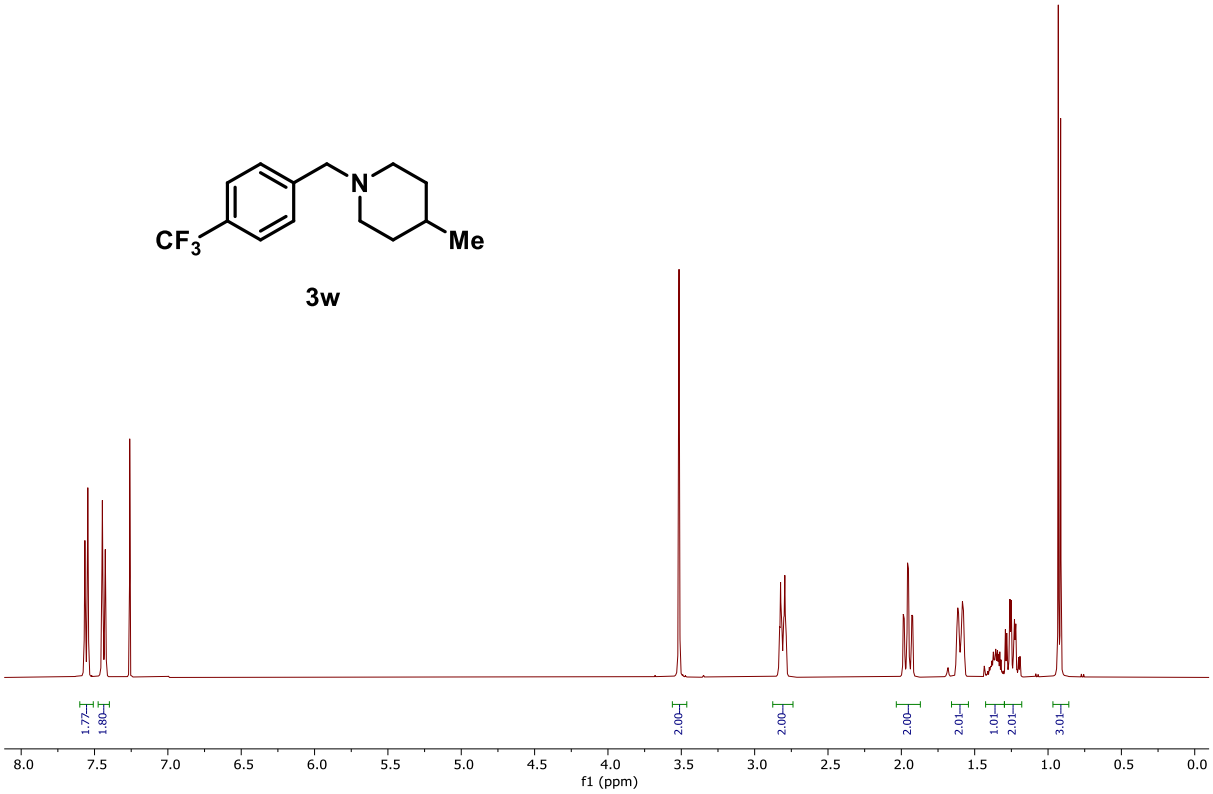

139.92
128.73
128.17
126.58
64.25
59.92
34.41
31.51
29.71
22.61
f1 (ppm)

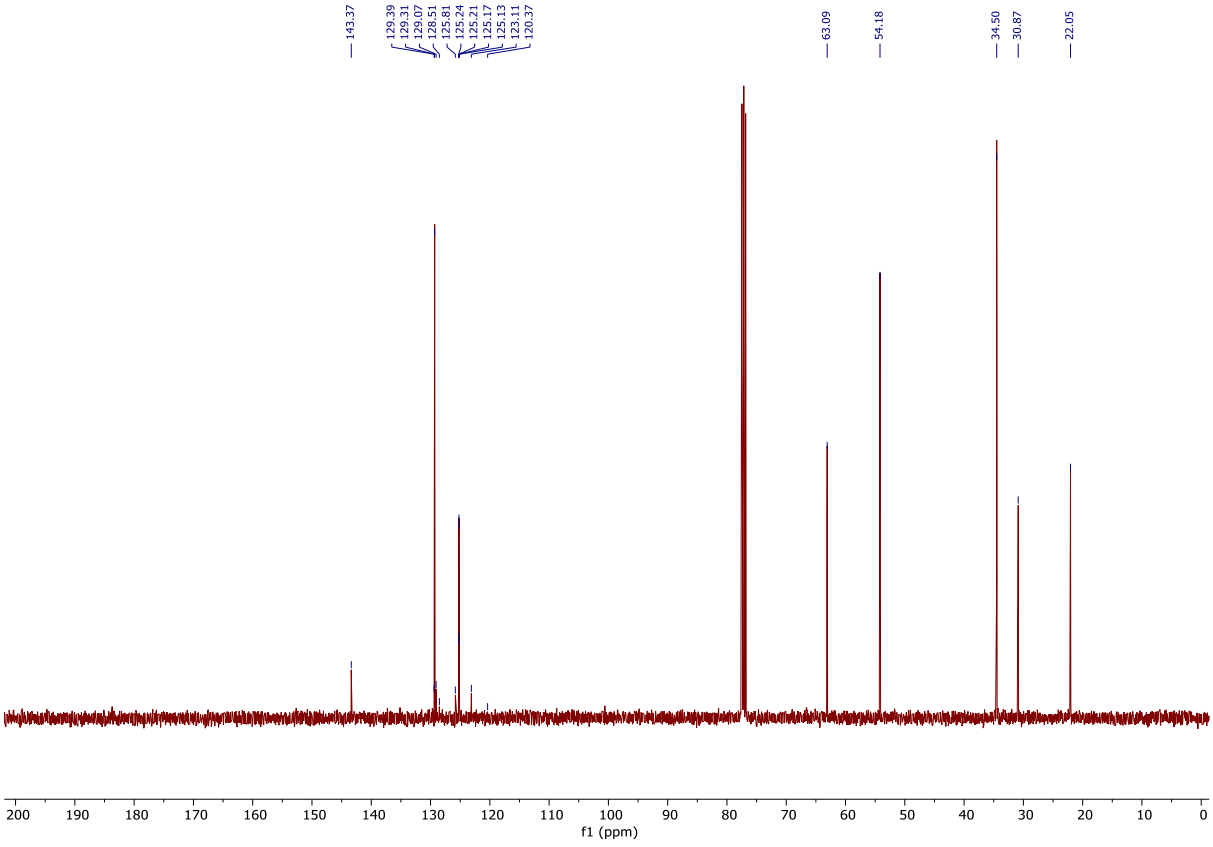

Me
Me
Me
N
Ph

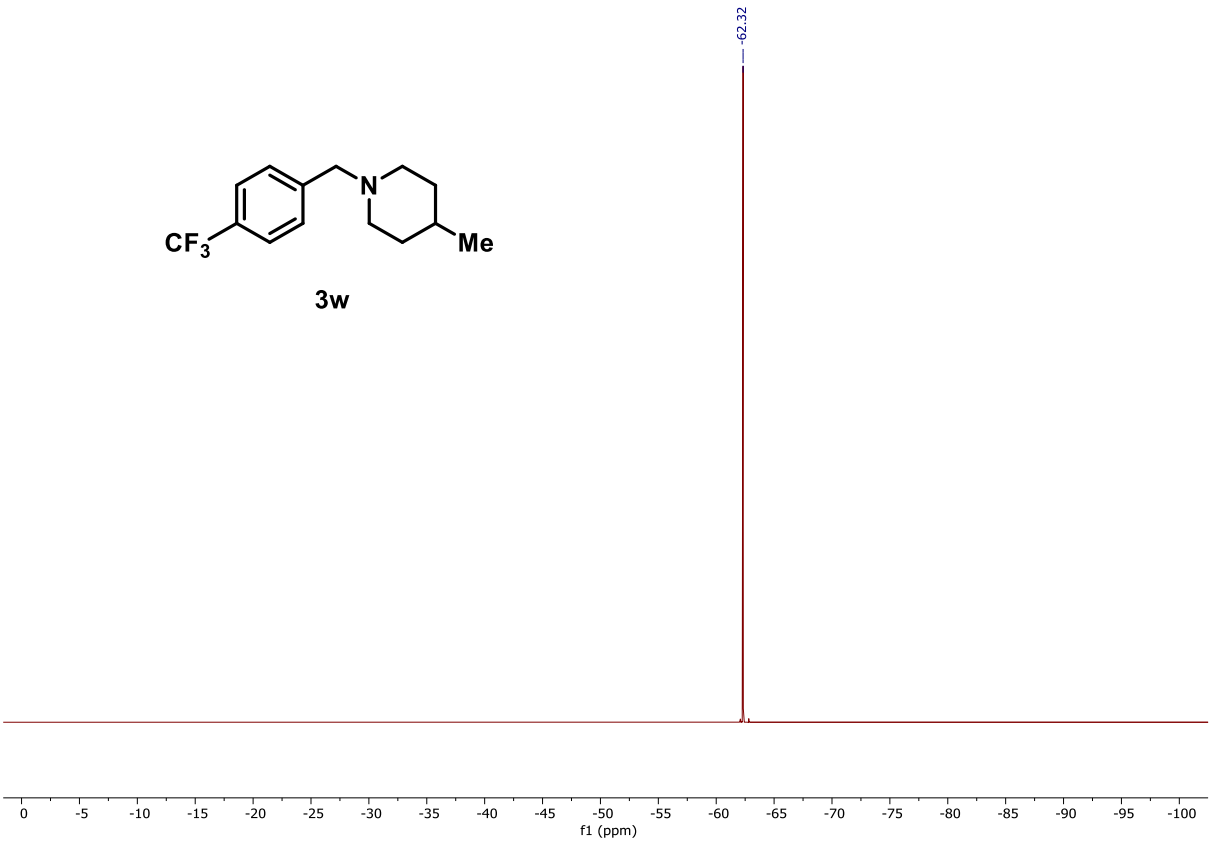
3v

5.03
2.00
1.00
1.00
1.01
1.00
3.11
2.23
3.05
3.05
3.03
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

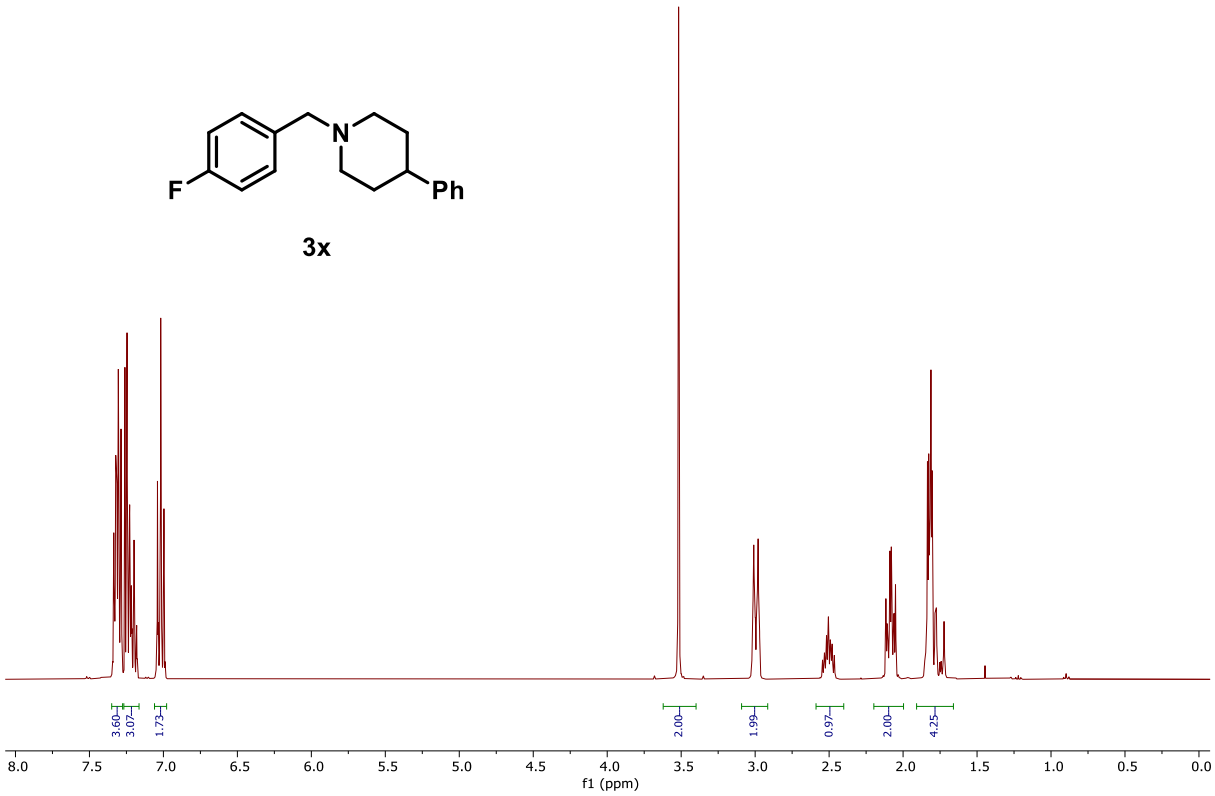

139.93
128.60
128.07
126.58
61.90
61.22
54.64
46.11
42.78
41.67
35.61
26.79
24.43
18.32
17.88
150 145 140 135 130 125 120 115 110 105 100 95 90 85 80 75 70 65 60 55 50 45 40 35 30 25 20 15 10 5 0
f1 (ppm)

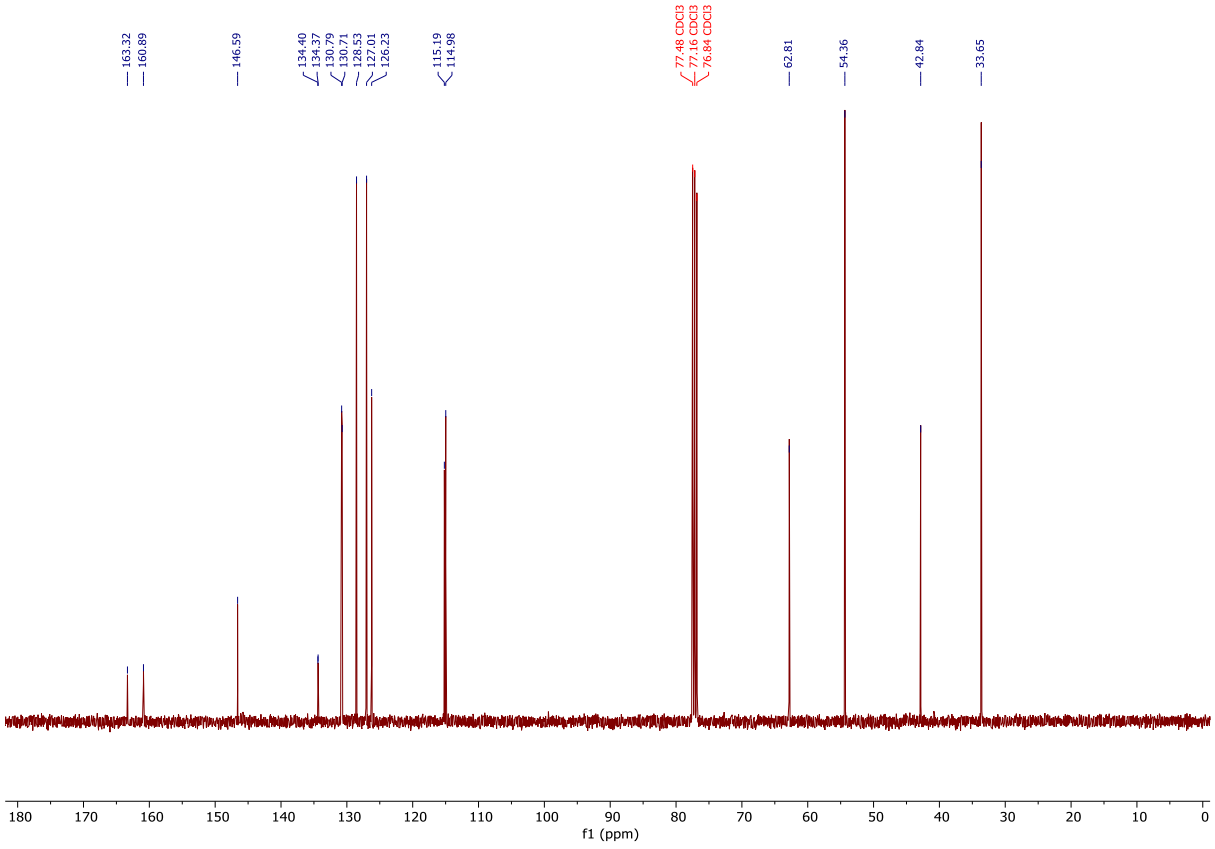

CF3
N
Me
3w
1.77
1.80
2.00
2.00
2.00
2.01
1.01
2.01
3.01
f1 (ppm)

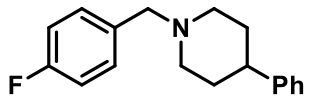

143.37
129.39
129.31
129.07
128.51
125.81
125.24
125.21
125.17
125.13
123.11
120.37
63.09
54.18
34.50
30.87
22.05
f1 (ppm)


-62.32
N
CF3
Me
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
f1 (ppm)

3w

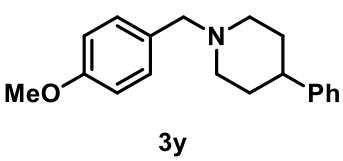

F
N
Ph
3x
3.60
3.07
1.73
2.00
1.99
0.97
2.00
4.25
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


163.32
160.89
146.59
134.40
134.37
130.79
130.71
128.53
127.01
126.23
115.19
114.98
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
62.81
54.36
42.84
33.65
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


N
F
Ph

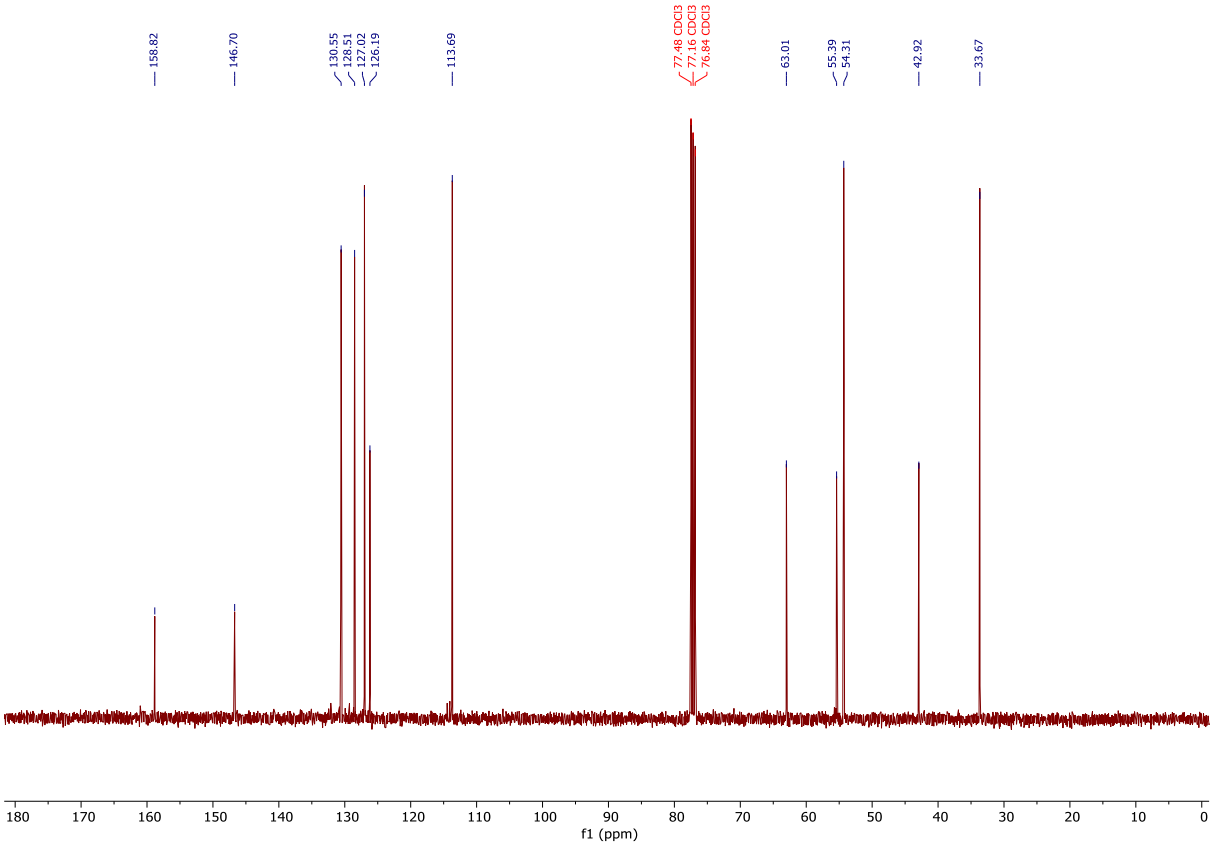
3x

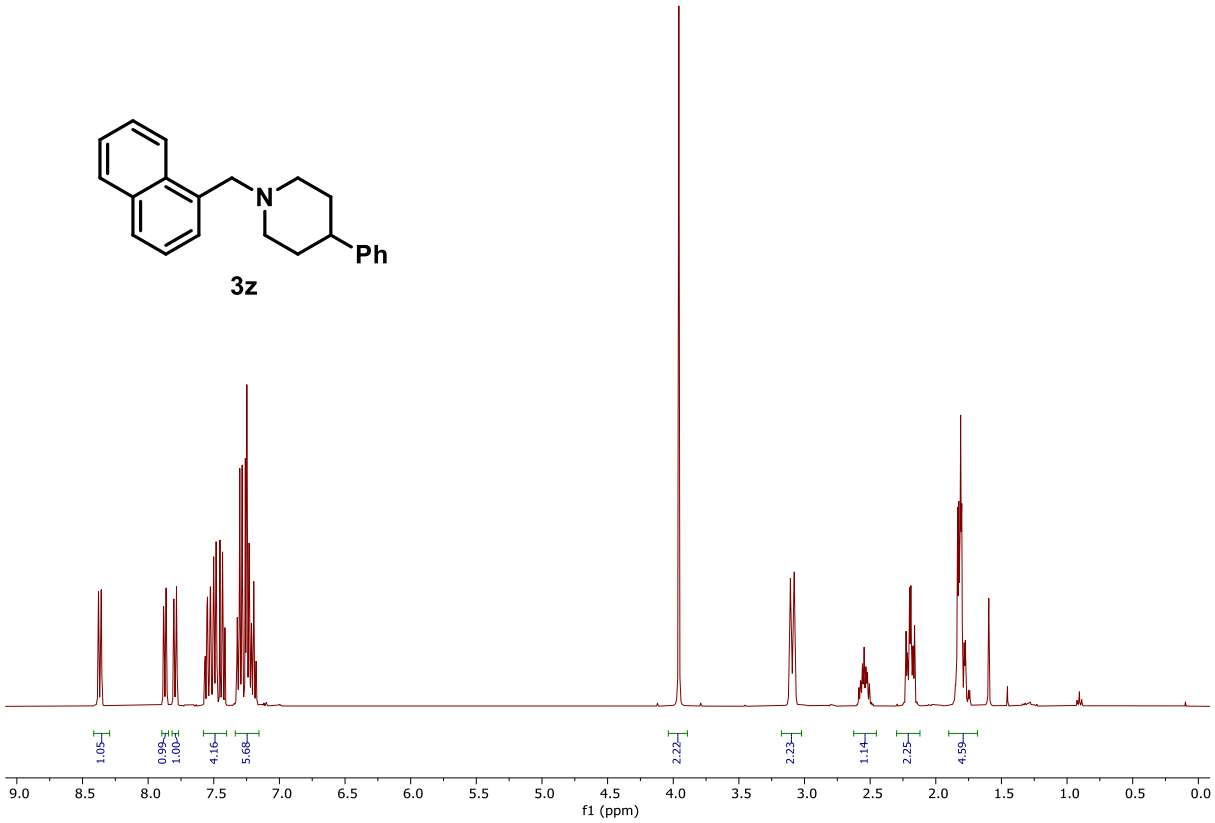
-116.13
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240
f1 (ppm)

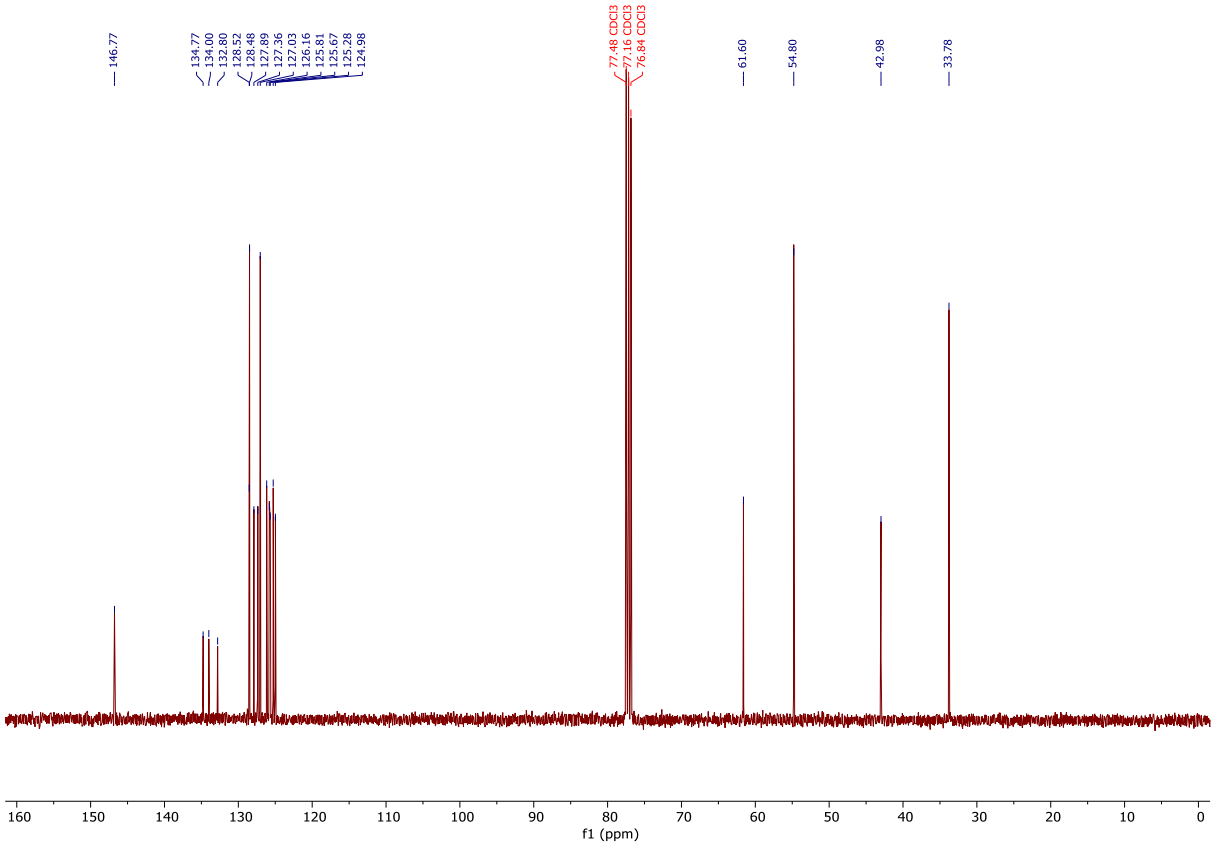

MeO
N
Ph

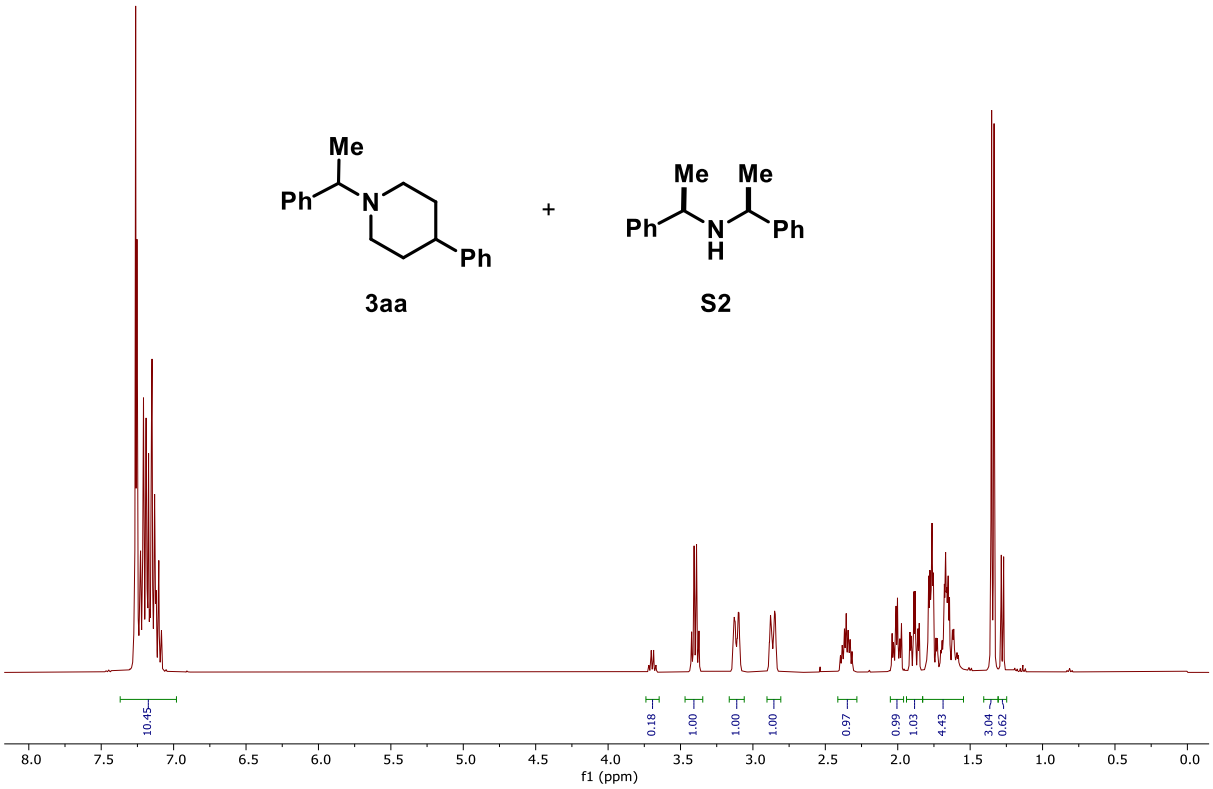
3y

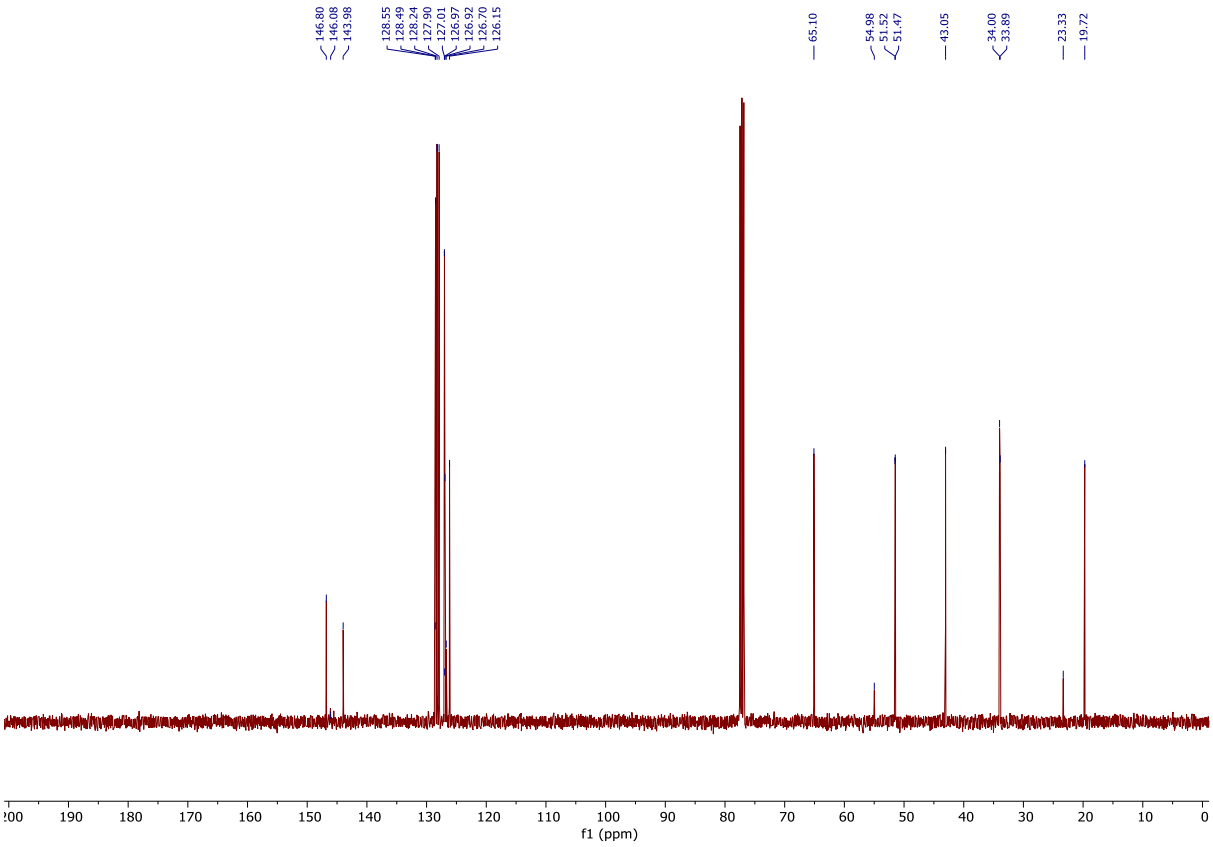
7.09
1.95
3.08
2.07
2.04
1.00
2.06
4.47
8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

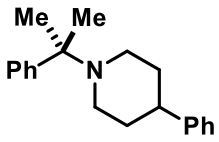

158.82
146.70
130.55
128.51
127.02
126.19
113.69
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
63.01
55.39
54.31
42.92
33.67
180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)


N
Ph
3z
1.05
0.99
1.00
4.16
5.68
2.22
2.23
1.14
2.25
4.59
f1 (ppm)


146.77
134.77
134.00
132.80
128.52
128.48
127.89
127.36
127.03
126.16
125.81
125.67
125.28
124.98
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
61.60
54.80
42.98
33.78
f1 (ppm)

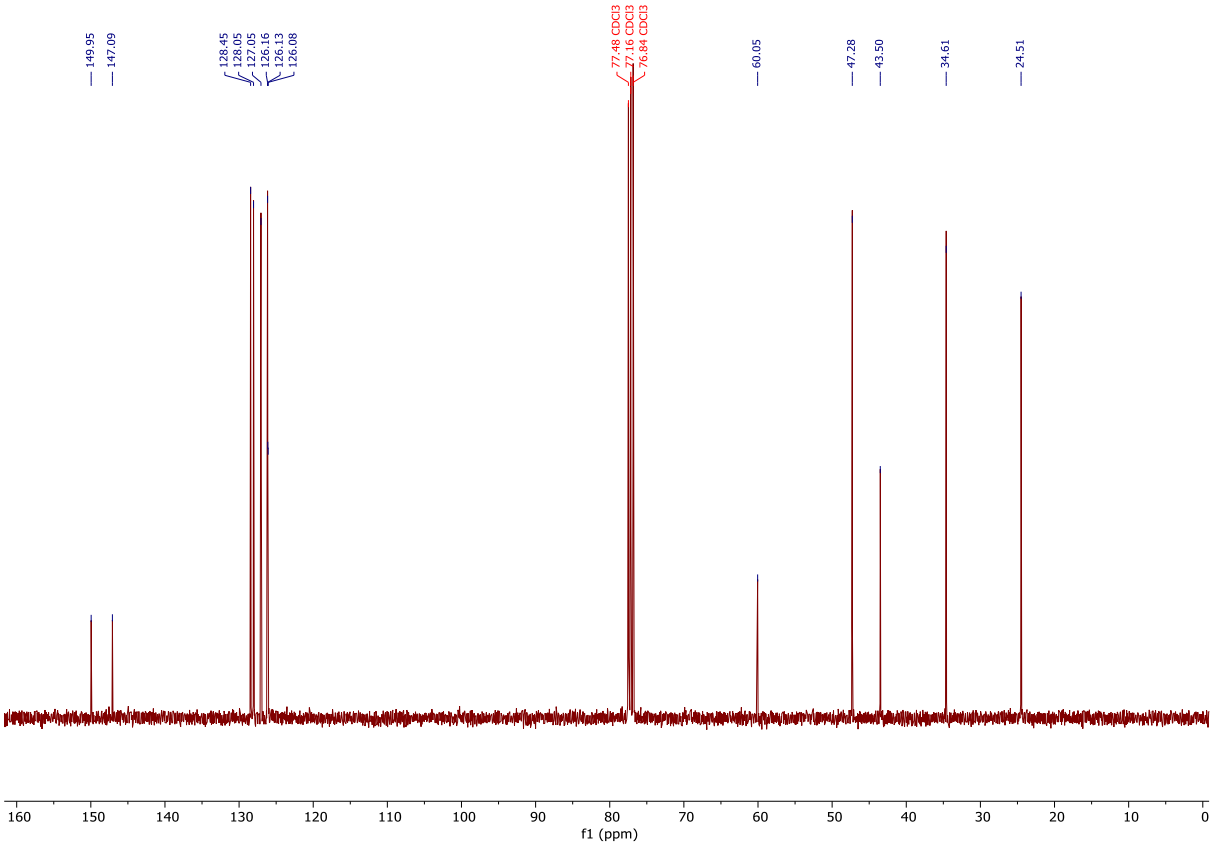

Me
Ph
N
Ph
3aa
+
Me
Me
Ph
N
H
Ph
S2
10.45
0.18
1.00
1.00
1.00
0.97
0.99
1.03
4.43
3.04
0.62
f1 (ppm)

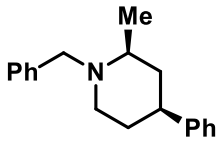

146.80
146.08
143.98
128.55
128.49
128.24
127.90
127.01
126.97
126.92
126.70
126.15
65.10
54.98
51.52
51.47
43.05
34.00
33.89
23.33
19.72
f1 (ppm)


Me
Me
Ph
N
Ph

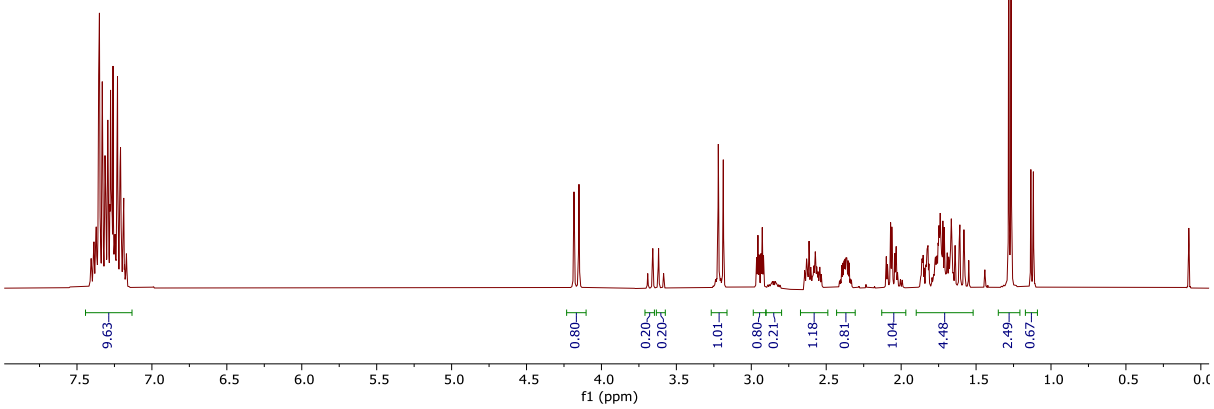
3ab

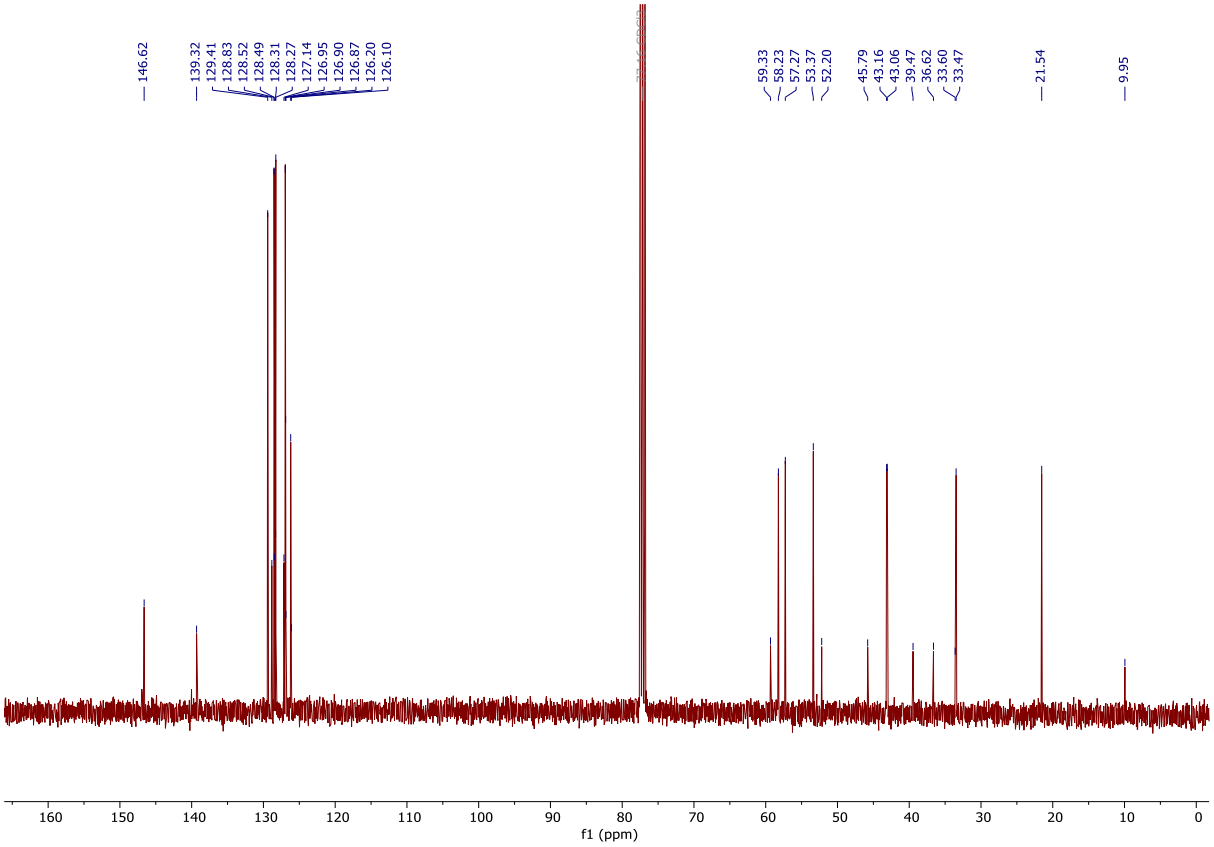
0.96
3.82
1.00
0.49
1.00
2.02
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

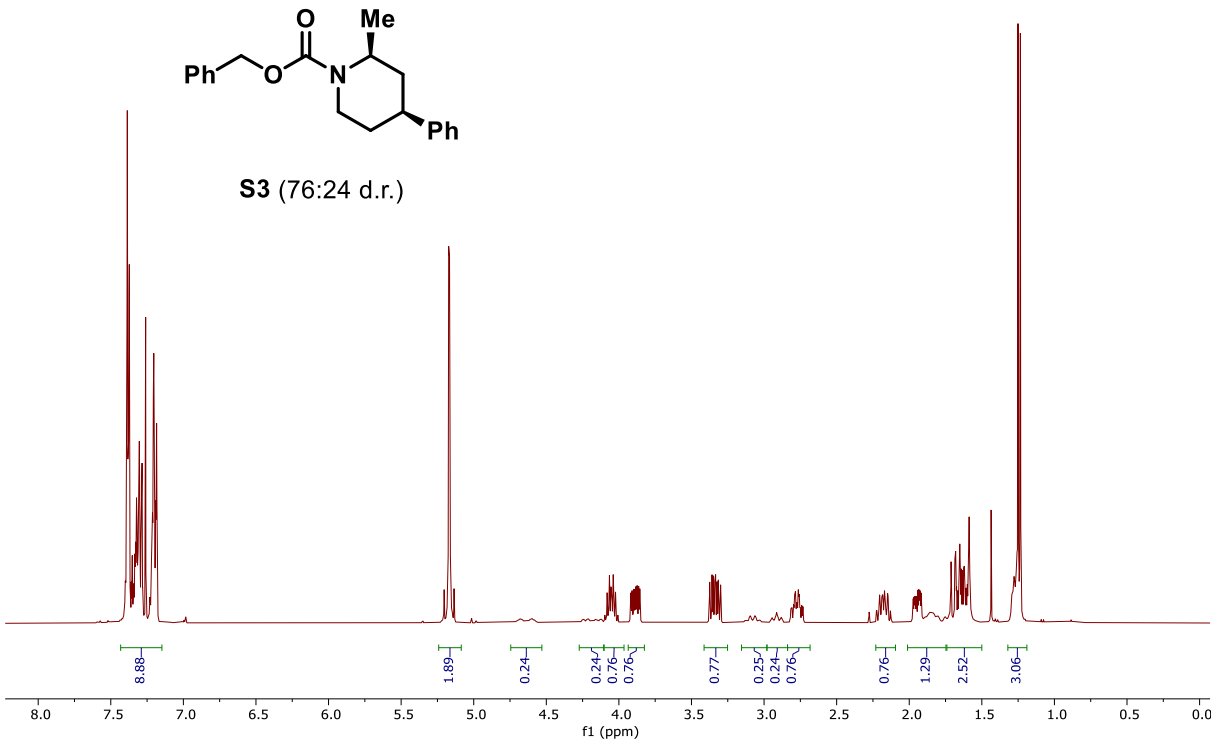

149.95
147.09
128.45
128.05
127.05
126.16
126.13
126.08
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
60.05
47.28
43.50
34.61
24.51
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Me
Ph
N
Ph

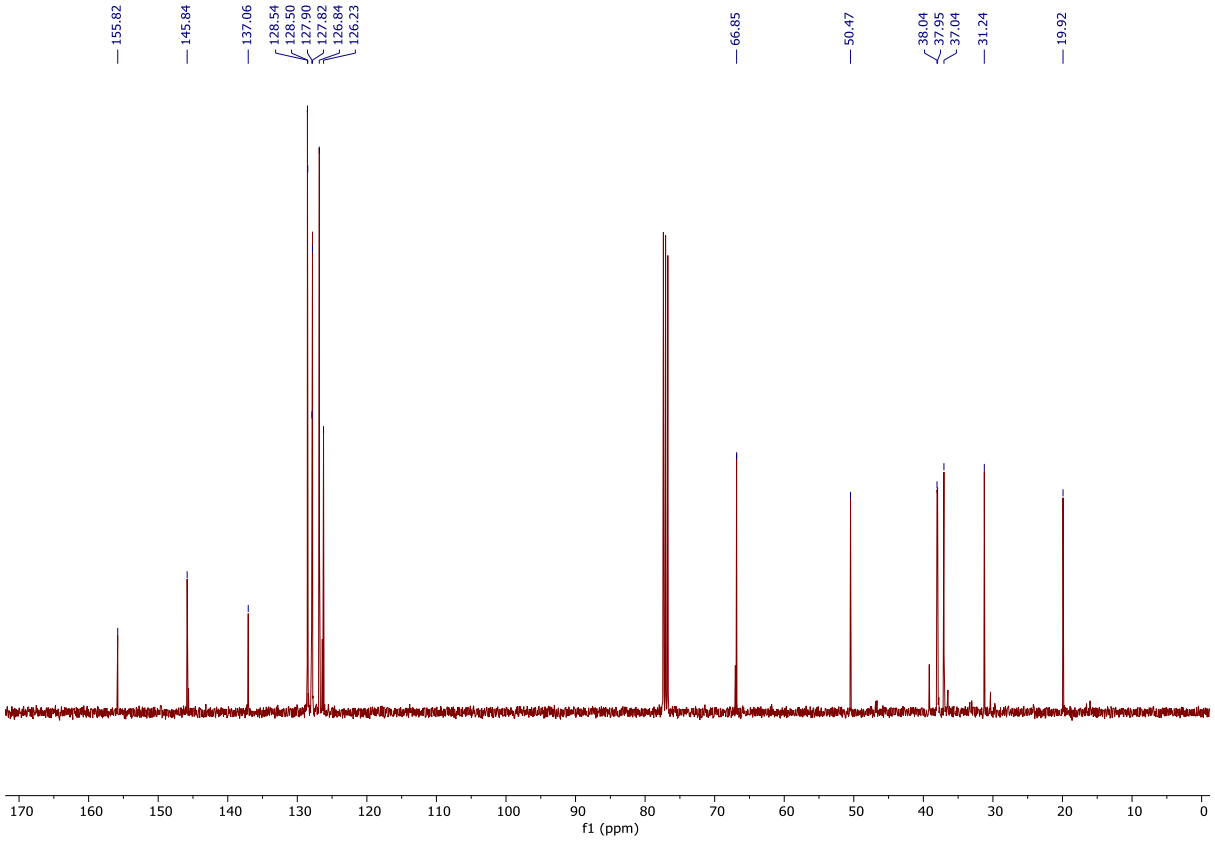
(+)-**3ac** (80:20 d.r.)

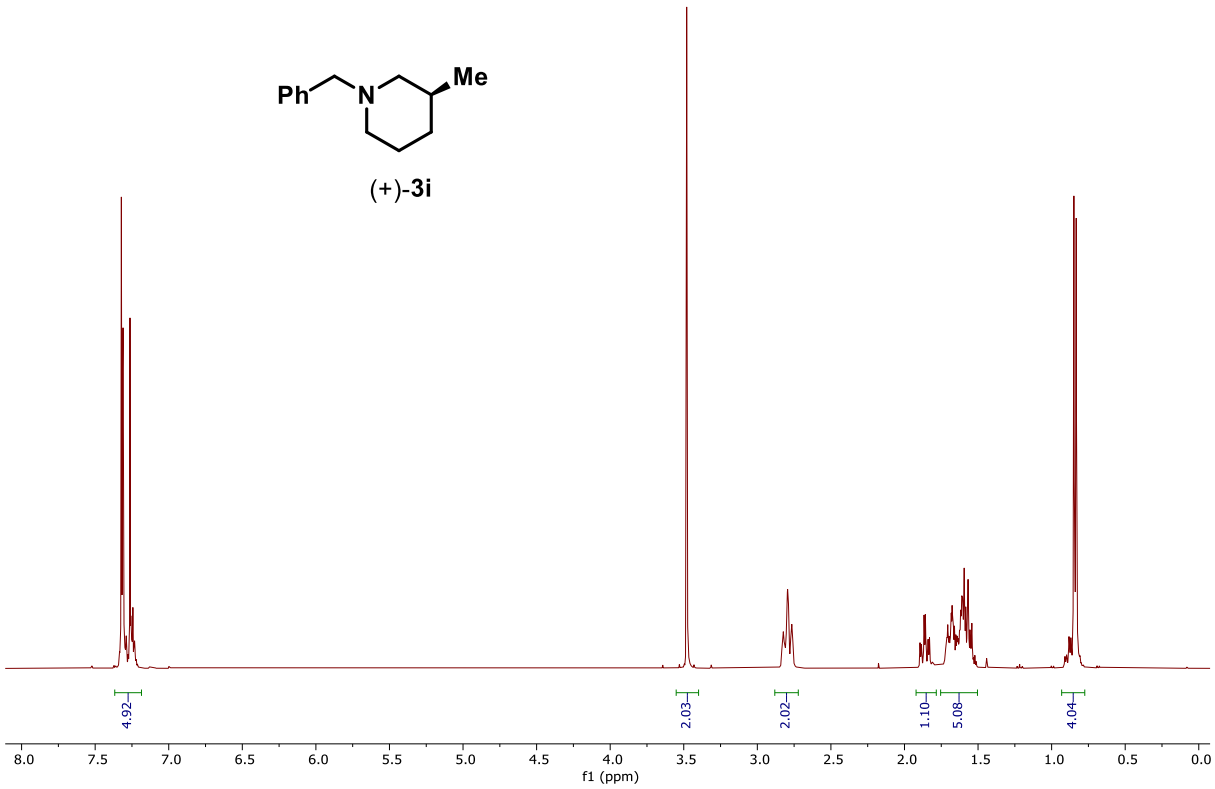

9.63
0.80
0.20
0.20
1.01
0.80
0.21
1.18
0.81
1.04
4.48
2.49
0.67
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

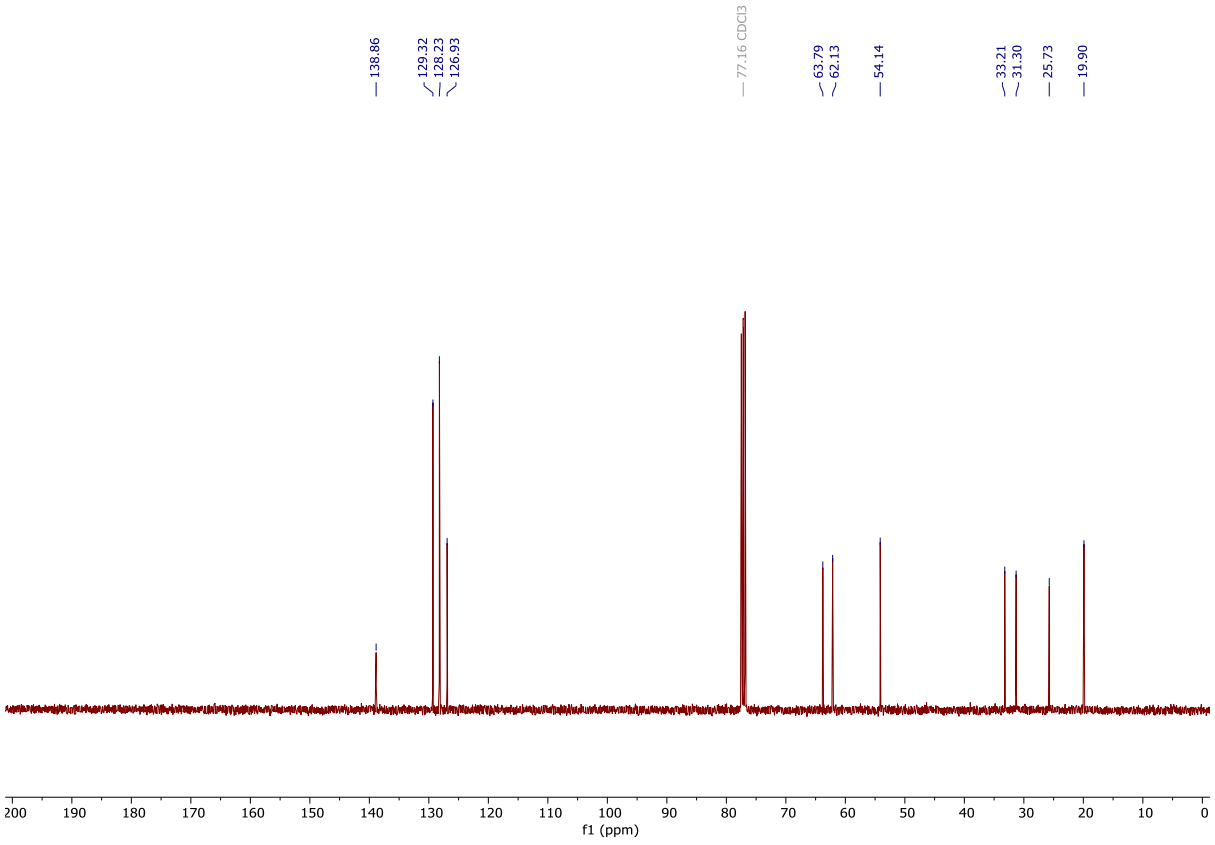

146.62
139.32
129.41
128.83
128.52
128.49
128.31
128.27
127.14
126.95
126.90
126.87
126.20
126.10
59.33
58.23
57.27
53.37
52.20
45.79
43.16
43.06
39.47
36.62
33.60
33.47
21.54
9.95
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

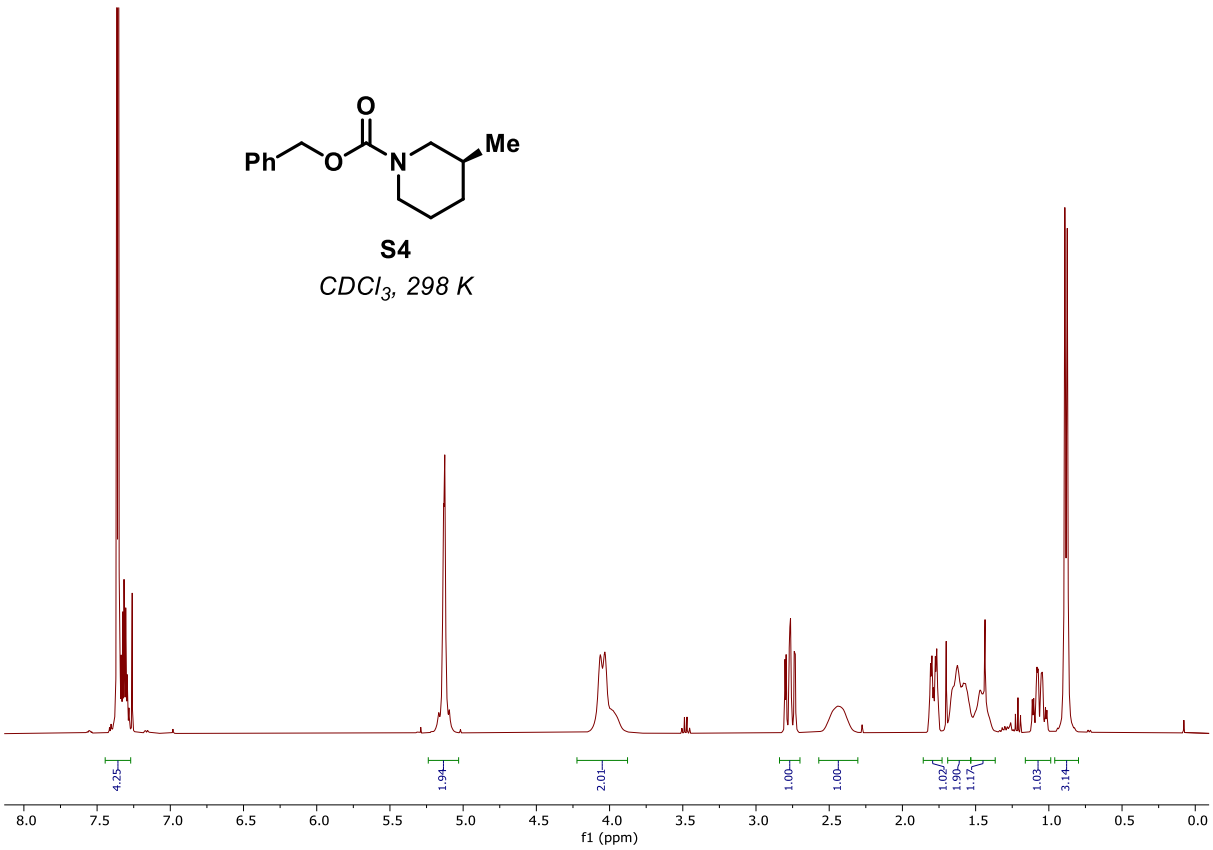

O
Me
Ph
O
N
Ph
8.88
1.89
0.24
0.24
0.76
0.76
0.77
0.25
0.24
0.76
0.76
1.29
2.52
3.06
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

S3 (76:24 d.r.)


155.82
145.84
137.06
128.54
128.50
127.90
127.82
126.84
126.23
66.85
50.47
38.04
37.95
37.04
31.24
19.92
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

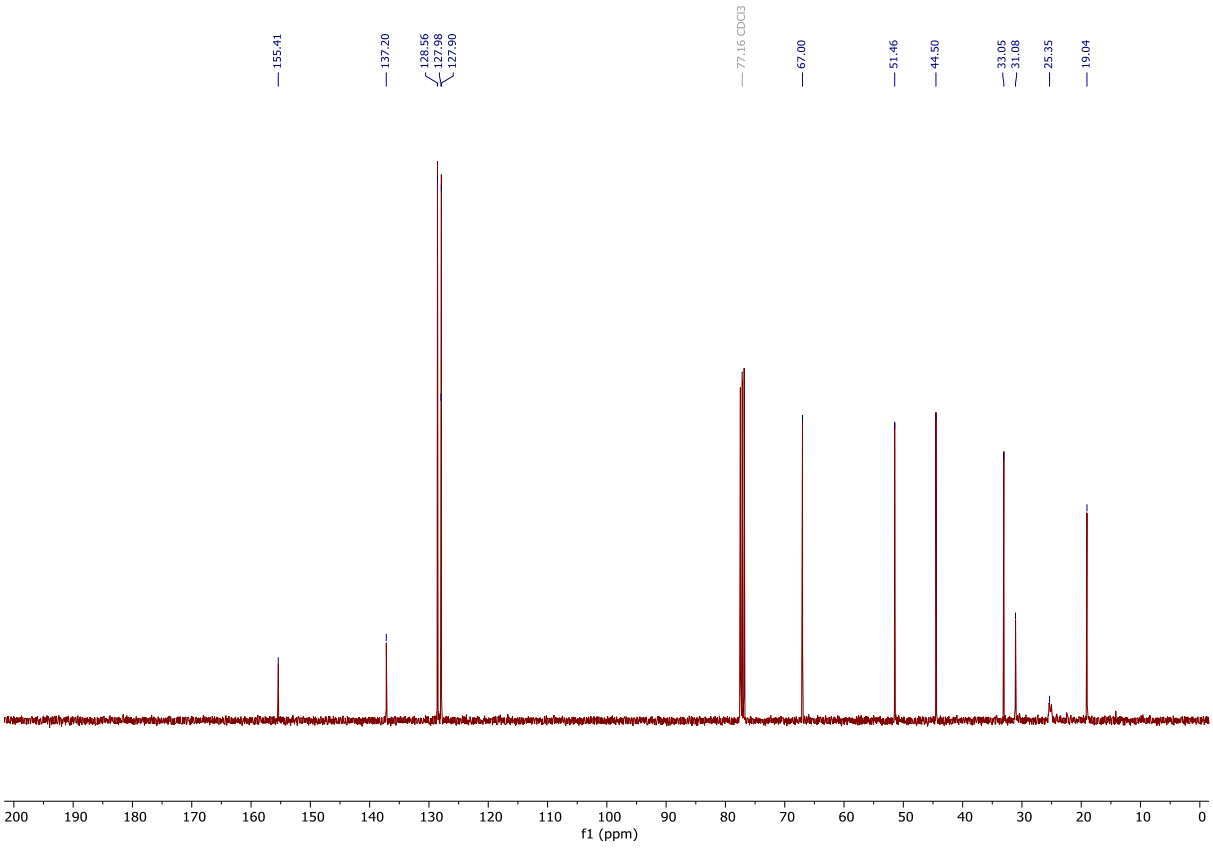

Ph
N
Me
(+)-3i
4.92
2.03
2.02
1.10
5.08
4.04
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

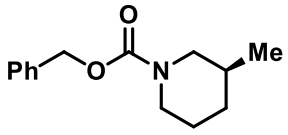

138.86
129.32
128.23
126.93
77.16 CDCl3
63.79
62.13
54.14
33.21
31.30
25.73
19.90
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)



S4

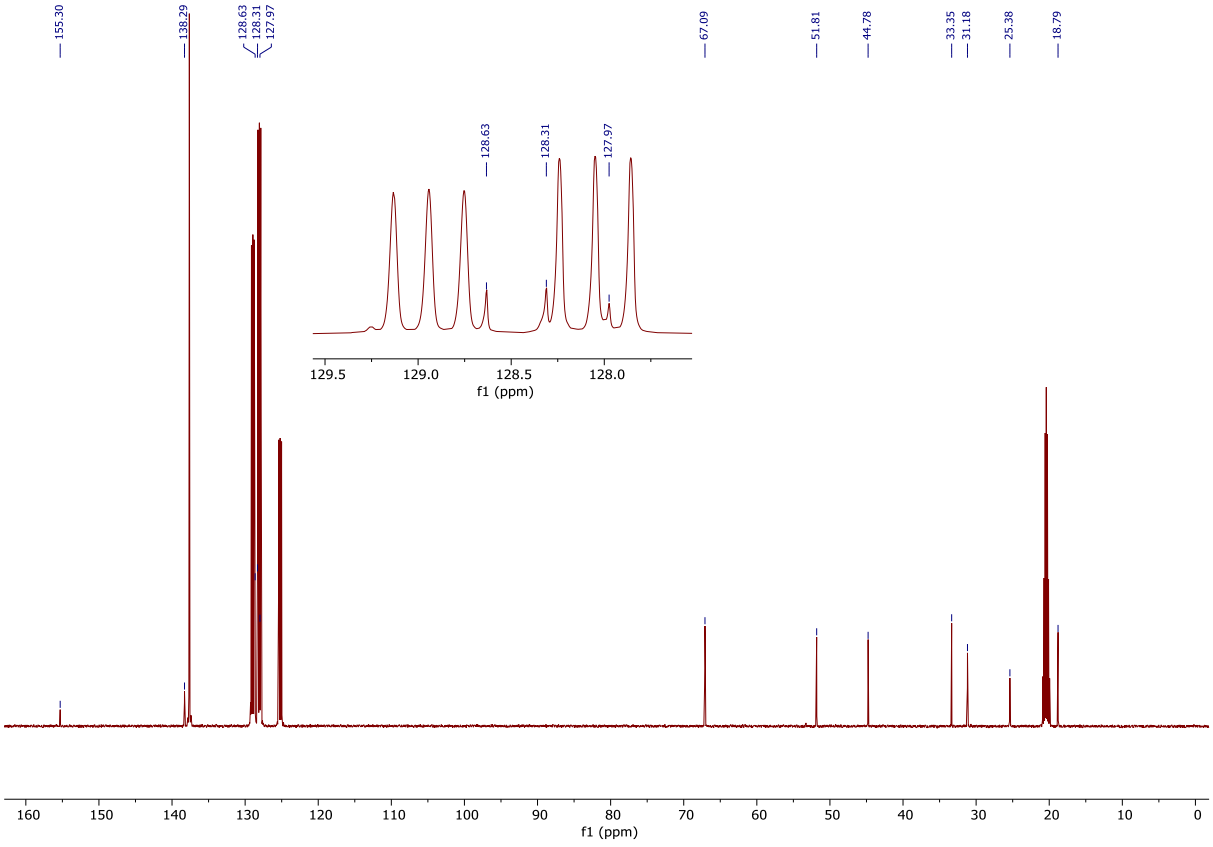
$CDCl_3$, 298 K

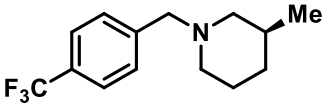




S4

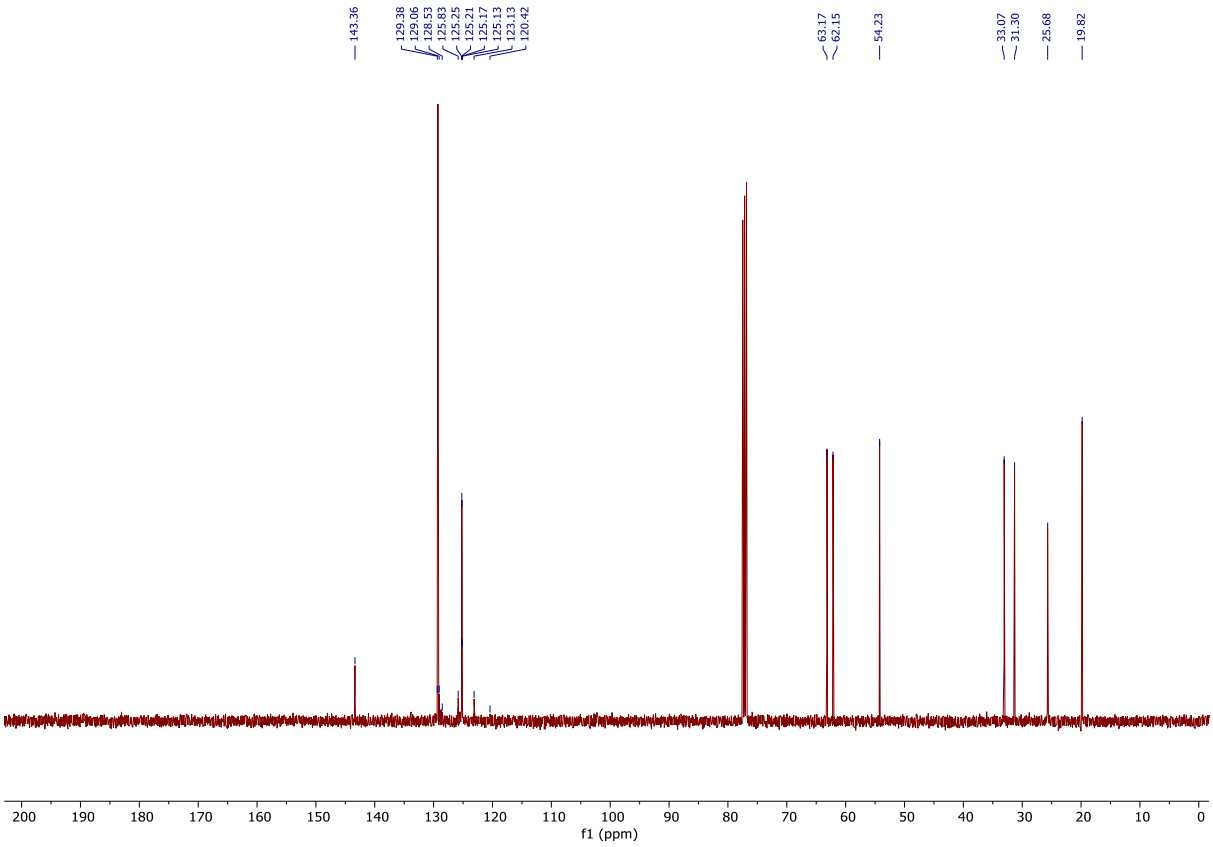
d_8-toluene, 363 K

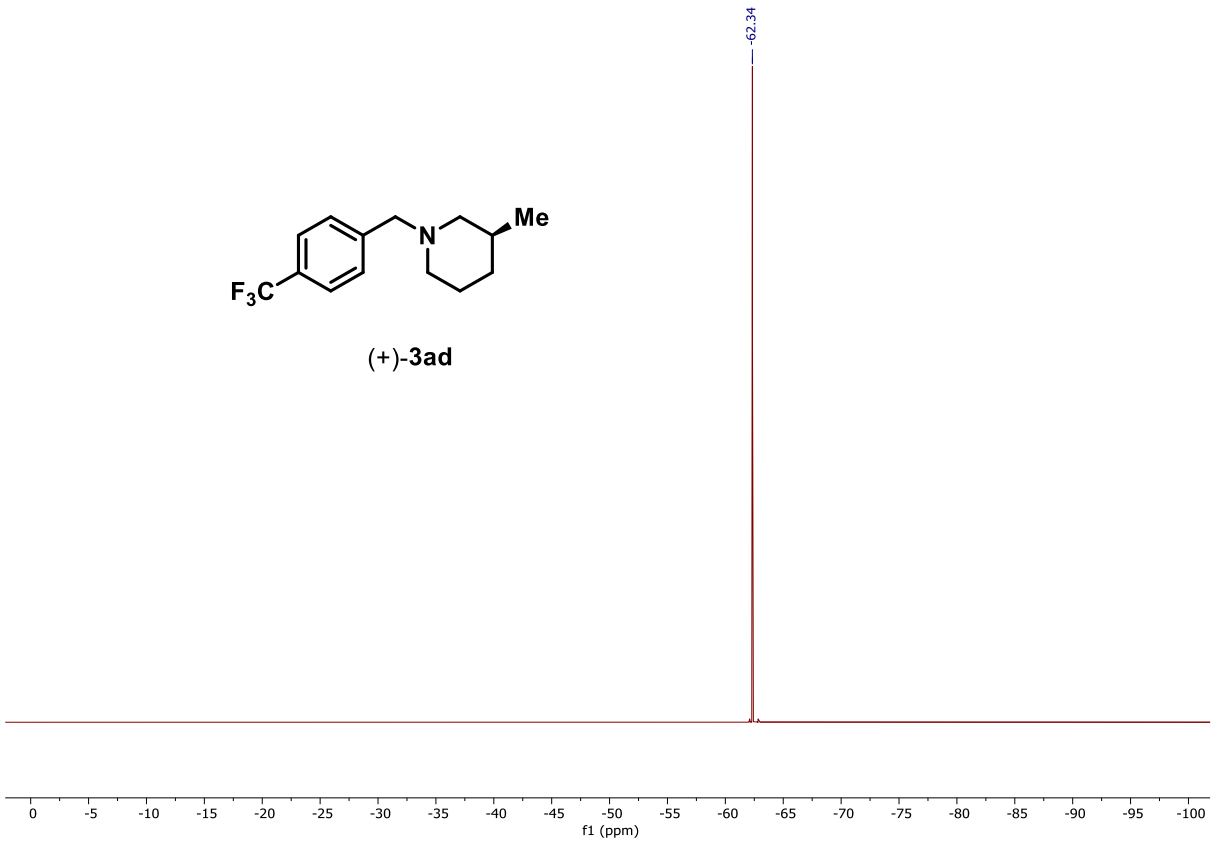



Me
N
F3C

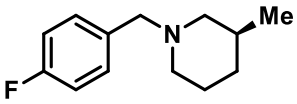
(+)-**3ad**

1.81
1.85
2.00
2.00
1.00
5.08
4.03
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


143.36
129.38
129.06
128.53
125.33
125.25
125.21
125.17
125.13
123.13
120.42
63.17
62.15
54.23
33.07
31.30
25.68
19.82
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

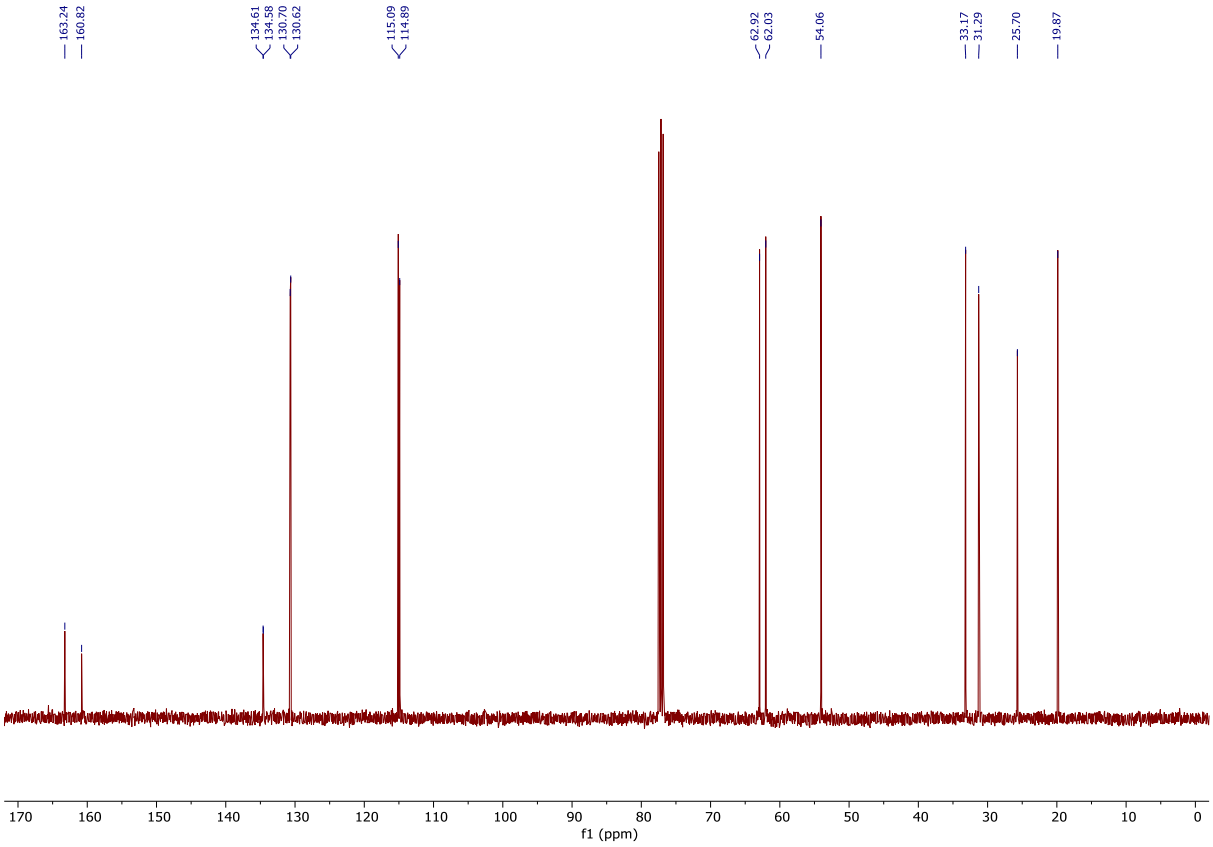

-62.34
Me
N
F3C
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
-100
f1 (ppm)

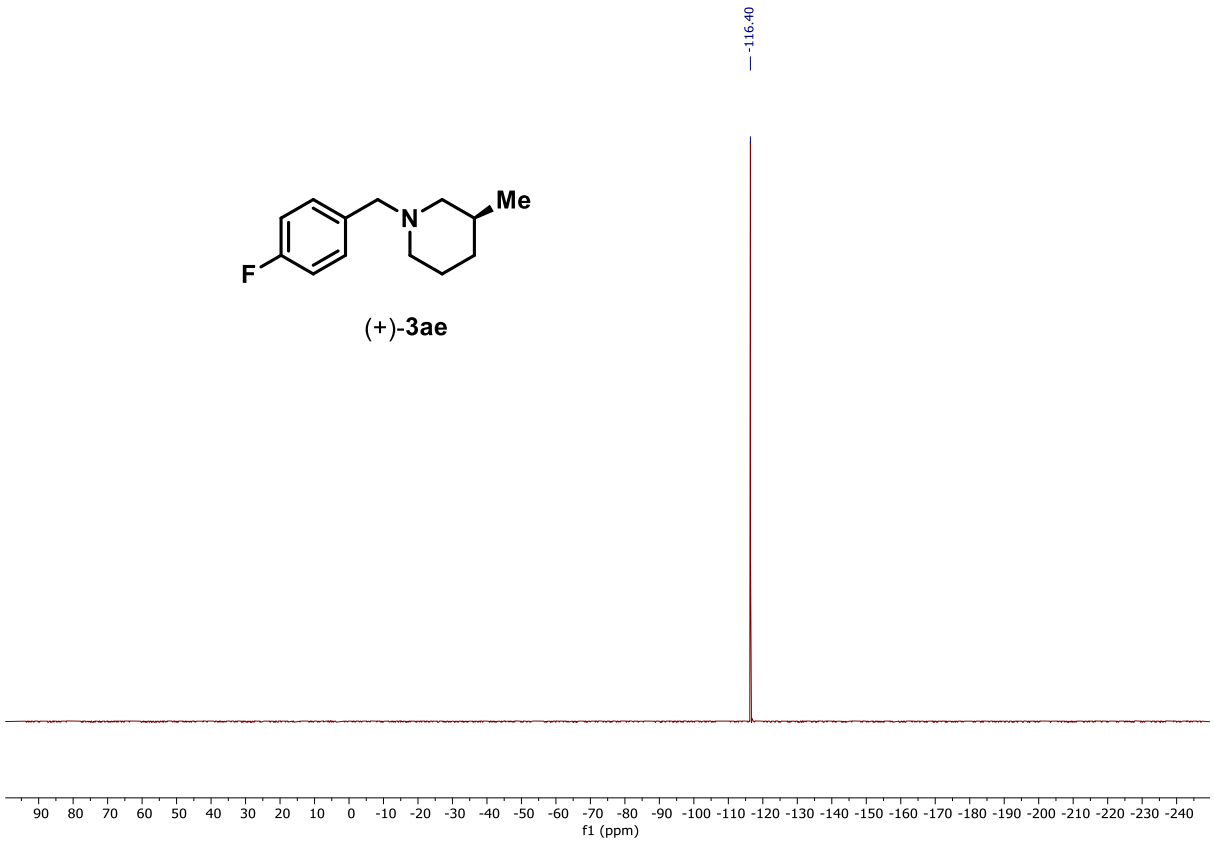
(+)-**3ad**

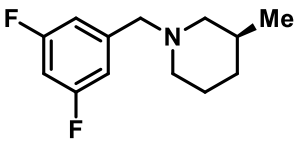

Me
N
F

(+)-**3ae**

2.17
1.68
1.94
1.93
1.00
4.82
3.90
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

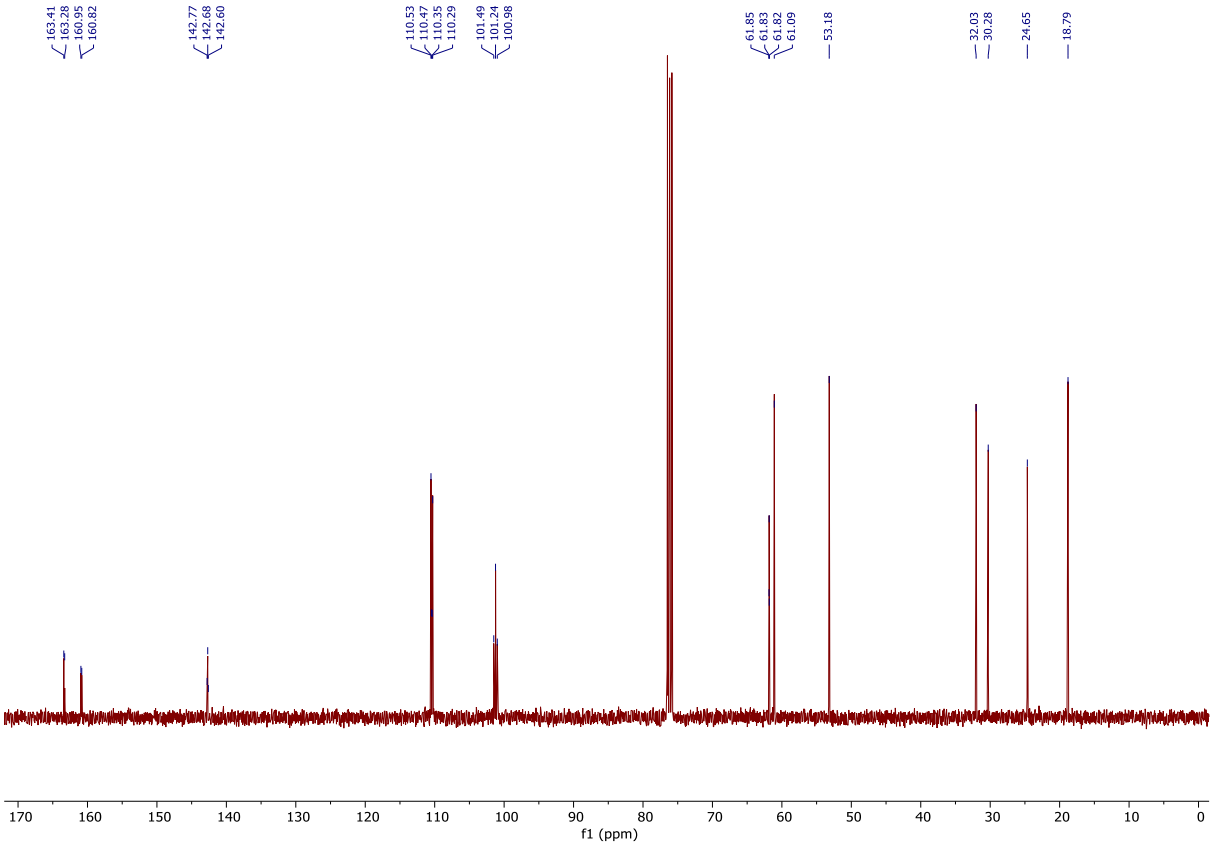

163.24
160.82
134.61
134.58
130.70
130.62
115.09
114.89
62.92
62.03
54.06
33.17
31.29
25.70
19.87
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

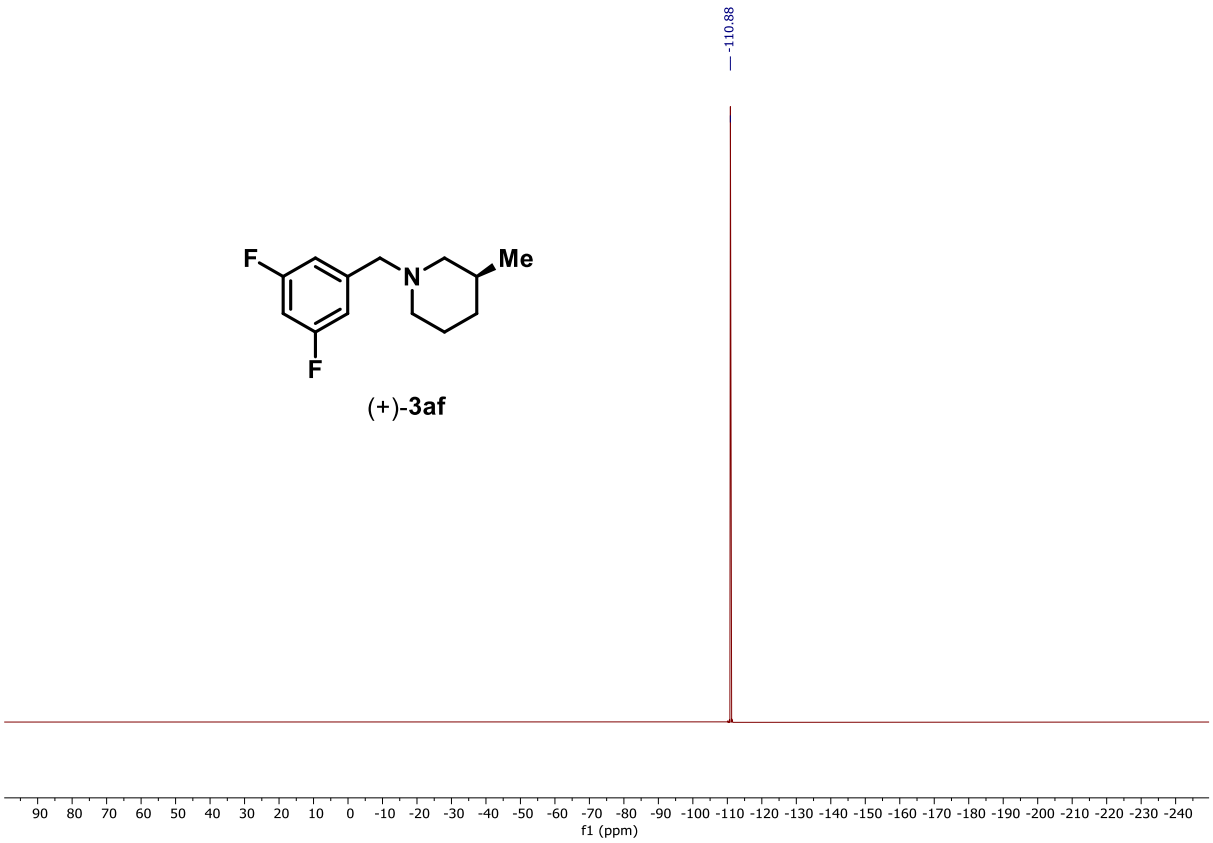

-116.40
Me
N
F
(+)-3ae
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240
f1 (ppm)


F
N
Me
F

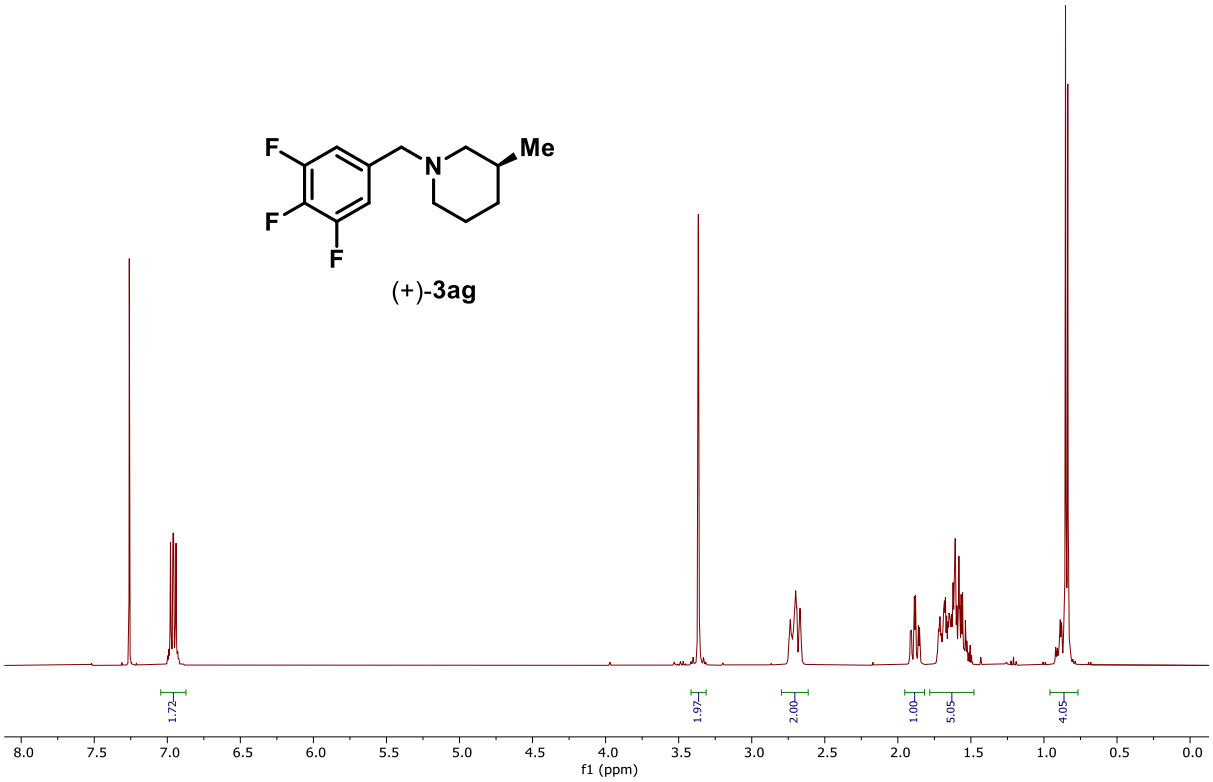
(+)-**3af**

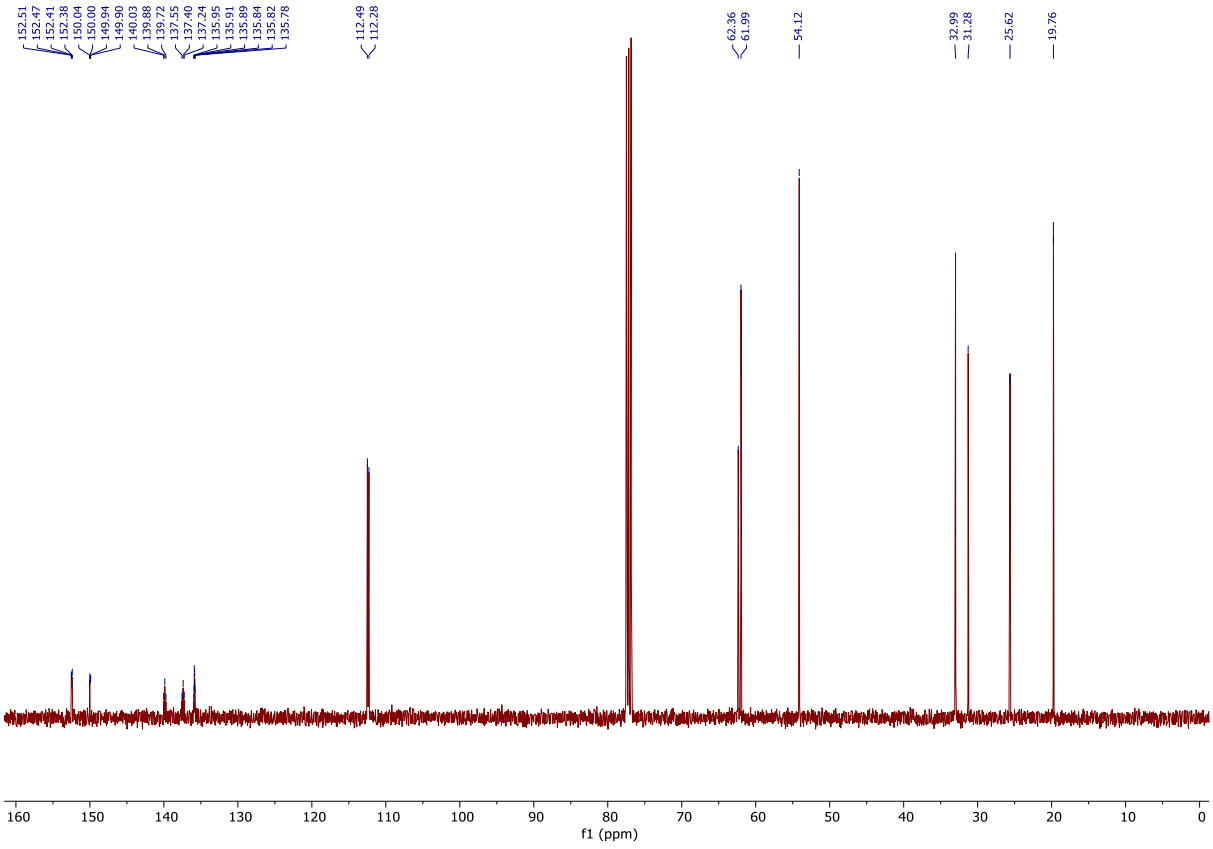
2.00
1.99
0.99
5.04
4.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

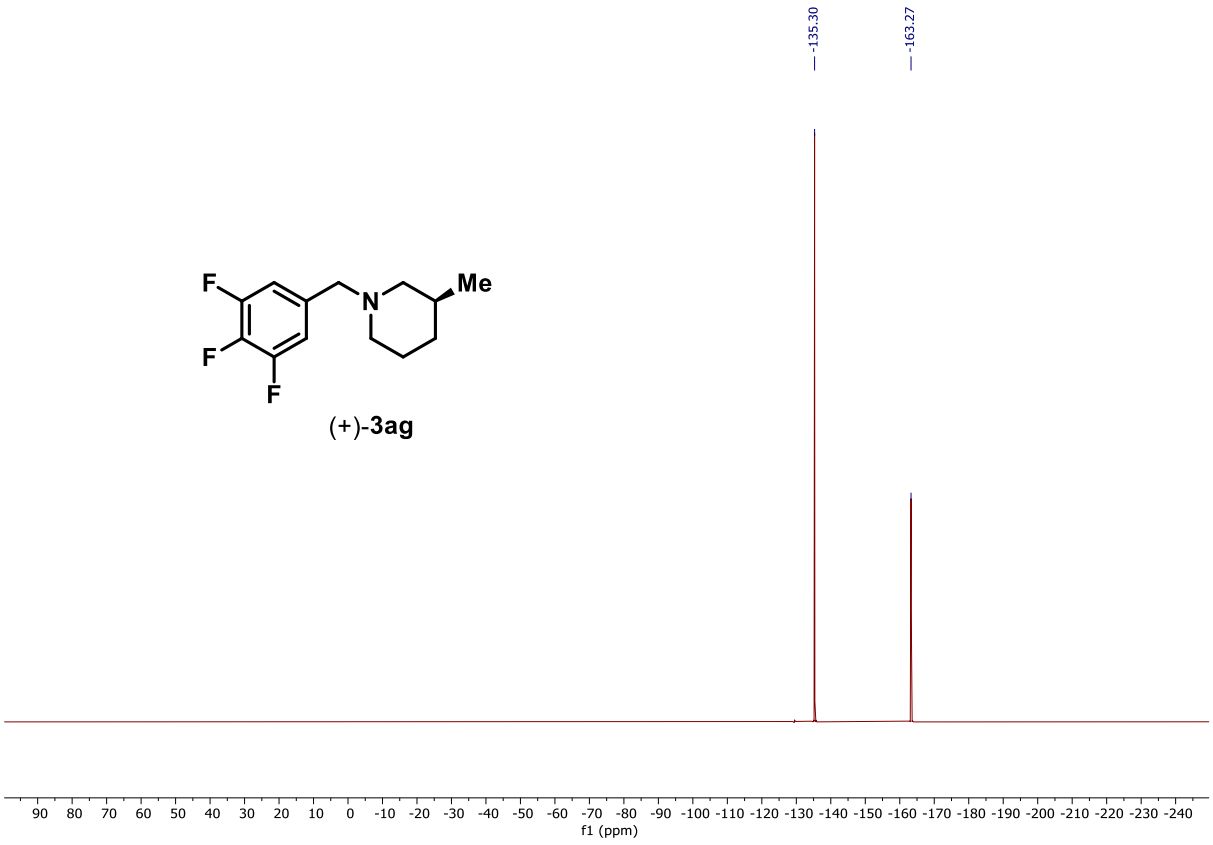

163.41
163.28
160.95
160.82
142.77
142.68
142.60
110.53
110.47
110.35
110.29
101.49
101.24
100.98
61.85
61.83
61.82
61.09
53.18
32.03
30.28
24.65
18.79
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


-110.88
F
N
Me
F
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240
f1 (ppm)

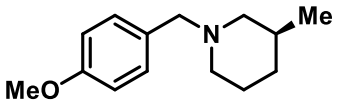
(+)-**3af**


F
F
F
N
Me
(+)-3ag
1.72
1.97
2.00
1.00
5.05
4.05
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


152.51
152.47
152.41
152.38
150.04
150.00
149.94
149.90
140.03
139.88
139.72
137.55
137.40
137.24
135.95
135.91
135.89
135.84
135.82
135.78
112.49
112.28
62.36
61.99
54.12
32.99
31.28
25.62
19.76
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

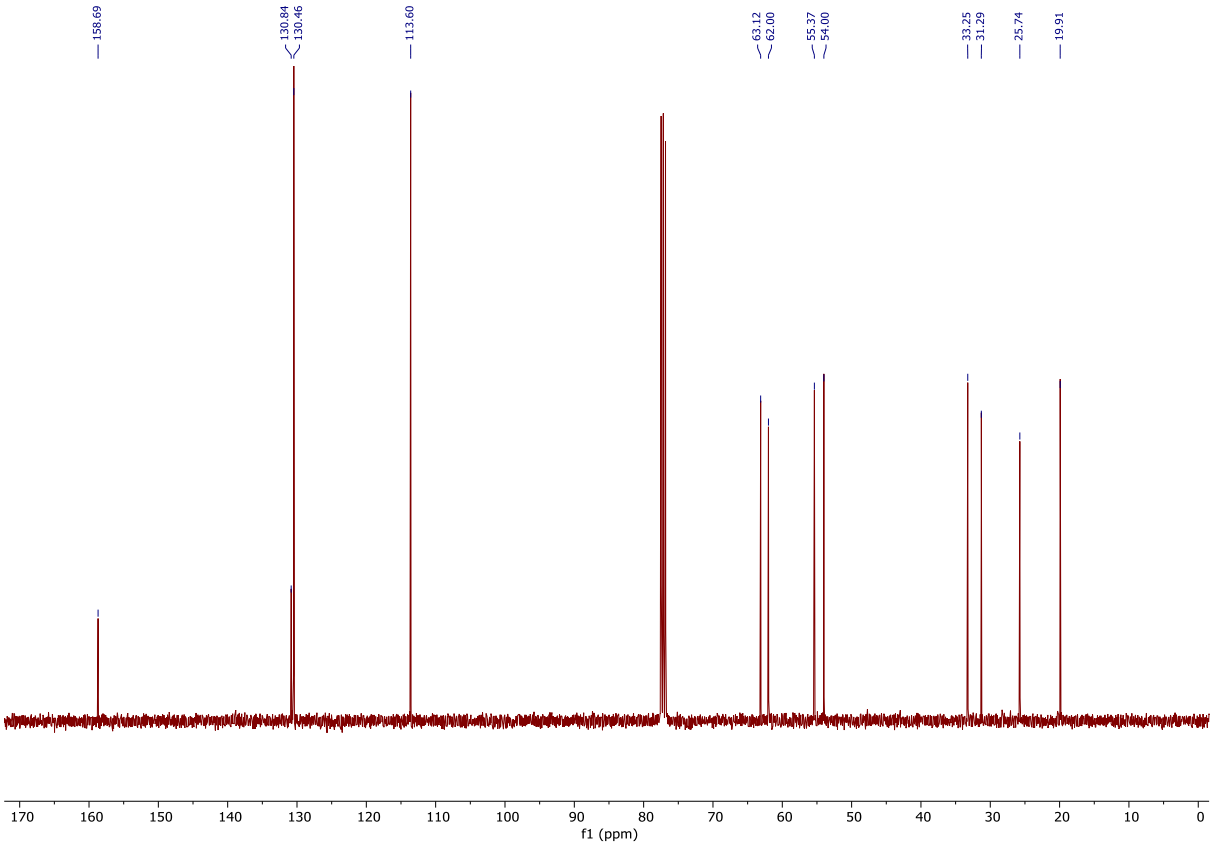

-135.30
-163.27
F
F
F
N
Me
90 80 70 60 50 40 30 20 10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -220 -230 -240
f1 (ppm)

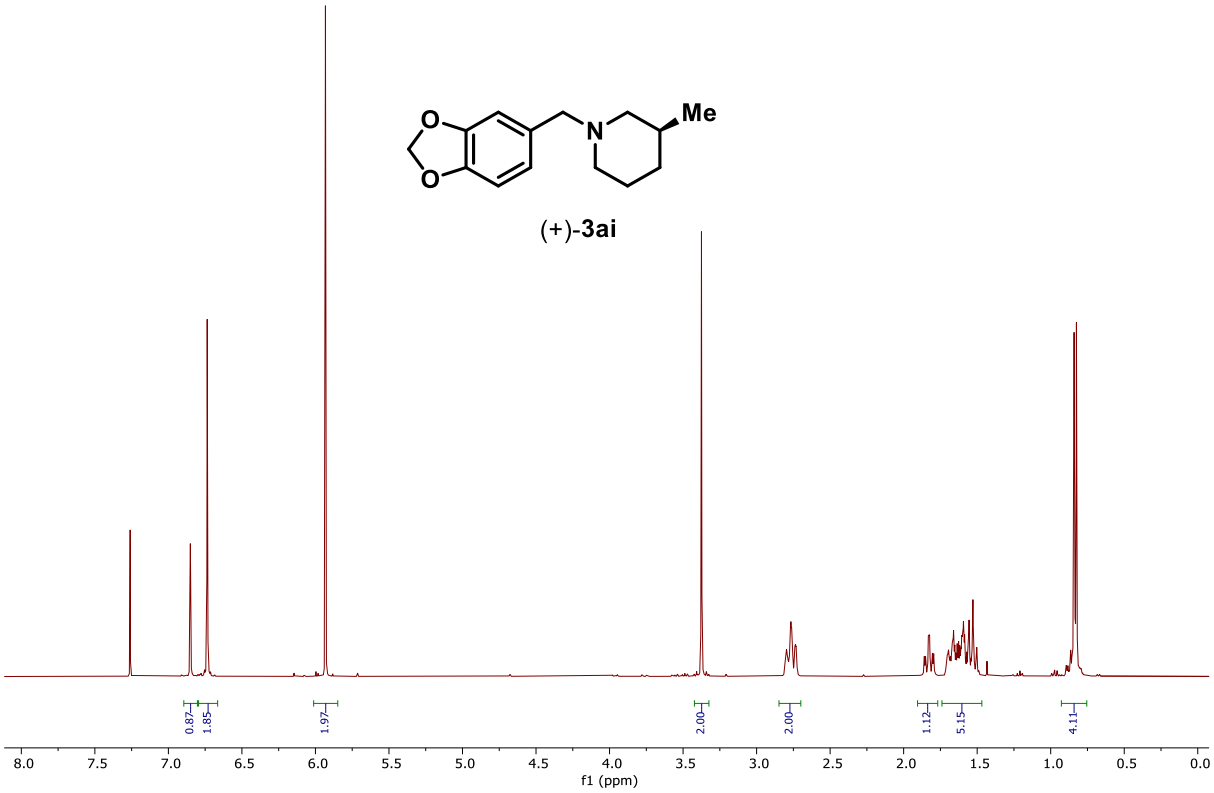
(+)-**3ag**

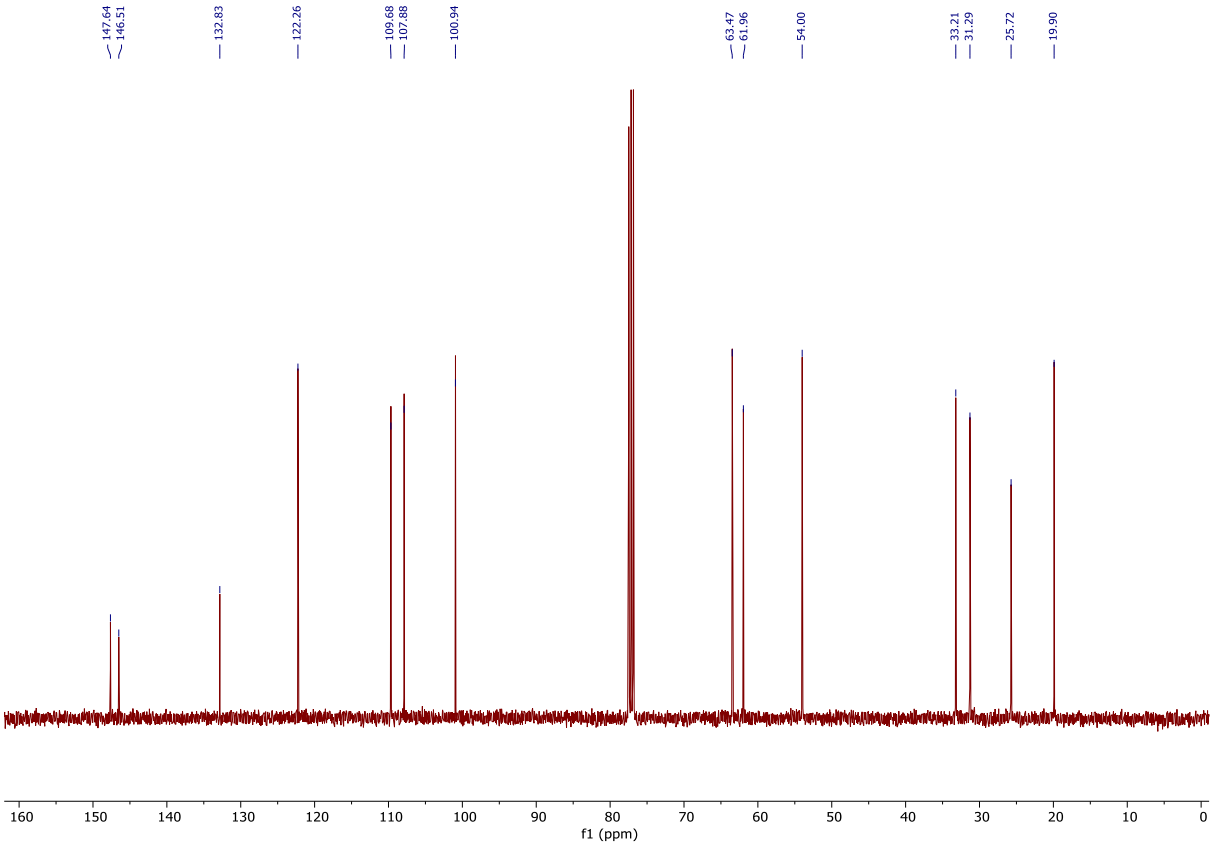

Me
N
MeO

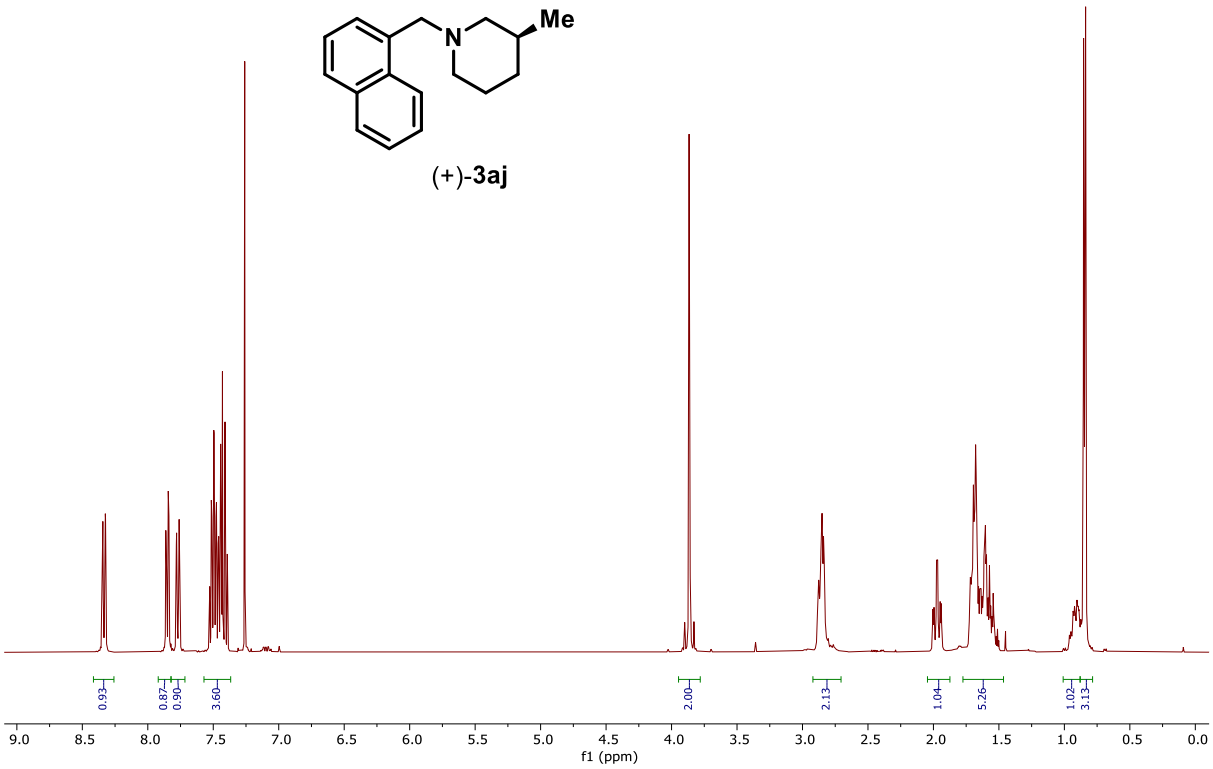
(+)-3ah

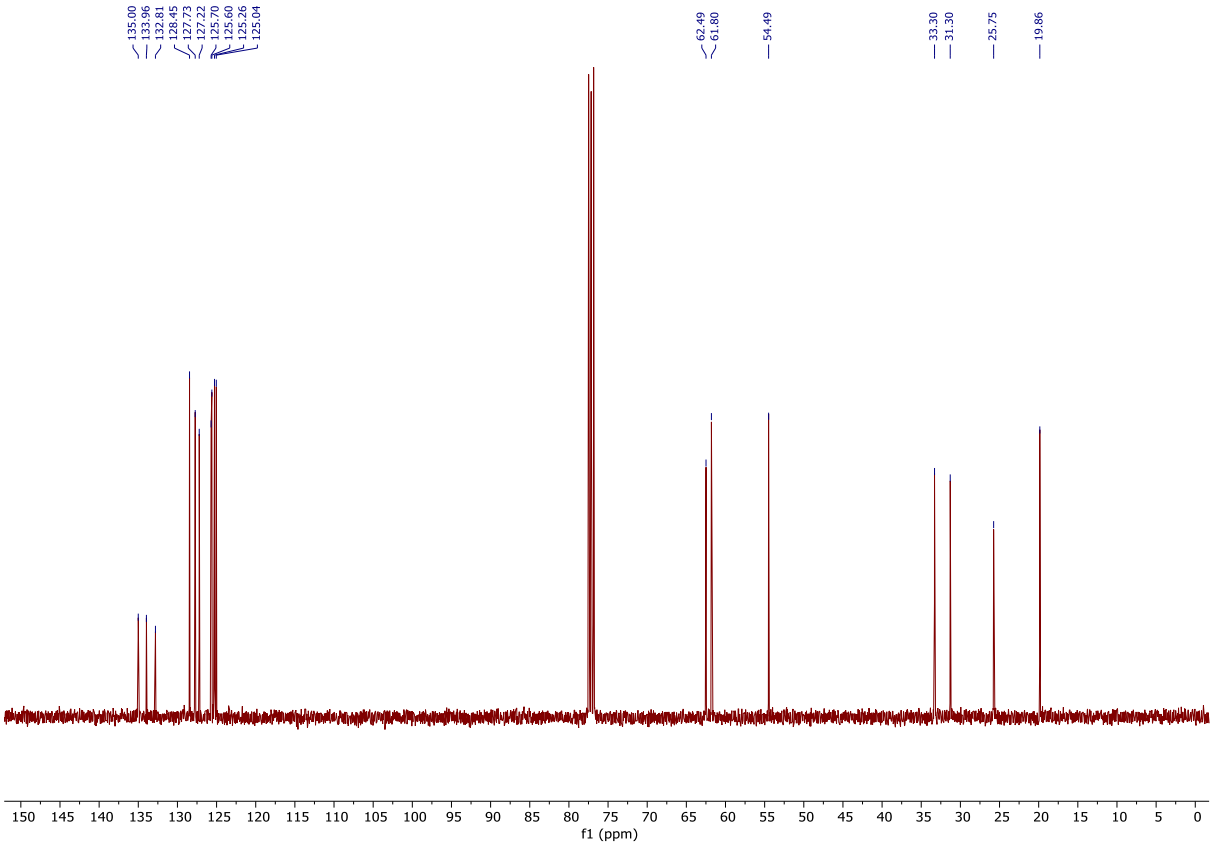
1.85
1.84
2.93
2.00
2.02
1.04
5.09
4.09
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

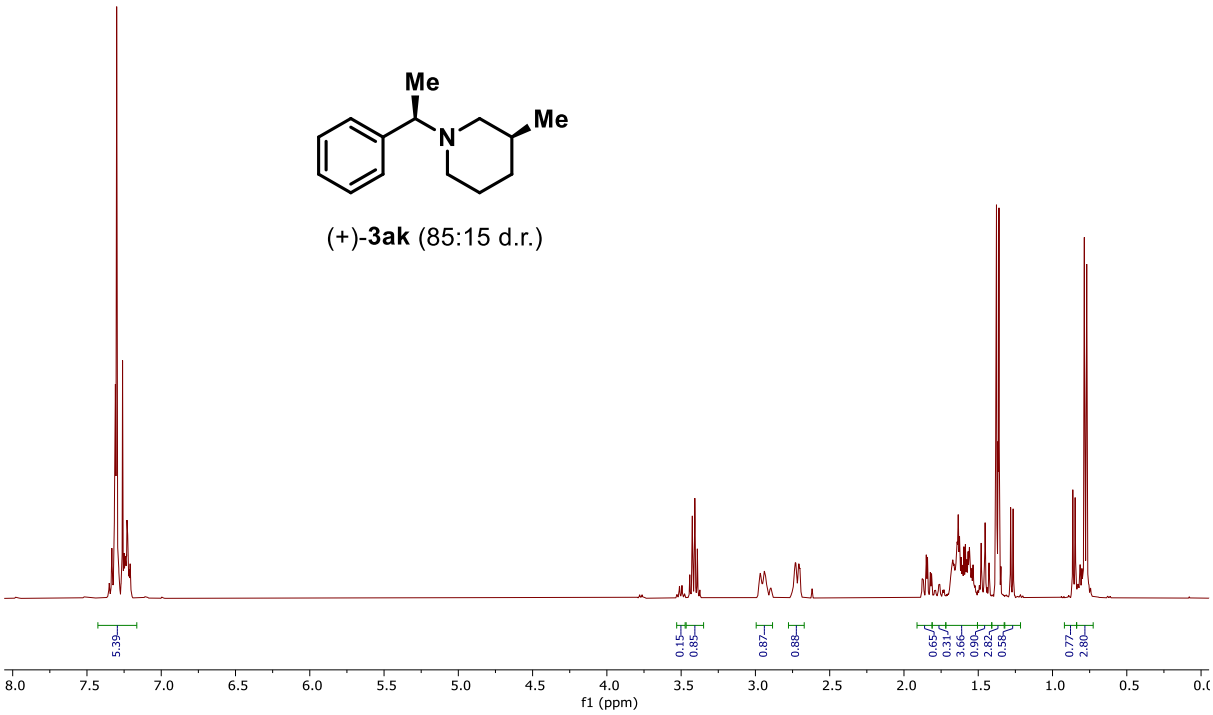

158.69
130.84
130.46
113.60
63.12
62.00
55.37
54.00
33.25
31.29
25.74
19.91
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

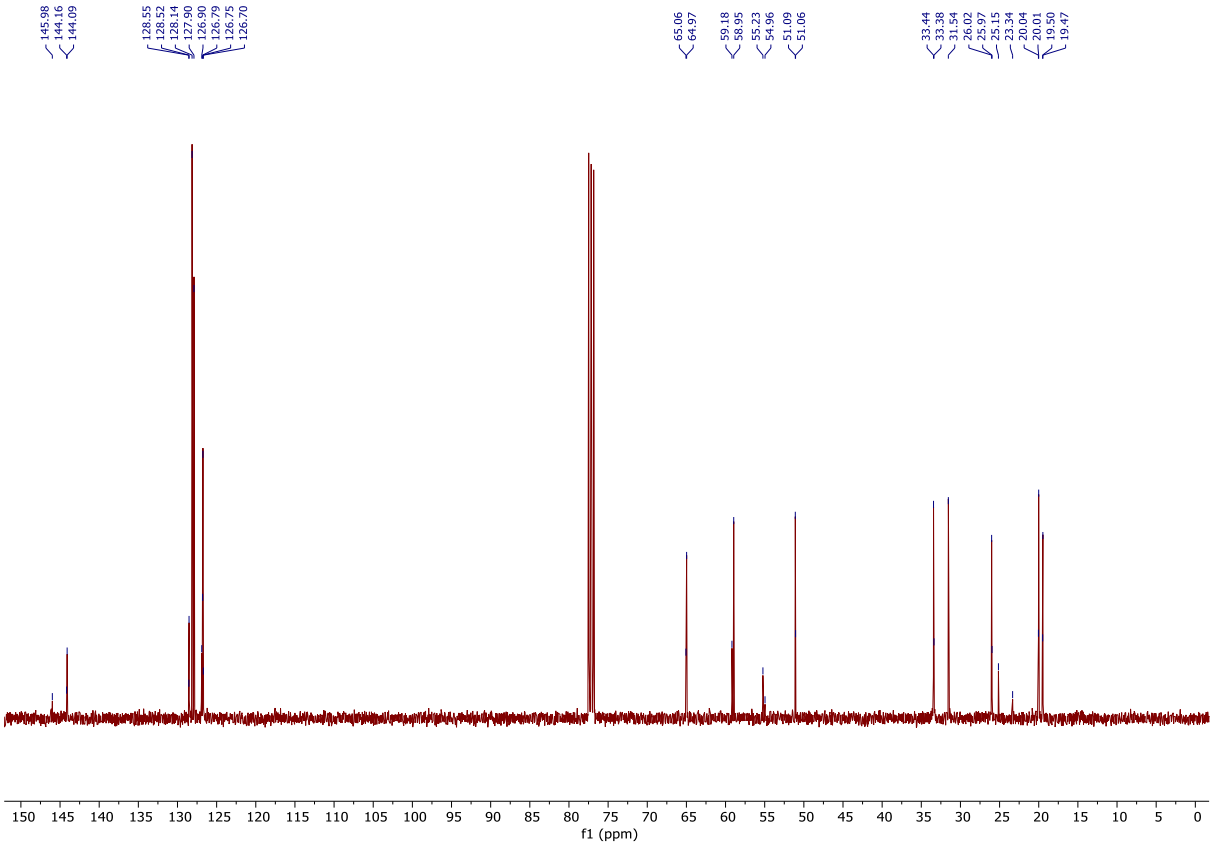

O
O
N
Me
(+)-3ai
0.87
1.85
1.97
2.00
2.00
1.12
5.15
4.11
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

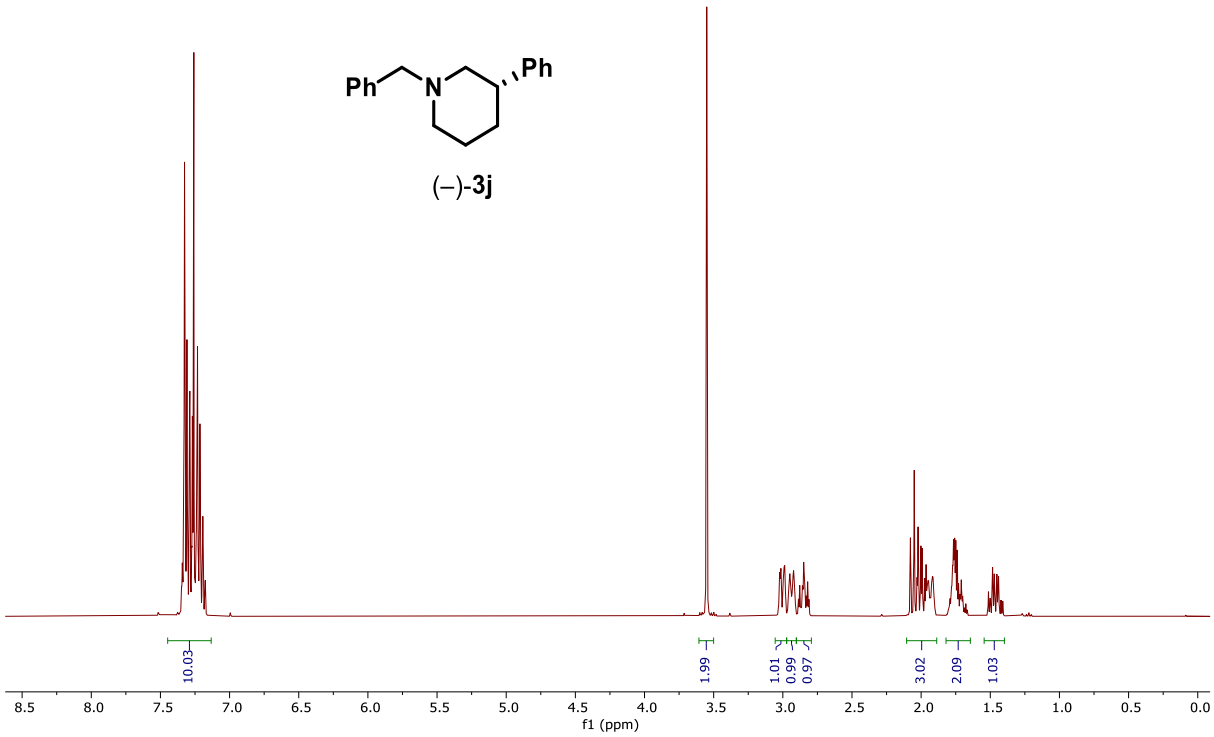

147.64
146.51
132.83
122.26
109.68
107.88
100.94
63.47
61.96
54.00
33.21
31.29
25.72
19.90
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Me
N
(+)-3aj
0.93
0.87
0.90
3.60
2.00
2.13
1.04
5.26
1.02
3.13
f1 (ppm)

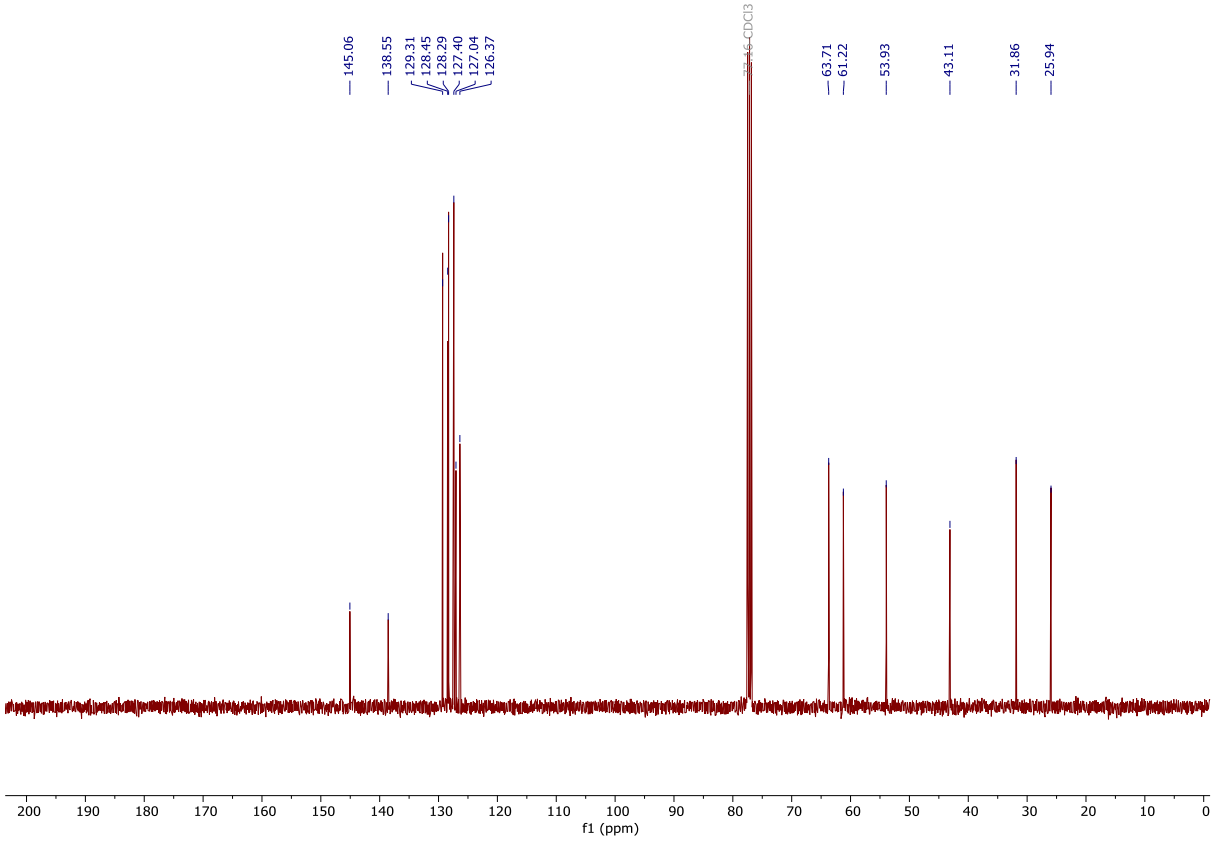

135.00
133.96
132.81
128.45
127.73
127.22
125.70
125.60
125.26
125.04
62.49
61.80
54.49
33.30
31.30
25.75
19.86
f1 (ppm)

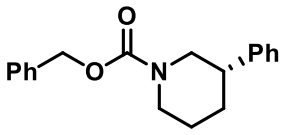

Me
N
Me
(+)-3ak (85:15 d.r.)
5.39
0.15
0.85
0.87
0.88
0.65
0.31
3.66
0.90
2.82
0.58
0.77
2.80
f1 (ppm)


145.98
144.16
144.09
128.55
128.52
128.14
127.90
126.90
126.79
126.75
126.70
65.06
64.97
59.18
58.95
55.23
54.96
51.09
51.06
33.44
33.38
31.54
26.02
25.97
25.15
23.34
20.04
20.01
19.50
19.47
f1 (ppm)


Ph
N
Ph
10.03
1.99
1.01
0.99
0.97
3.02
2.09
1.03
f1 (ppm)

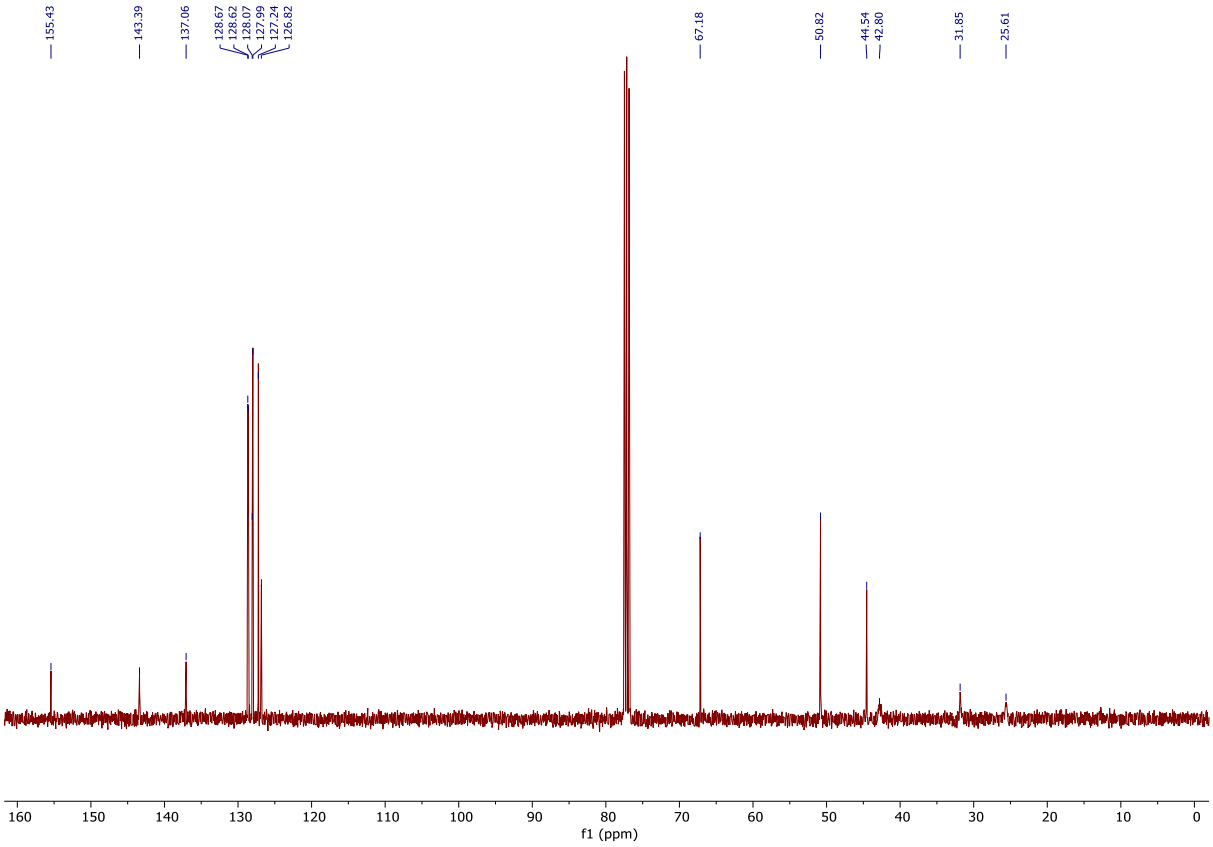
(–)-**3j**

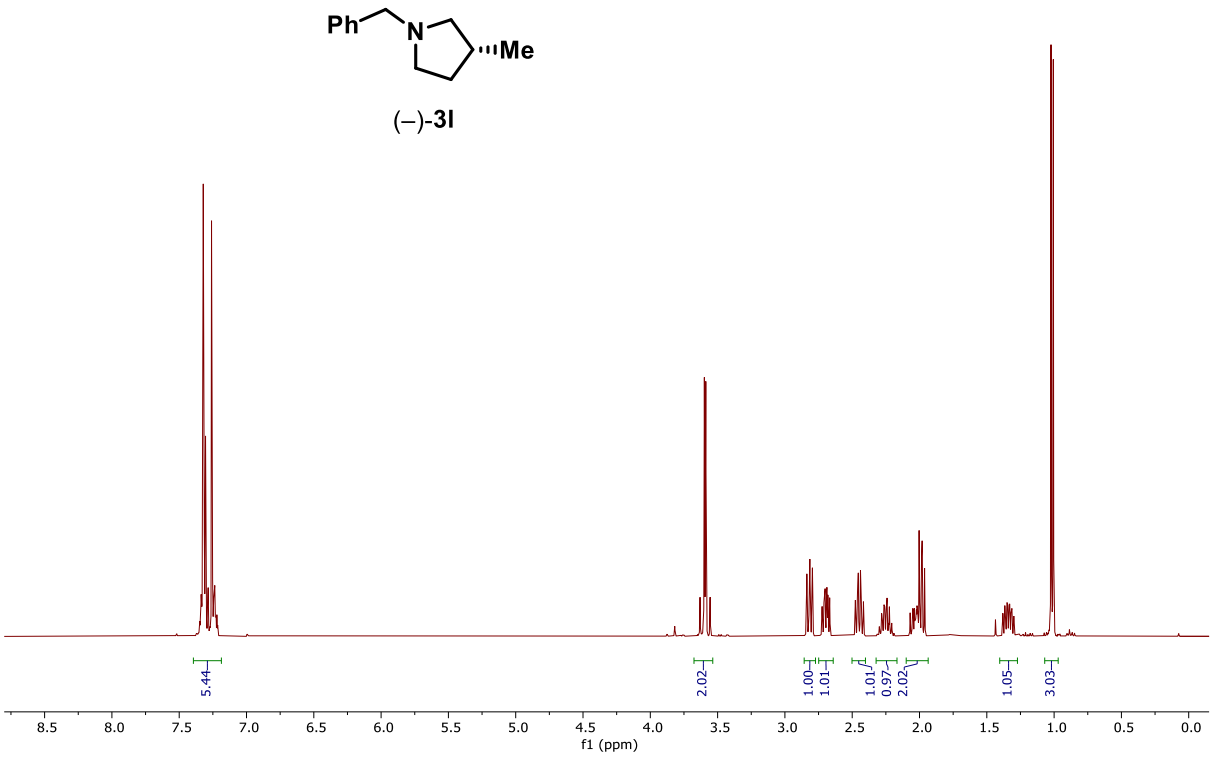

145.06
138.55
129.31
128.45
128.29
127.40
127.04
126.37
77.16-CDCl3
63.71
61.22
53.93
43.11
31.86
25.94
f1 (ppm)

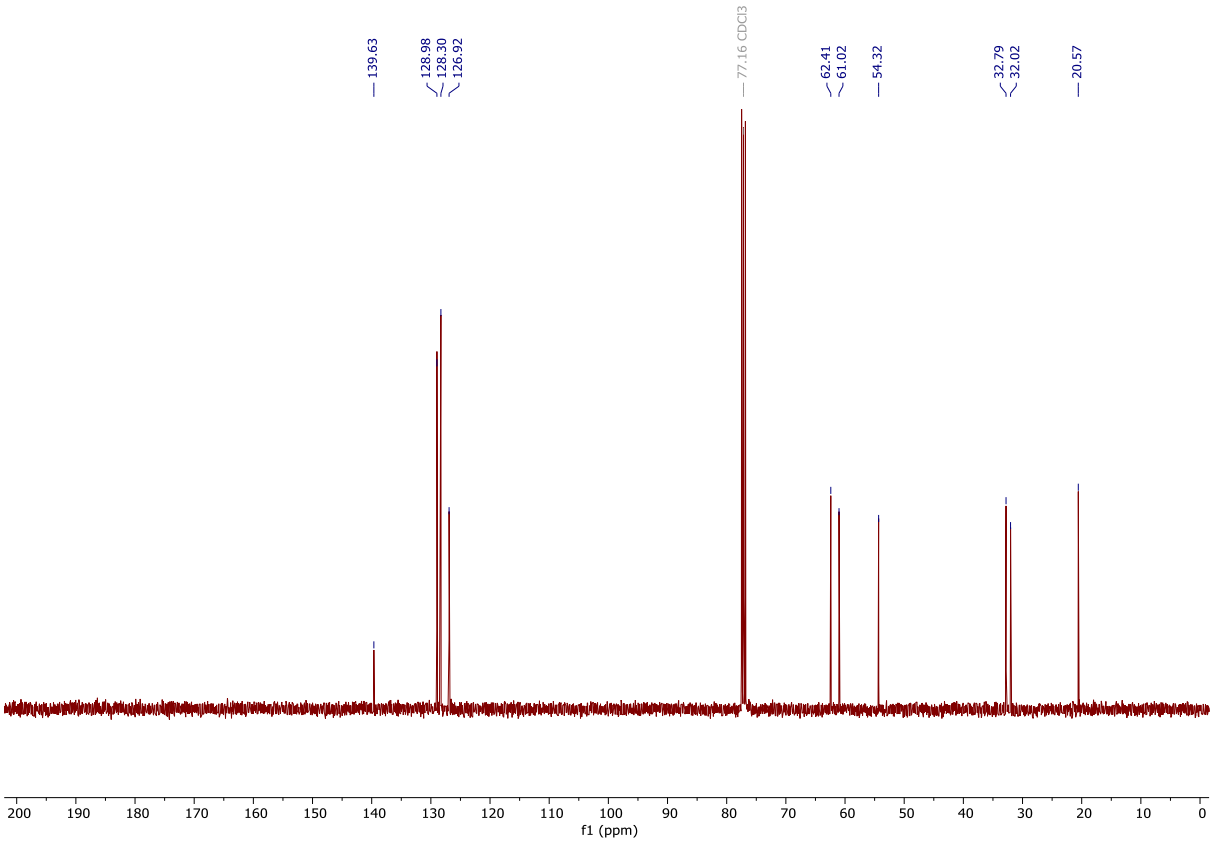

O
Ph
O
N
Ph

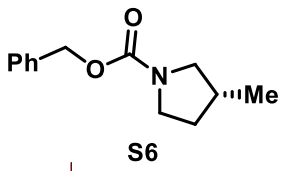
S5

10.44
2.00
2.09
3.11
1.05
3.26
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

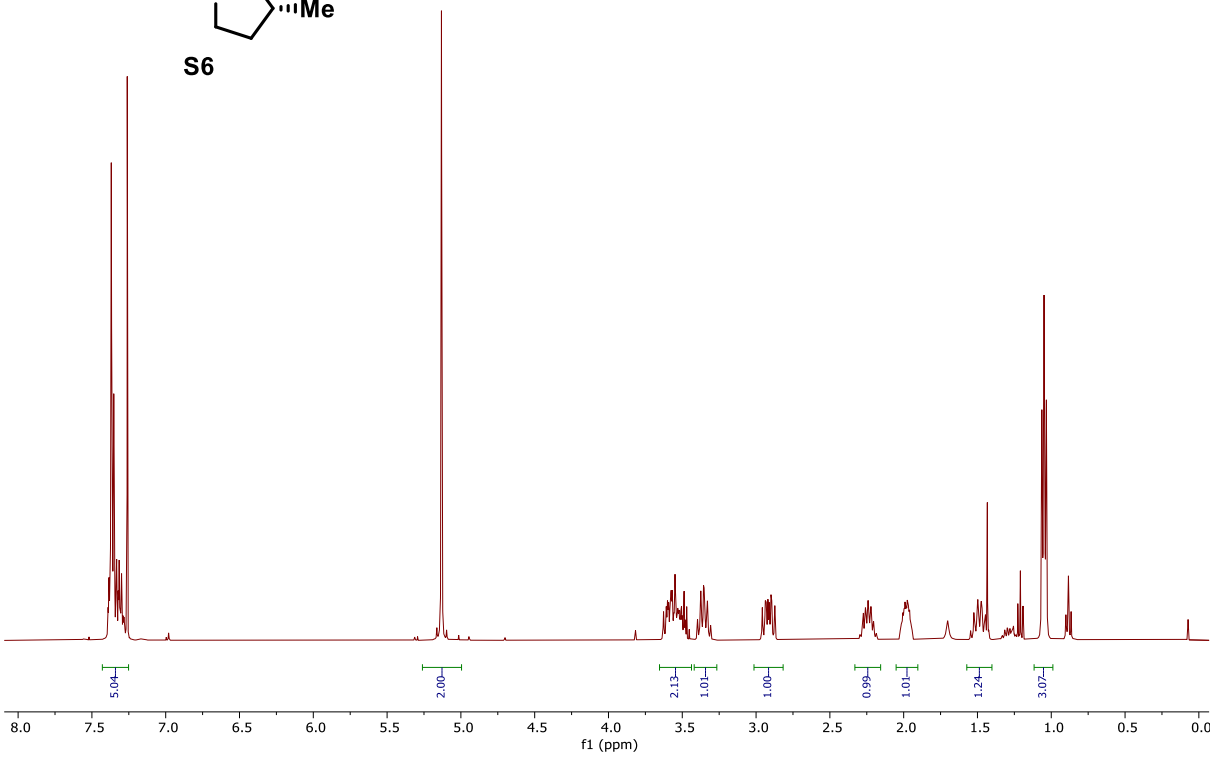

155.43
143.39
137.06
128.67
128.62
128.07
127.99
127.24
126.82
67.18
50.82
44.54
42.80
31.85
25.61
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

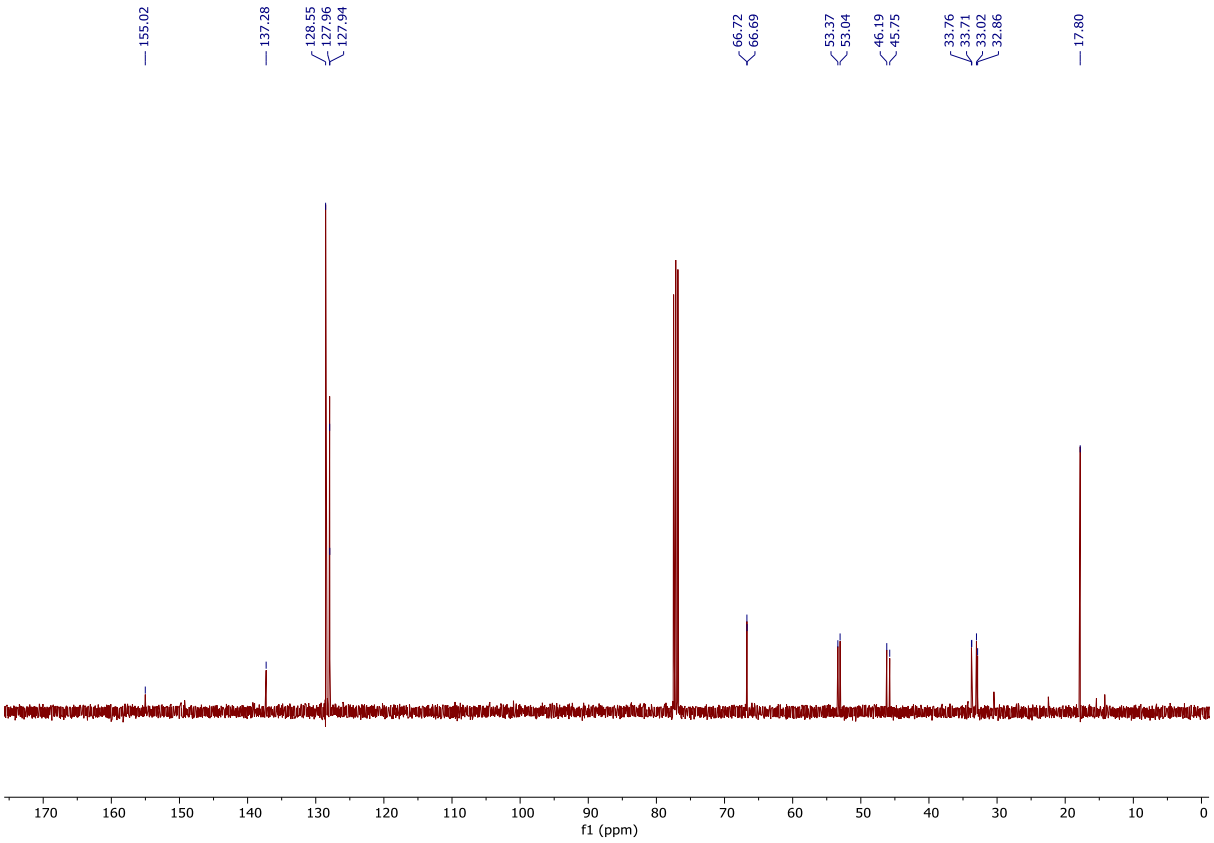

Ph
N
Me
(–)-3l
5.44
2.02
1.00
1.01
1.01
0.97
2.02
1.05
3.03
8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
f1 (ppm)

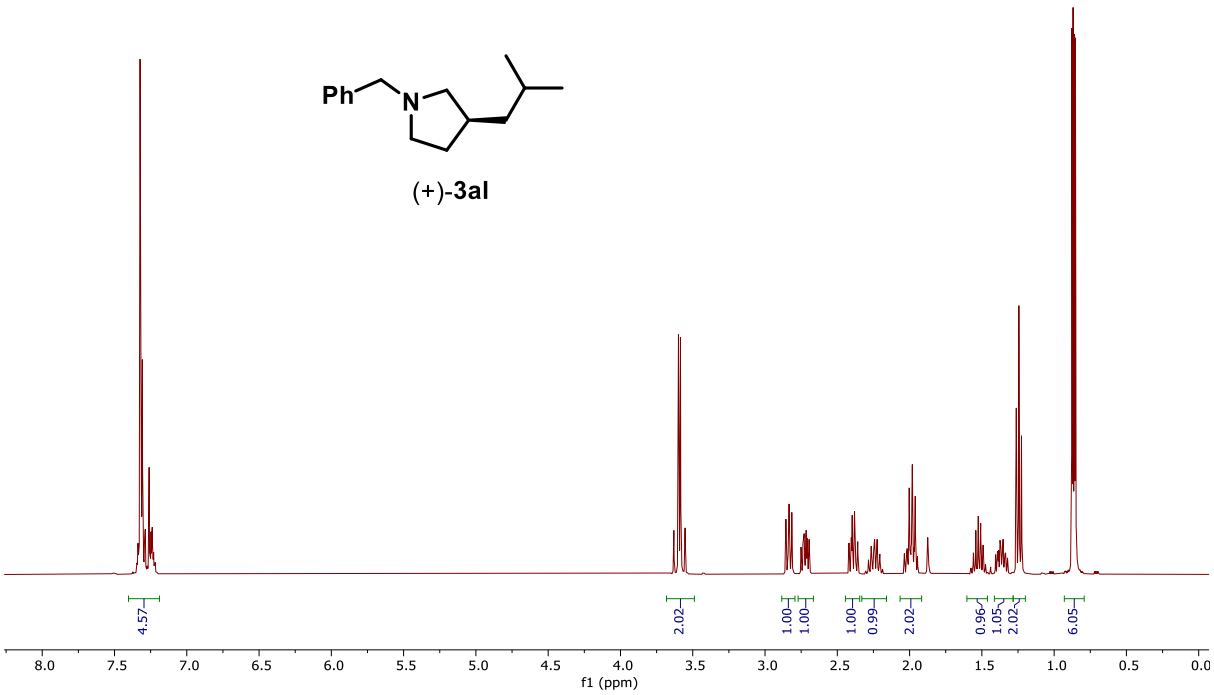

139.63
128.98
128.30
126.92
77.16 CDCl3
62.41
61.02
54.32
32.79
32.02
20.57
200 190 180 170 160 150 140 130 120 110 100 90 80 70 60 50 40 30 20 10 0
f1 (ppm)

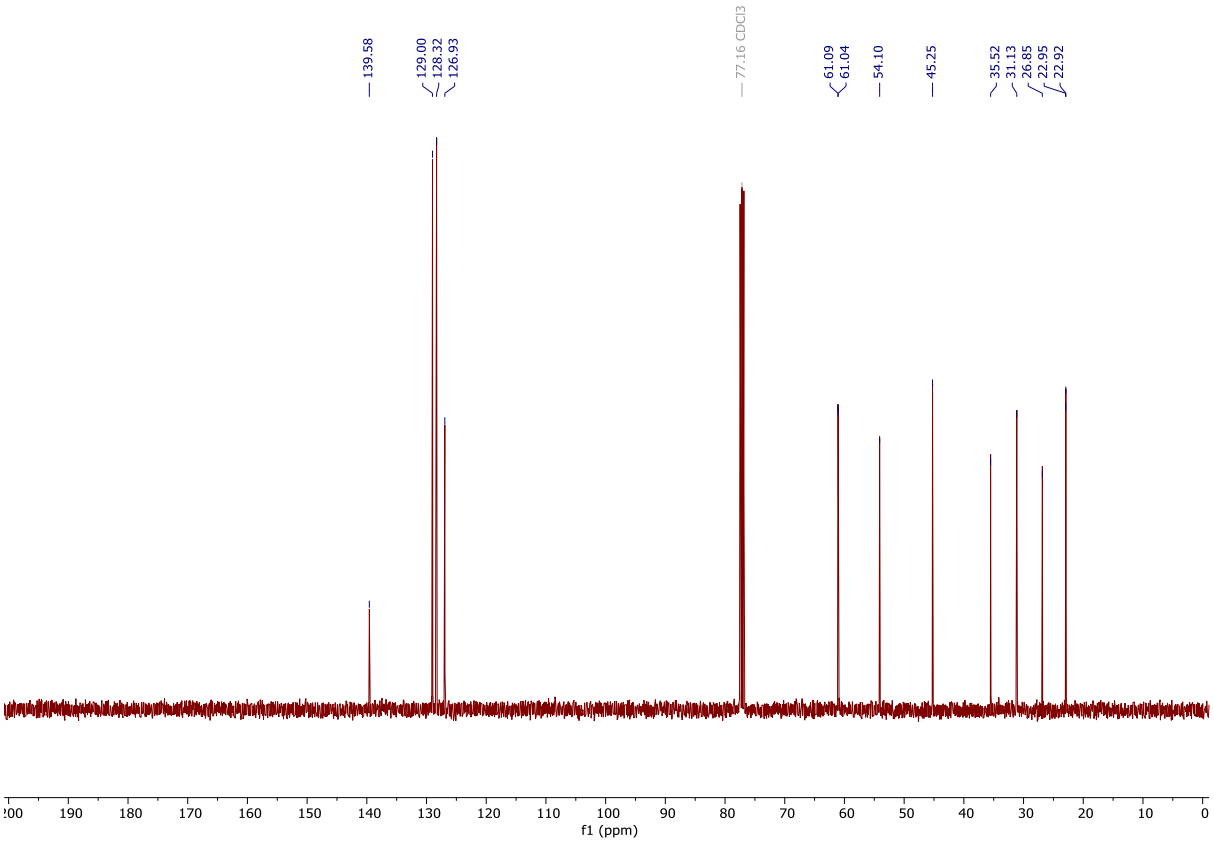

O
Ph
O
N
Me

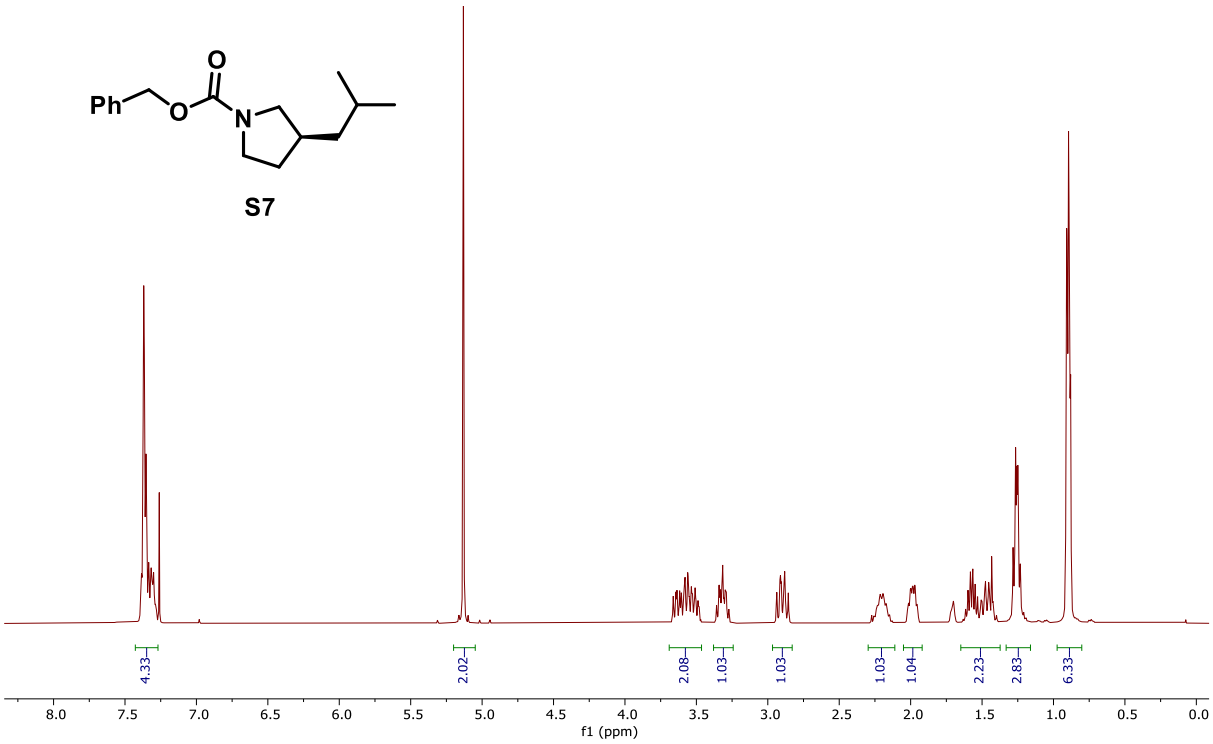
S6


5.04
2.00
2.13
1.01
1.00
0.99
1.01
1.24
3.07
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

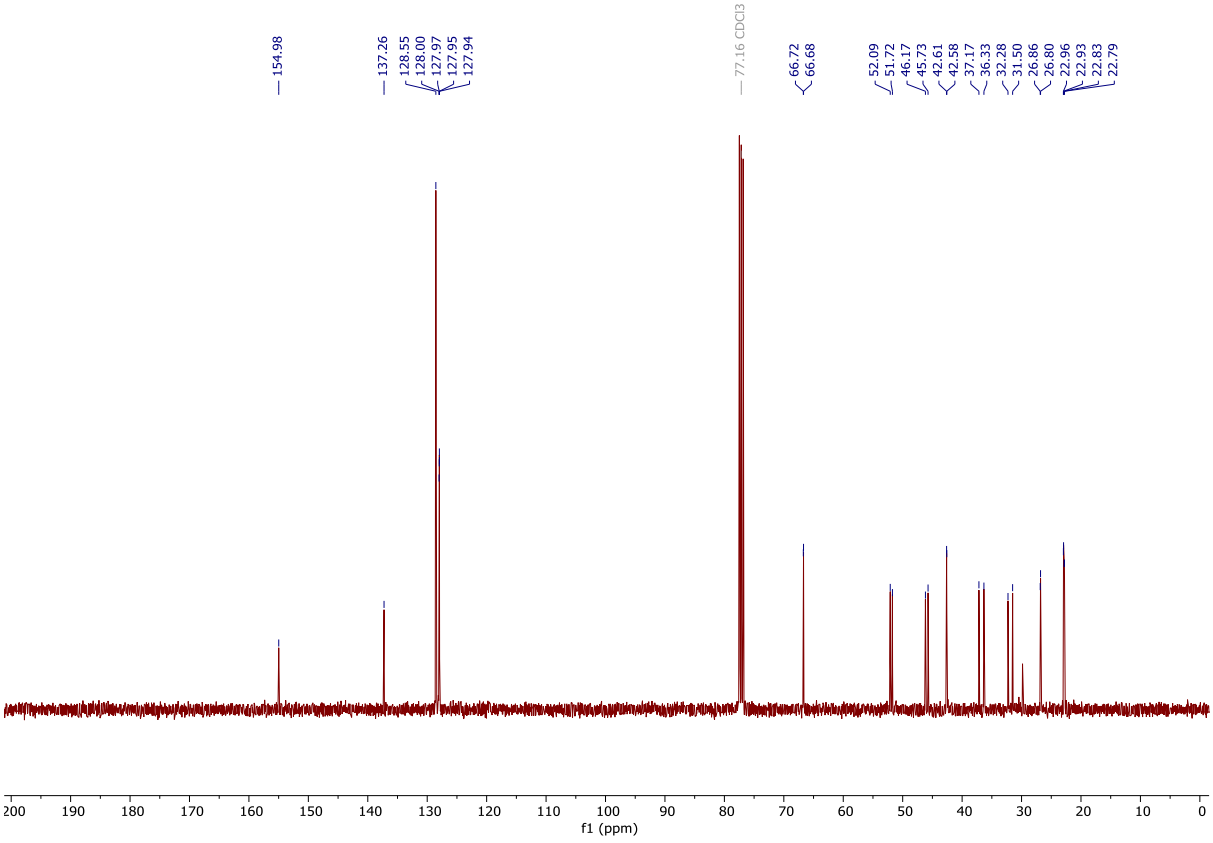

155.02
137.28
128.55
127.96
127.94
66.72
66.69
53.37
53.04
46.19
45.75
33.76
33.71
33.02
32.86
17.80
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

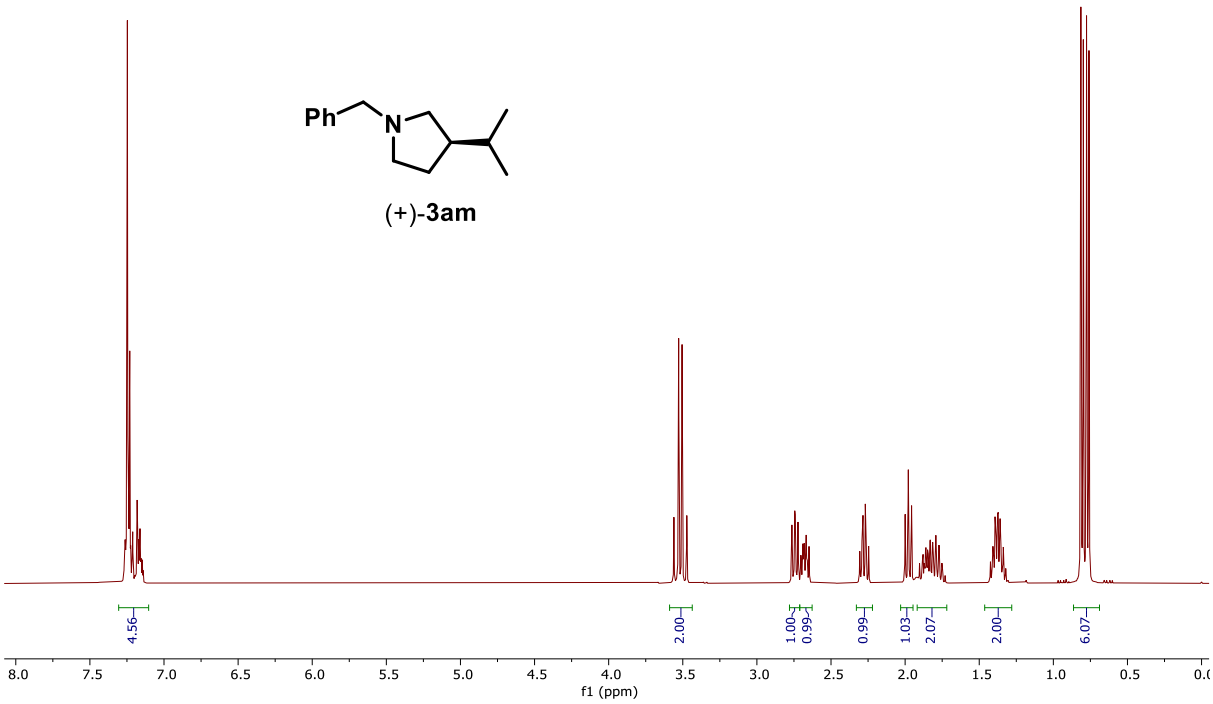

Ph
N
(+)-3al
4.57
2.02
1.00
1.00
1.00
0.99
2.02
0.96
1.05
2.02
6.05
f1 (ppm)

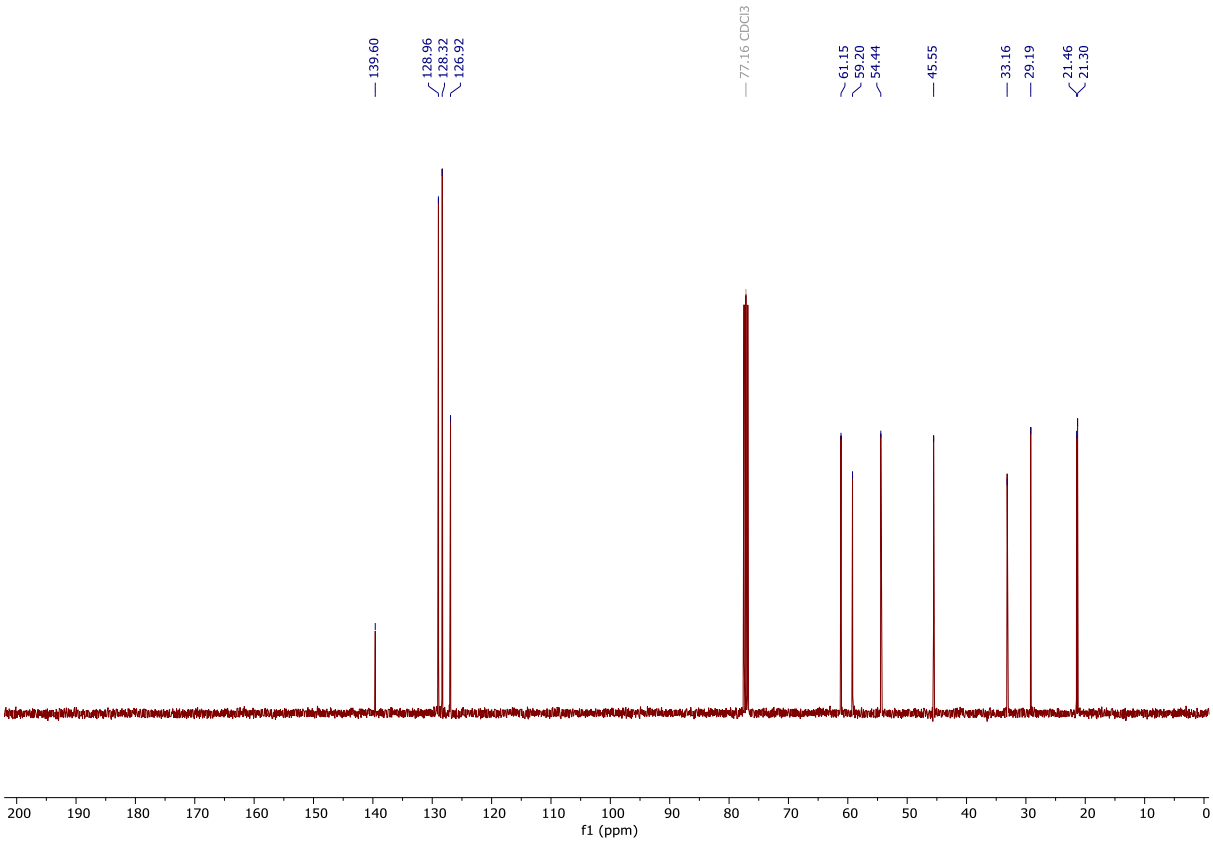

139.58
129.00
128.32
126.93
77.16 CDCl3
61.09
61.04
54.10
45.25
35.52
31.13
26.85
22.95
22.92
f1 (ppm)

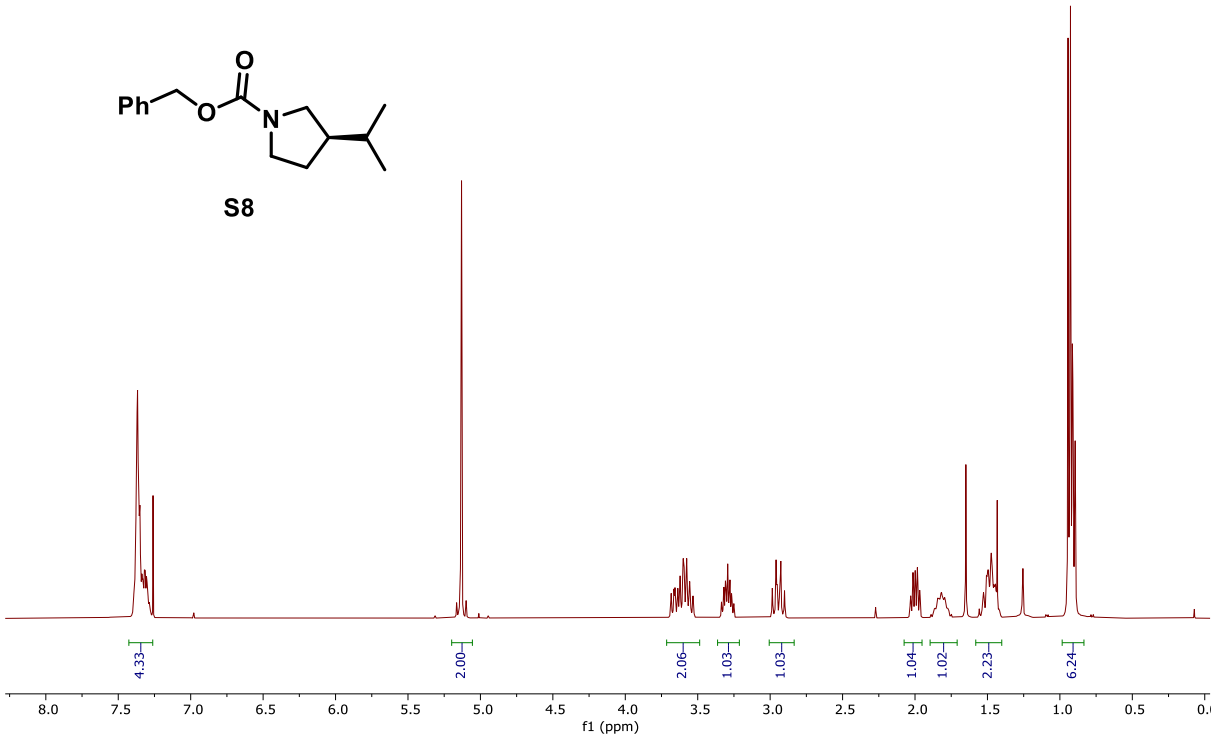

Ph
O
O
N
4.33
2.02
2.08
1.03
1.03
1.03
1.04
2.23
2.83
6.33
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

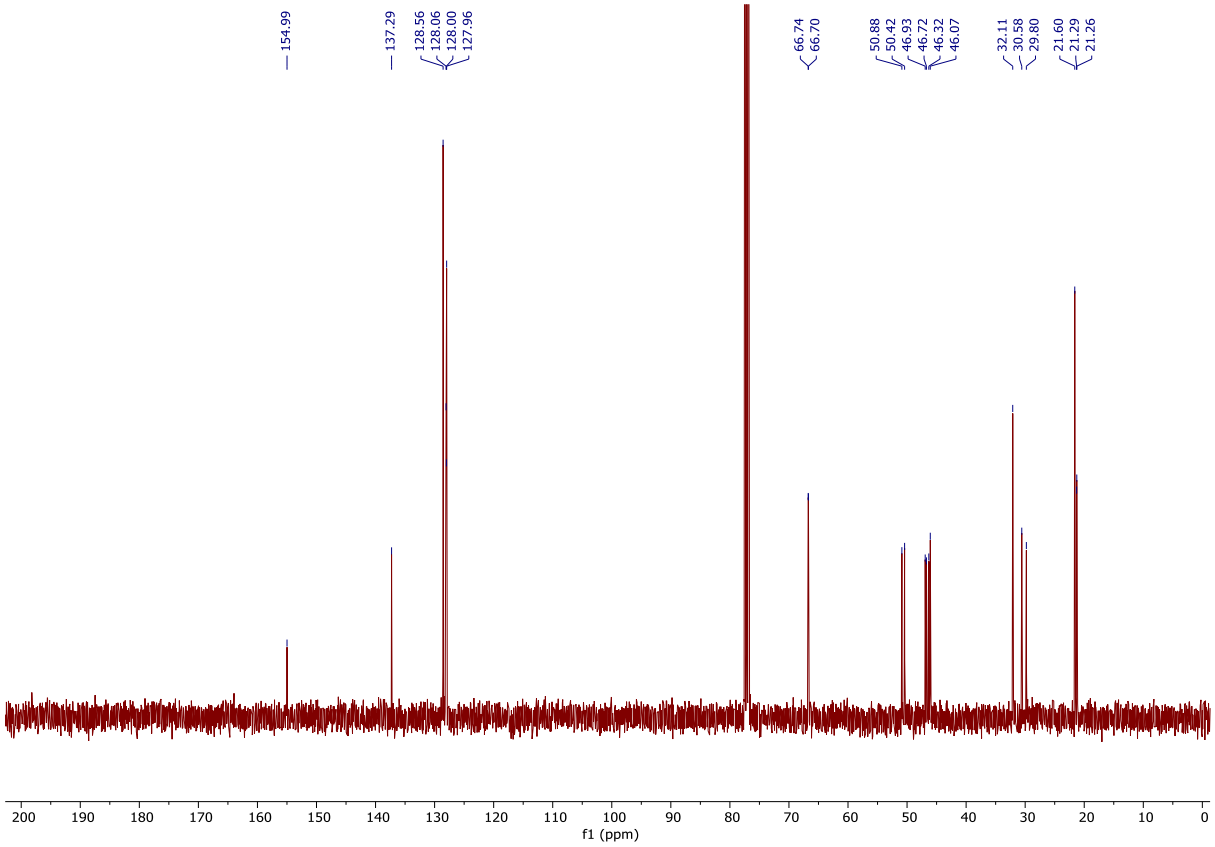
S7

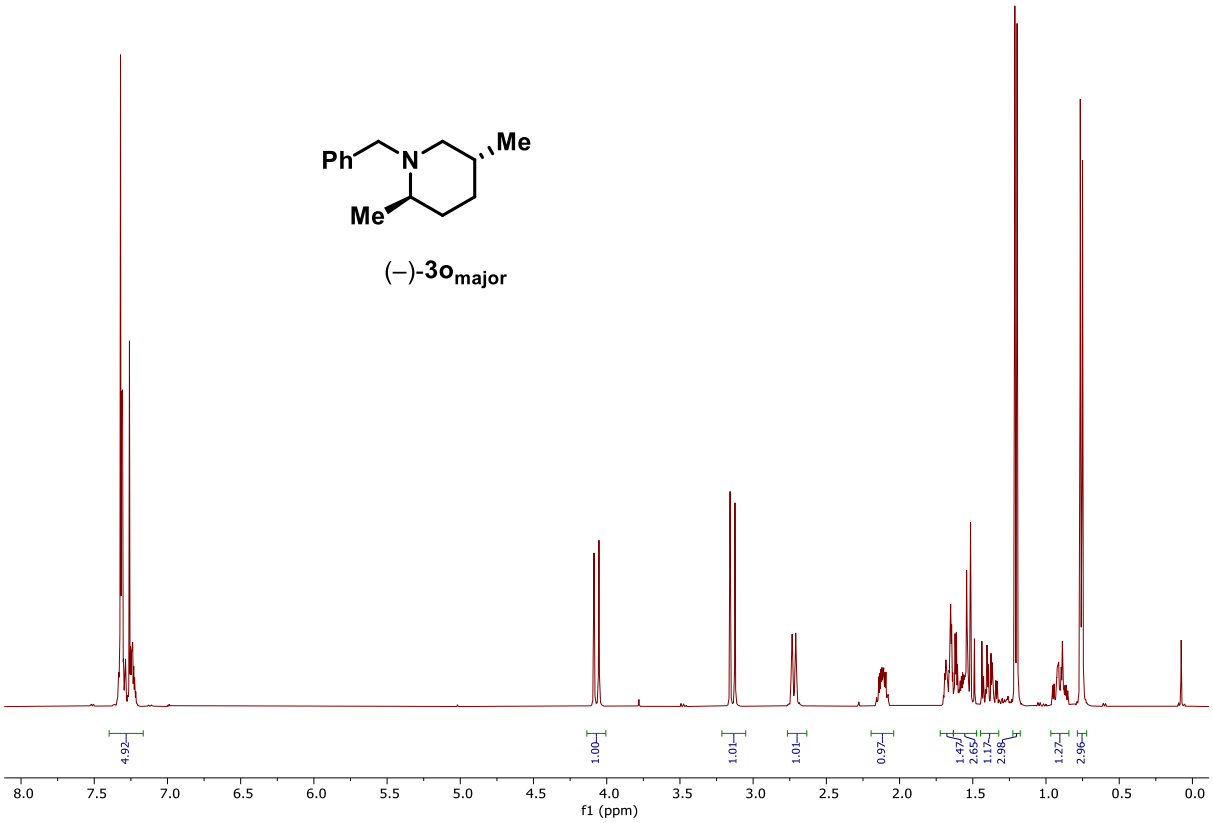

154.98
137.26
128.55
128.00
127.97
127.95
127.94
77.16 CDCl3
66.72
66.68
52.09
51.72
46.17
45.73
42.61
42.58
37.17
36.33
32.28
31.50
26.86
26.80
22.96
22.93
22.83
22.79
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)

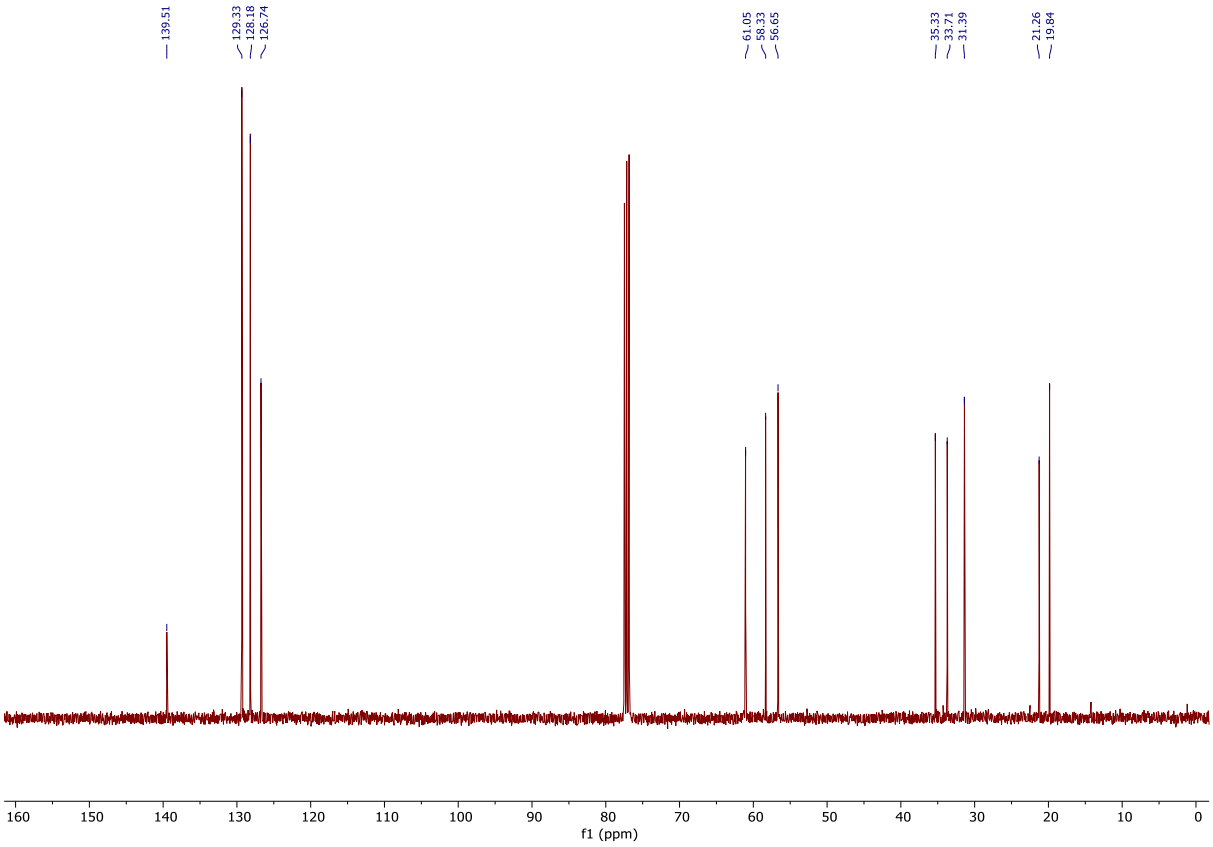

Ph
N
(+)-3am
4.56
2.00
1.00
0.99
0.99
1.03
2.07
2.00
6.07
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
f1 (ppm)

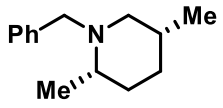

139.60
128.96
128.32
126.92
77.16 CDCl3
61.15
59.20
54.44
45.55
33.16
29.19
21.46
21.30
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


Ph
O
O
N
S8
4.33
2.00
2.06
1.03
1.03
1.04
1.02
2.23
6.24
f1 (ppm)


154.99
137.29
128.56
128.06
128.00
127.96
66.74
66.70
50.88
50.42
46.93
46.72
46.32
46.07
32.11
30.58
29.80
21.60
21.29
21.26
f1 (ppm)

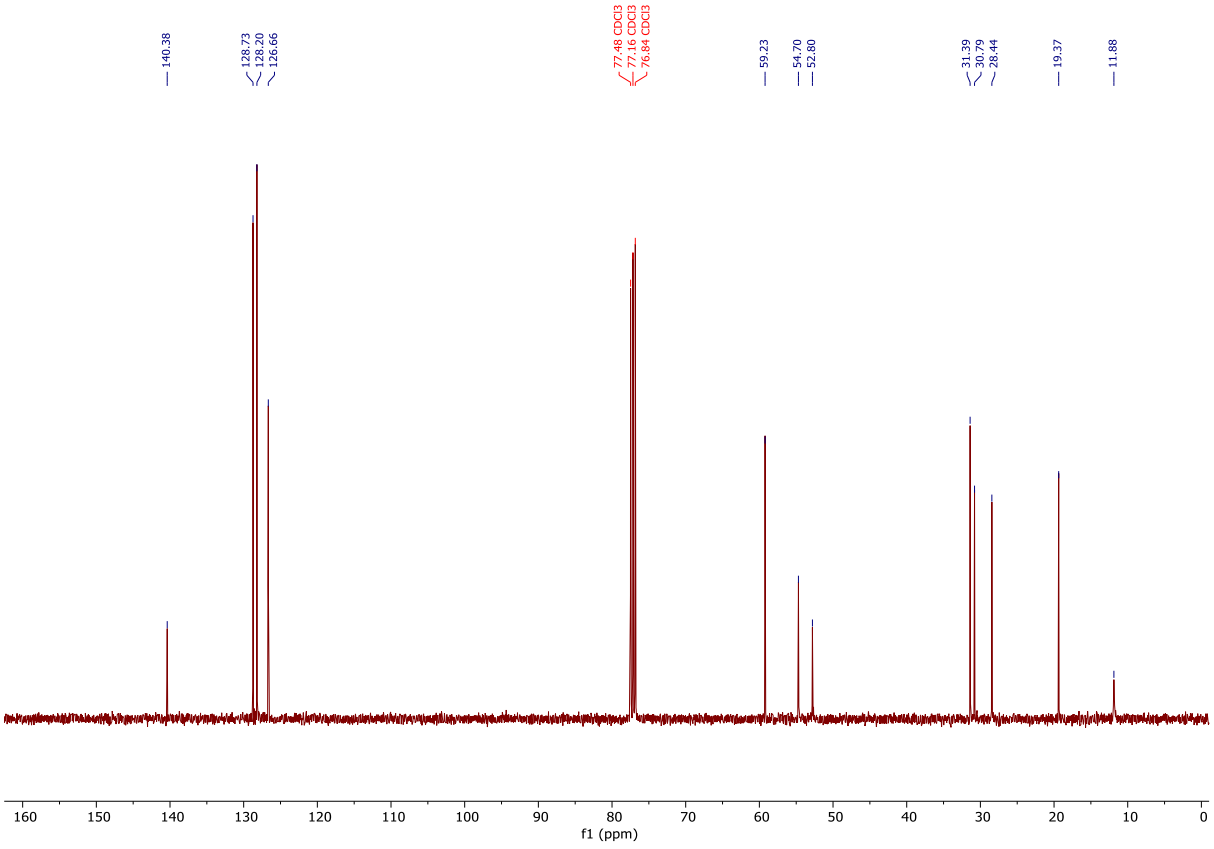

Ph
N
Me
Me
(–)-3o$_{major}$
4.92
1.00
1.01
1.01
0.97
1.47
2.65
1.12
2.98
1.27
2.96
f1 (ppm)

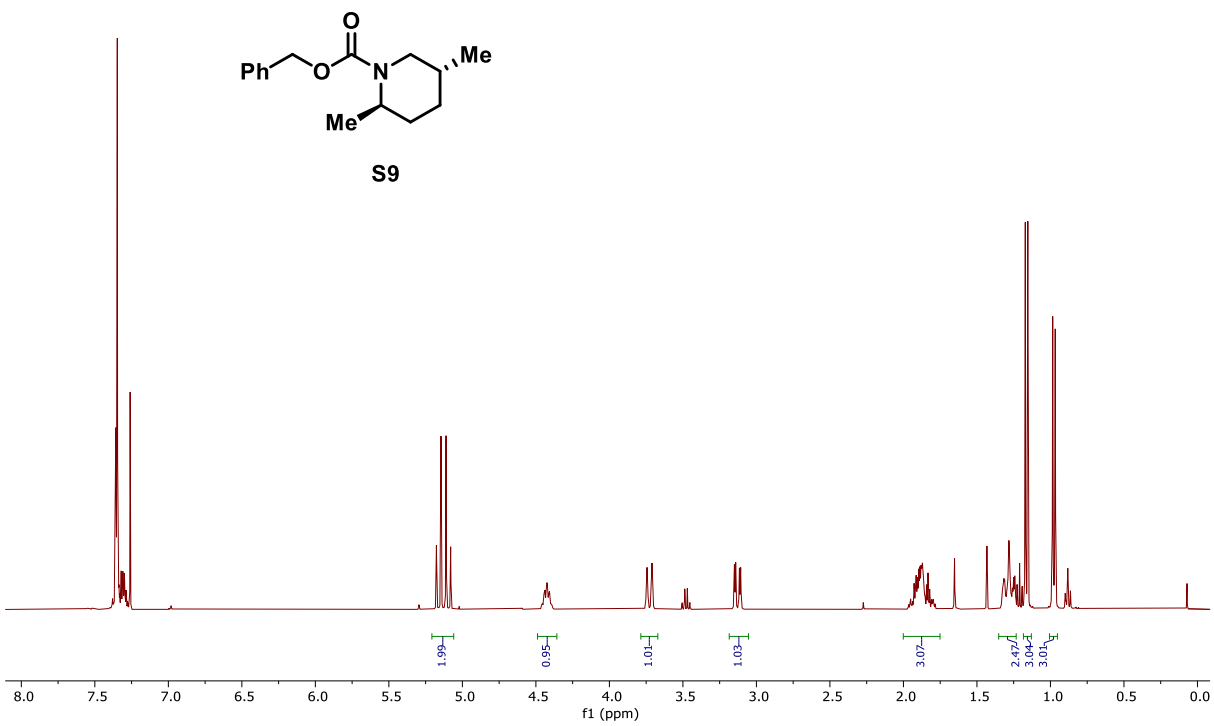

139.51
129.33
128.18
126.74
61.05
58.33
56.65
35.33
33.71
31.39
21.26
19.84
f1 (ppm)


Ph
N
Me
Me

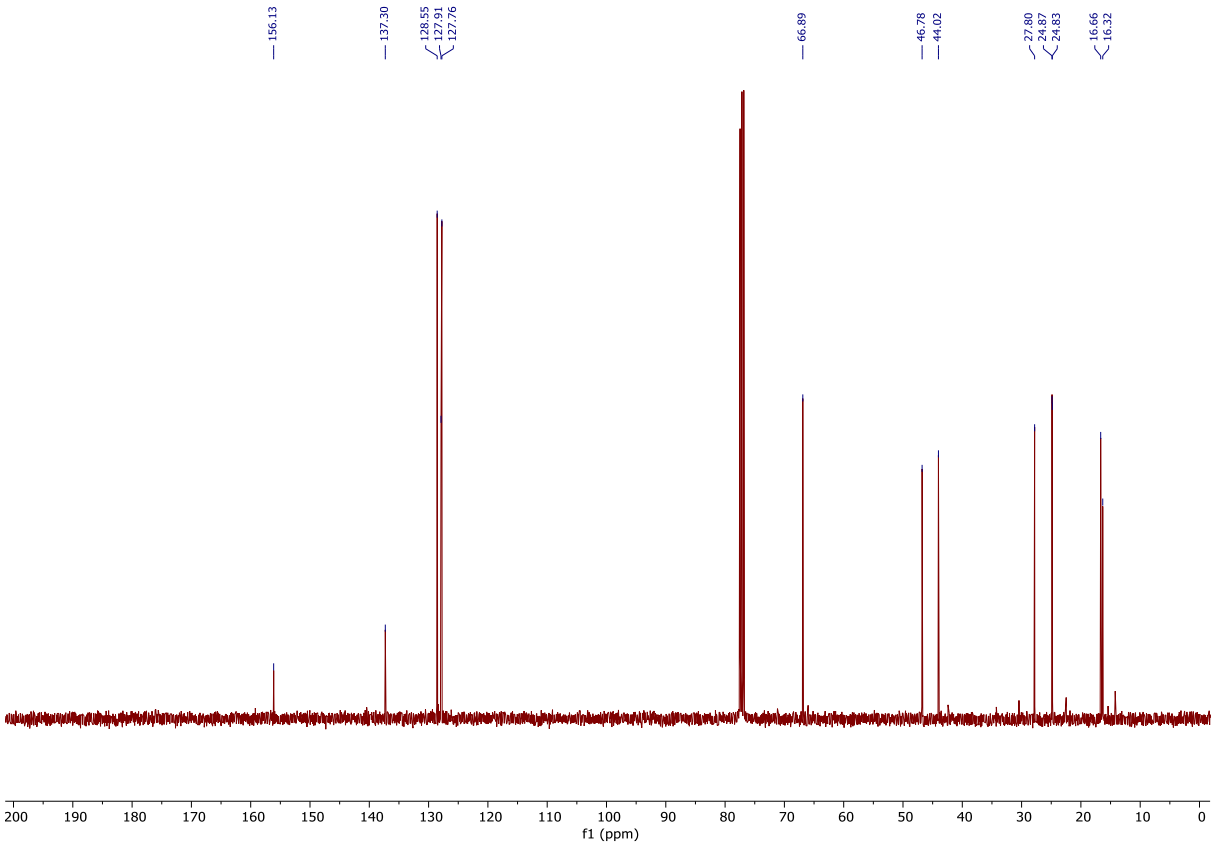
(+)-**3o**$_{minor}$

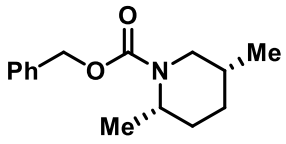
4.74
1.00
1.01
0.93
1.01
1.00
2.07
2.08
1.12
2.99
3.15
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


140.38
128.73
128.20
126.66
77.48 CDCl3
77.16 CDCl3
76.84 CDCl3
59.23
54.70
52.80
31.39
30.79
28.44
19.37
11.88
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Ph
O
N
Me
Me
1.99
0.95
1.01
1.03
3.07
2.47
3.04
3.01
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)

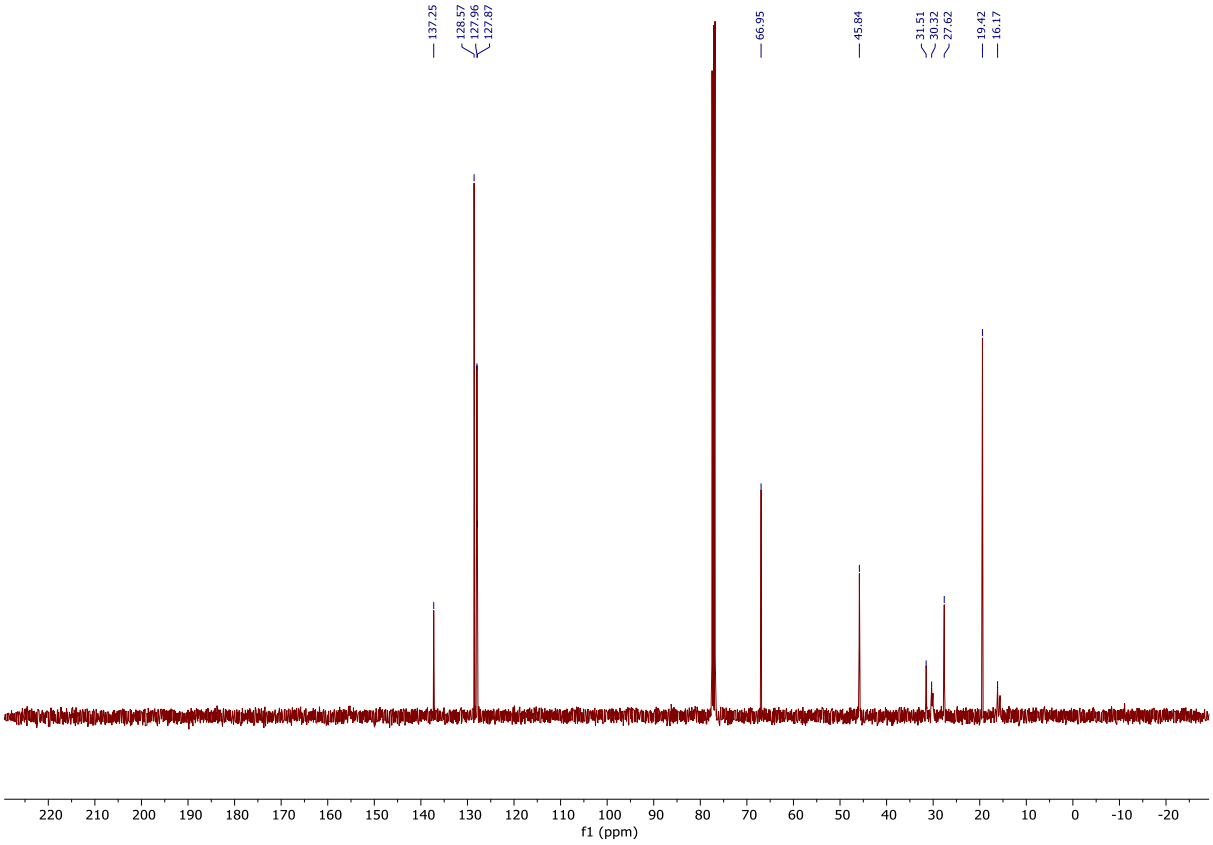
S9

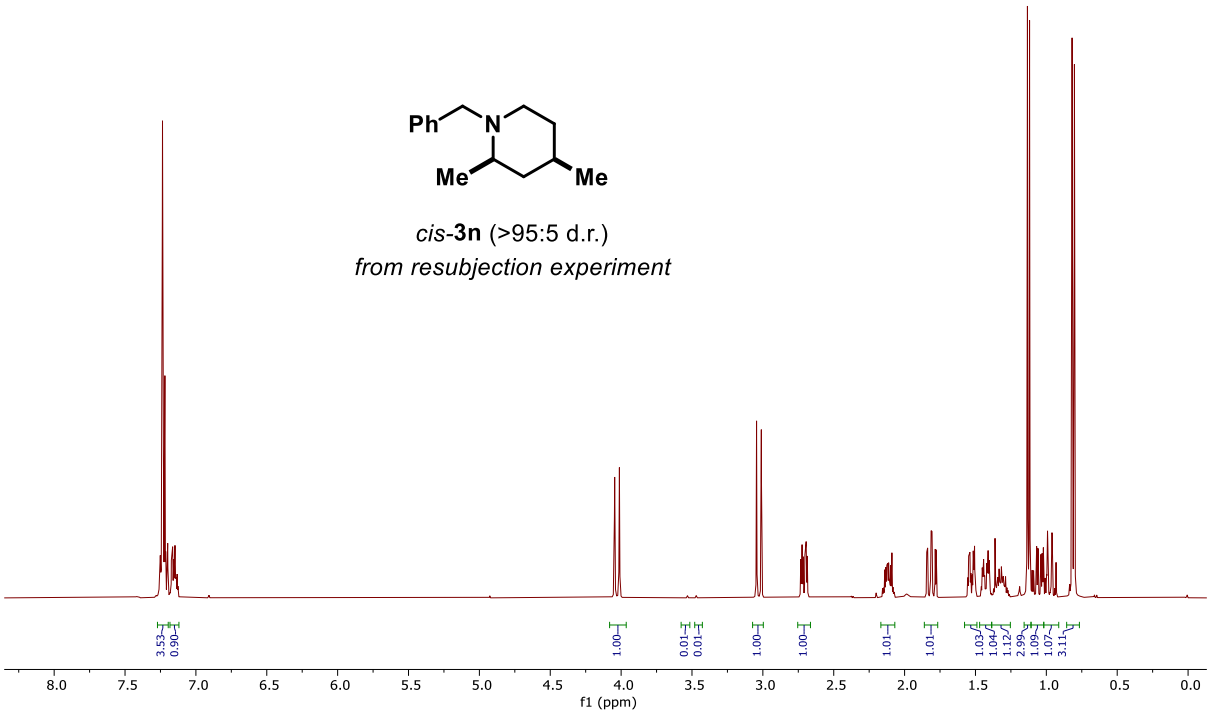

156.13
137.30
128.55
127.91
127.76
66.89
46.78
44.02
27.80
24.87
24.83
16.66
16.32
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
f1 (ppm)


O
Ph
O
N
Me
Me

S10

5.31
2.11
1.00
1.07
1.08
1.22
3.35
1.23
3.27
3.32
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
f1 (ppm)


137.25
128.57
127.96
127.87
66.95
45.84
31.51
30.32
27.62
19.42
16.17
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
-20
f1 (ppm)



cis-**3n** (>95:5 d.r.)
from resubjection experiment