Reaction of Nitrogen-Radicals with Organometallics Under Ni-Catalysis: N-Arylations and Amino-Functionalization Cascades

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SI-1
2 General Experimental Details

All required fine chemicals were used directly without purification unless stated otherwise. All air and moisture sensitive reactions were carried out under nitrogen atmosphere using standard Schlenk manifold technique. THF was distilled from sodium/benzophenone, CH$_2$Cl$_2$ and was distilled from CaH$_2$, CH$_3$CN was distilled from activated 4Å molecular sieves, EtN(i-Pr)$_2$ was distilled over KOH. $^1$H and $^{13}$C Nuclear Magnetic Resonance (NMR) spectra were acquired at various field strengths as indicated and were referenced to CHCl$_3$ (7.26 and 77.0 ppm for $^1$H and $^{13}$C respectively). $^1$H NMR coupling constants are reported in Hertz and refer to apparent multiplicities and not true coupling constants. Data are reported as follows: chemical shift, integration, multiplicity ($s =$ singlet, br $s =$ broad singlet, $d =$ doublet, $t =$ triplet, $q =$ quartet, qi = quintet, sx = sextet, sp = septet, m = multiplet, dd = doublet of doublets, etc.), proton assignment (determined by 2D NMR experiments: COSY, HSQC and HMBC) where possible. High-resolution mass spectra were obtained using a JEOL JMS-700 spectrometer or a Fissions VG Trio 2000 quadrupole mass spectrometer. Spectra were obtained using electron impact ionization (EI) and chemical ionization (CI) techniques, or positive electrospray (ES). Infra-red spectra were recorded using a JASCO FT/IR 410 spectrometer or using an ATI Mattson Genesis Series FTIR spectrometer as evaporated films or liquid films. Analytical TLC: aluminum backed plates pre-coated (0.25 mm) with Merck Silica Gel 60 F254. Compounds were visualized by exposure to UV-light or by dipping the plates in permanganate (KMnO$_4$) stain followed by heating. Flash column chromatography was performed using Merck Silica Gel 60 (40–63 µm). All mixed solvent eluents are reported as v/v solutions.
3 Starting Material Synthesis

3.1 Synthesis of Known Compounds

Compounds 19 and S1–9 have been prepared according to previously reported procedures.\textsuperscript{1–3}

Catalysts [nickel(II)(4,4′-di-tert-butyl-2,2′-bipyridine)(chloride)] (C1) and [nickel(II) (4,4′-di-tert-butyl-2,2′-bipyridine)(bromide)] (C2) have been prepared according to literature procedures.\textsuperscript{4,5}

(4-(2,4-Dinitrophenoxy)piperazin-1-yl)(furan-2-yl)methanone (S9)

Following the reported procedure,\textsuperscript{2} furan-2-yl(piperazin-1-yl)methanone (1.0 g, 5.5 mmol), gave S9 (557 mg, 28%) as an orange solid. FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 2974, 2876, 2360, 1695, 1607, 1553, 1480, 1447, 1393, 1318, 1241, 1217, 1187, 1154, 1046; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 8.83 (1H, d, $J = 2.1$ Hz), 8.43 (1H, dd, $J = 9.3, 2.1$ Hz), 7.91 (1H, d, $J = 9.3$ Hz), 7.51 (1H, s), 7.10 (1H, d, $J = 3.4$ Hz), 6.58–6.46 (1H, m), 4.47 (2H, d, $J = 13.4$ Hz), 3.65 (2H, br s), 3.42 (2H, d, $J = 11.1$ Hz), 3.19 (2H, t, $J = 9.9$ Hz); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 159.1, 157.2, 147.6, 144.2, 140.9, 136.8, 129.6, 122.3, 117.6, 116.8, 111.8, 55.7; HRMS (ESI) Found M$^+$ Na $446.1898$ C$_{20}$H$_{29}$N$_3$O$_7$Na requires 446.1890.
4-(2,4-Dinitrophenoxymorpholine (S10)

Step 1. Following the reported procedure, morpholine (1.01 g, 10 mmol, 1.0 equiv.) gave morpholin-4-ol (685 mg, 85%) as an oil. $^1$H NMR (500 MHz, CDCl$_3$, OH missing) δ 4.06 (2H, dt, $J = 13.1, 3.4$ Hz), 3.75 (2H, ddd, $J = 12.6, 10.2, 2.4$ Hz), 3.29 (2H, dt, $J = 12.5, 2.9$ Hz), 3.04 (2H, ddd, $J = 11.8, 10.2, 3.4$ Hz); $^{13}$C NMR (CDCl$_3$, 126 MHz) δ 22.3, 22.4, 44.4. Data in accordance with the literature.$^6$

Step 2. Following the reported procedure, morpholin-4-ol (685 mg, 6.6 mmol), gave S10 (710 mg, 40 %) as an orange solid. $^1$H NMR (400 MHz, CDCl$_3$) δ 8.80 (1H, d, $J = 2.7$ Hz), 8.40 (1H, dd, $J = 9.4, 2.7$ Hz), 7.89 (1H, d, $J = 9.4$ Hz), 4.06 (2H, br d, $J = 12.2$ Hz), 3.75 (2H, ddd, $J = 12.2, 10.3, 2.3$ Hz), 3.48–3.29 (2H, m), 3.15 (2H, td, $J = 10.6, 3.3$ Hz); $^{13}$C NMR (101 MHz, CDCl$_3$) δ 157.2, 140.6, 137.6, 129.3, 122.1, 116.7, 65.7, 56.5. Data in accordance with the literature.$^2$

$N$-Methyl-$5,5$-diphenylpent-4-en-1-amine (S11)

S11 has been prepared according to the reported procedure.$^7$

$O$-Benzoyl-$N$-(5,5-diphenylpent-4-en-1-yl)-$N$-methylhydroxylamine (4)

To a solution of $N$-methyl-5,5-diphenylpent-4-en-1-amine S11 (5.03 g, 20 mmol, 1.0 equiv.) in DMF (100 mL, 0.2 M), K$_2$HPO$_4$ (6.97 g, 40 mmol, 2.0 equiv.) and BPO (wet with 25% of water, 6.66 g, 1.1 equiv.) were loaded and the reaction was vigorously stirred at room temperature for 10 h. After this time, ice (100 g) was added to the mixture and the crude was diluted with EtOAc (350 mL) and NaHCO$_3$ (100 mL). The organic phase was washed with water (2×), brine, dried over magnesium sulphate and concentrate under reduced pressure to afford a crude oil. Purification by column chromatography on silica gel eluting with [petrol:EtOAc (90:10)] gave 4 (58%) as a white solid. FT-IR $\nu_{\max }$ (film)/cm$^{-1}$ 3058, 3023, 2935, 2845, 1739, 1599, 1495, 1450, 1442, 1259, 1175, 1081, 1061, 1024; $^1$H NMR (500
MHz, CDCl$_3$) $\delta$ 8.00 (2H, dd, $J = 8.3$, 1.4 Hz), 7.62–7.53 (1H, m), 7.49–7.41 (2H, m), 7.38–7.32 (2H, m), 7.31–7.28 (1H, m), 7.28–7.22 (2H, m), 7.22–7.18 (3H, m), 7.16 – 7.11 (2H, m), 6.07 (1H, t, $J = 7.4$ Hz), 2.99 – 2.92 (2H, m), 2.87 (3H, s), 2.20 (2H, q, $J = 7.5$ Hz), 1.77 (2H, p, $J = 7.6$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 165.3, 142.7, 142.4, 140.1, 133.2, 129.9, 129.6, 129.4, 129.0, 128.5, 128.3, 128.2, 127.3, 127.1, 127.0, 60.9, 47.2, 31.1, 27.6.

**N-(5,5-Diphenylpent-4-en-1-yl)-N-methylhydroxylamine (S12)**

K$_2$CO$_3$ (2.76 g, 20 mmol, 2.0 equiv.) was loaded to a solution of O-benzoyl-N-(5,5-diphenylpent-4-en-1-yl)-N-methylhydroxylamine 4 (3.72 g, 10 mmol) in MeOH (100 mL, 0.1 M) and the reaction was stirred at room temperature for 2 h. After this time, ice (50 g) and NH$_4$Cl (100 mL) were added to the mixture and the organic solvent was removed under reduced pressure. The remaining aqueous phase was extracted with EtOAc ($\times 3$) and the organic phase was washed brine, dried over magnesium sulphate and concentrate under reduced pressure to provide a crude oil. Purification by column chromatography on silica gel eluting with [petrol:EtOAc (70:30)] gave S12 (85%) as a white solid. FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 3205, 3052, 3020, 2949, 2844, 2358, 2342, 1597, 1495, 1442, 1073, 1029; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.48–7.02 (10H, m), 6.09 (1H, t, $J = 7.5$ Hz), 2.60 (3H, s), 2.64–2.58 (2H, m), 2.16 (2H, q, $J = 7.5$ Hz), 1.71 (2H, p, $J = 7.5$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 142.7, 142.2, 140.3, 130.0, 129.4, 128.3, 128.2, 127.3, 127.1, 127.0, 61.9, 48.8, 27.8, 27.6.

**O-(2,4-dinitrophenyl)-N-(5,5-diphenylpent-4-en-1-yl)-N-methylhydroxylamine (3)**

To a solution of N-(5,5-diphenylpent-4-en-1-yl)-N-methylhydroxylamine S12 (1.34 g, 5 mmol) and 1-fluoro-2,4-dinitrobenzene (1.86 g, 10 mmol, 2.0 equiv.) in degassed and anhydrous DCM (25 mL, 0.2 M) was added anhydrous NEt$_3$ (1.74 mL, 12.5 mmol, 2.5 equiv.) and the reaction was stirred under nitrogen at room temperature for 16 h. After this time, the solvent was evaporated, then the crude was diluted with EtOAc (150 mL), the
organic phase was washed with NaHCO₃ (2×), brine, dried over magnesium sulphate and concentrate under reduced pressure to provide a crude oil. Purification by column chromatography on silica gel eluting with [petrol:EtOAc (85:15)] gave 3 (35%) as an off-white solid. FT-IR ν_max (film)/cm⁻¹ 1603, 1524, 1459, 1470, 1442, 1340, 1315, 1271, 1139, 1065; ¹H NMR (500 MHz, CDCl₃) δ 8.75 (1H, d, J = 2.7 Hz), 8.22 (1H, dd, J = 9.3, 2.7 Hz), 7.55 (1H, d, J = 9.3 Hz), 7.43–7.31 (3H, m), 7.28–7.21 (3H, m), 7.18 (2H, d, J = 6.7 Hz), 7.12 (2H, d, J = 6.5 Hz), 6.00 (1H, t, J = 7.5 Hz), 3.16–2.85 (2H, m), 2.90 (1H, br s), 2.80 (3H, s), 2.18 (2H, q, J = 7.4 Hz), 1.68 (2H, br s); ¹³C NMR (126 MHz, CDCl₃) δ 158.3, 142.8, 142.4, 140.2, 140.1, 136.2, 130.0, 129.5, 128.5, 128.3, 127.3, 127.2, 127.1, 122.1, 116.8, 60.5, 46.6, 31.1, 27.4, 27.1.

N-Chloro-N-methyl-5,5-diphenylpent-4-en-1-amine (5)

To a solution of N-methyl-5,5-diphenylpent-4-en-1-amine S11 (377 mg, 1.5 mmol, 1.5 equiv.) in CH₂Cl₂ (10 mL, 0.1 M), NCS (133.5 mg, 1.0 mmol, 1.0 equiv.) was added and the reaction was stirred at room temperature for 15 min. The solvent was evaporated and the crude was filtered on a short plug of Al₂O₃ eluting with CH₂Cl₂. The organic solvent was evaporated, pentane (2 mL) was added and the crude was filtered on a short plug of Celite. The filtrate was evaporated to give 5 (75%) as an oil. ¹H NMR (500 MHz, CDCl₃) δ 7.37 (2H, t, J = 7.8 Hz), 7.33–7.27 (2H, m), 7.25–7.19 (4H, m, 2H), 7.18–7.15 (2H, m), 6.08 (1H, t, J = 7.5 Hz), 2.90 (3H, s), 2.88–2.82 (2H, m), 2.17 (2H, q, J = 7.5 Hz), 1.78 (2H, p, J = 8.1, 7.6 Hz).
Compounds S13–18 have been prepared according to previously reported procedures.  

\[
\text{Me} NO NO_2 \quad \text{Ph} NO NO_2 \quad \text{Me} NO NO_2
\]

S13 \hspace{1cm} S14 \hspace{1cm} S15

\[
\text{Me} NO \quad \text{Me} NO \quad \text{Me} NO \quad \text{Me} NO
\]

S16 \hspace{1cm} S17 \hspace{1cm} S18

**Synthesis of 28 and 60. General Procedure 1 – GP1**

R-CO_2H

1. SOCl_2 (10 equiv.), reflux, 3h
2. MeNHOOHCl (1,2 equiv.), NaHCO_3 (2.0 equiv.) THF (0.3 M), rt, 16 h
3. NaH (1.3 equiv.), THF (0.2 M), 0 °C, 30 min then Ar–F (1.1 equiv.), 0 °C→rt, 16 h

The appropriate carboxylic acid (20 mmol) was loaded in a 150 mL flask equipped with a condenser and a stirring bar, then SOCl_2 (14.5 mL, 200 mmol, 10 equiv.) was slowly added in one portion and the reaction mixture was refluxed for 3 h. After cooling to room temperature, the mixture was treated with ice (100 g) under vigorous stirring, the organic fraction was extracted with pentane (100 mL, 3×), then the combined organic layers were washed with brine, dried over magnesium sulphate and concentrate under reduced pressure to provide a crude oil. To a solution of the former oil in THF (67 mL, 0.3 M) N-methylhydroxylamine hydrochloride (2.00 g, 24 mmol, 1.2 equiv.) and NaHCO_3 (3.36 g, 40 mmol, 2.0 equiv.) were loaded and the reaction was stirred at room temperature for 16 h. After this time, the solvent was evaporated, then the crude was diluted with EtOAc (250 mL), the organic phase was washed with NaHCO_3 (5×), brine, dried over magnesium sulphate and concentrate under reduced pressure to provide a crude oil. To a solution of the former crude oil in THF (100 mL), NaH (60%, 1.01 g, 30 mmol, 1.5 equiv.) was added portionwise at 0 °C. After the addition, the reaction was continued stirring for additional 30 min at 0 °C, then 1-fluoro-2,4-dinitrobenzene was slowly added in one portion and the reaction mixture
was stirred for 16 h at room temperature. Upon completion, the mixture was diluted with H$_2$O (50 mL) and the organic solvent was removed under reduced pressure. Then, the crude was diluted with EtOAc (250 mL), the organic phase was washed with Na$_2$CO$_3$ (5×), brine, dried over magnesium sulphate and concentrate under reduced pressure to provide a crude oil, which was dissolved in the minim amount of CH$_2$Cl$_2$ and treated with MeOH/H$_2$O (90:10, 150 mL) affording the pure desired compound as an off-white solid in a 9:1 ratio of endo/exo isomers.

*N-(2,4-dinitrophenoxy)-N-methylbicyclo[2.2.1]hept-5-ene-2-carboxamide (28)*

Following GP1 with 5-norbornene-2-carboxylic acid (2.76 g, 20 mmol, mixture of endo and exo, predominantly endo), 28 was obtained in 65% yield. The pure endo isomer was obtained by purification by column chromatography on silica gel eluting with [petrol:CH$_2$Cl$_2$:EtOAc (65:30:5)]. $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 8.92 (1H, d, $J$ = 2.7 Hz), 8.52 (1H, dd, $J$ = 9.3, 2.7 Hz), 7.57 (1H, d, $J$ = 9.3 Hz), 6.21 (1H, dd, $J$ = 5.7, 3.1 Hz), 5.97 (1H, dd, $J$ = 5.7, 2.8 Hz), 3.32 (3H, s), 3.18 (1H, dt, $J$ = 9.1, 3.9 Hz), 3.12 (1H, br s), 2.89 (1H, br s), 1.84 (1H, ddd, $J$ = 11.4, 9.2, 3.7), 1.47–1.33 (2H, m), 1.26 (1H, d, $J$ = 8.1 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 156.5, 142.3, 138.6, 137.9, 135.8, 132.1, 130.0, 122.8, 115.3, 49.9, 45.7, 42.7, 42.6, 36.7, 30.2. Data in accordance with the literature.$^8$

**Synthesis of 52 and 78. General Procedure 2 – GP2**

A solution of the appropriate alcohol (10 mmol), tert-butyl 2,4-dinitrophenoxycarbamate$^3$ (3.59 g, 12 mmol, 1.2 equiv.) and PPh$_3$ (3.93 g, 15 mmol, 1.5 equiv.) in THF (30 mL) was cooled to 0 °C, then diisopropyl azodicarboxylate (2.95 mL, 15 mmol, 1.5 equiv.) was added dropwise over 15 min. After the addition, the mixture was stirred at room temperature for 16
h and then evaporated. The residue was purified by column chromatography to give the desired product.

**tert-Butyl (2,4-dinitrophenoxy)(pent-4-en-1-yl)carbamate (52)**

Following GP2, 4-pente-1-ol (10 mmol, 1.03 mL) gave 47 (3.340 g, 91%) as an oil. FT-IR ν_{max} (film)/cm^{-1} 2978, 2836, 1727, 1641, 1604, 1532, 1474, 1394, 1368, 1342, 1281, 1260, 1146, 1066; ^1H NMR (500 MHz, CDCl₃) δ 8.83 (1H, d, J = 2.7 Hz), 8.42 (1H, dd, J = 9.3, 2.7 Hz), 7.57 (1H, d, J = 9.3 Hz), 5.78 (1H, ddt, J = 16.9, 10.2, 6.6 Hz), 5.09–4.95 (2H, m), 3.77–3.59 (2H, m), 2.12 (2H, q, J = 7.2 Hz), 1.80 (2H, p, J = 7.4 Hz), 1.43 (9H, s); ^13C NMR (126 MHz, CDCl₃) δ 158.1, 156.1, 141.6, 137.1, 136.7, 129.3, 122.2, 116.3, 115.9, 84.3, 51.6, 30.9, 28.1, 25.8; HRMS (ESI) Found MNa⁺ 390.1263 C_{16}H_{21}N_{3}O_{7}Na requires 390.1272.

**tert-Butyl (2,4-dinitrophenoxy)(non-1-en-5-yl)carbamate (78)**

To a solution of acetone dimethylhydrazone (5.00 g, 50 mmol) in degassed and anhydrous THF (75 mL, 0.67 M) n-BuLi (1.6 M in hexane, 34 mL, 55 mmol, 1.1 equiv.) was added dropwise over 5 min at -5 °C. After 1 h, n-propyl iodide (4.88 mL, 50 mmol, 1.0 equiv.) was added in one portion and the mixture was stirred at room temperature for 10 h. After this time, the reaction mixture was cooled to -5 °C again and n-BuLi (1.6 M in hexane, 34 mL, 55 mmol, 1.1 equiv.) was added dropwise over 5 min. After 1 h, allyl bromide (4.32 mL, 50
mmol, 1.0 equiv.) was added in one portion and the mixture was stirred at room temperature for 10 h. Upon completion, the reaction mixture was poured in a 1L conical flask containing ice (350 g) and HCl (36%, 30 mL) under vigorous stirring for 15 min. Then, pentane (200 mL, 5×) was added and the organic material was extracted (5×). The combined organic layers were washed with brine, dried over magnesium sulphate and concentrate in vacuo to give non-1-en-5-one as a light brown oil (6.17 g), which was subsequently used without further purification. \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 5.76 (1H, ddt, \(J = 16.8, 10.2, 6.5\) Hz), 4.98 (1H, dq, \(J = 17.1, 1.7\) Hz), 4.93 (1H, dq, \(J = 10.2, 1.4\) Hz), 2.46 (2H, t, \(J = 7.4\) Hz), 2.37 (2H, t, \(J = 7.5\) Hz), 2.28 (2H, dtt, \(J = 7.7, 6.3, 1.3\) Hz), 1.52 (2H, p, \(J = 7.4\) Hz), 1.27 (2H, dq, \(J = 14.6, 7.3\) Hz), 0.86 (3H, t, \(J = 7.3\) Hz).

To a stirred solution of non-1-en-5-one (4.21 g, 30 mmol) in EtOH (270 mL), a solution of NaBH\(_4\) (567.5 mg, 15 mmol, 0.5 equiv.) in H\(_2\)O (30 mL) was added dropwise over 15 min at 0 °C and the mixture was stirred at room temperature for additional 6 h. After this time, the reaction was gently treated with acetone (50 mL), diluted with H\(_2\)O (100 mL), acidified to pH 4 with HCl (6%) and then the organic solvents were concentrated in vacuo. Et\(_2\)O (100 mL, 3×) was added, the organic material extracted (3×), the combined organic layers were washed with brine, dried over magnesium sulphate and concentrate under reduced pressure to provide a crude oil, which was purified by column chromatography [petrol:EtOAc (80:20)] affording non-1-en-5-ol as colourless oil (56%, 3.16 g). \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 5.84 (1H, ddt, \(J = 16.9, 10.1, 6.6\) Hz), 5.04 (1H, dd, \(J = 17.2, 1.9\) Hz), 4.96 (1H, dt, \(J = 10.2, 1.5\) Hz), 3.61 (1H, tt, \(J = 8.5, 4.6\) Hz, 1H), 2.34 – 2.00 (2H, m), 1.64 – 1.23 (8H, m), 0.90 (3H, t, \(J = 7.0\) Hz); \(^1\)C NMR (126 MHz, CDCl\(_3\)) \(\delta\) 138.8, 114.8, 71.6, 37.3, 36.6, 30.2, 27.9, 26.0, 22.4, 14.2. Data in accordance with the literature.\(^9\)

Following GP2 with 4-pent-1-ol (10 mmol, 1.42 g) gave 73 (56%) as a pale yellow oil. FT-IR \(\nu_{\text{max}}\) (film)/cm\(^{-1}\) 2932, 2862, 2360, 1726, 1606, 1538, 1475, 1394, 1343, 1259, 1157, 1065; \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 8.84 (1H, d, \(J = 2.7\) Hz), 8.42 (1H, dd, \(J = 9.4, 2.7\) Hz), 7.50 (1H, d, \(J = 9.3\) Hz), 5.77 (1H, ddt, \(J = 16.9, 10.1, 6.6\) Hz), 5.15–4.77 (2H, m), 4.16 (1H, tt, \(J = 8.6, 5.4\) Hz), 2.12 (2H, q, \(J = 7.4\) Hz), 1.78–1.51 (4H, m), 1.44 (9H, s), 1.39–1.17 (4H, m), 0.88 (3H, t, \(J = 6.7\) Hz); \(^1\)C NMR (126 MHz, CDCl\(_3\)) \(\delta\) 158.5, 156.5, 141.4, 137.5, 136.4, 129.1, 122.2, 116.3, 115.6, 84.1, 62.1, 31.9, 31.6, 30.8, 28.7, 28.1, 22.6, 14.0; HRMS (ESI) Found MNa\(^+\) 446.1898 C\(_{20}\)H\(_{29}\)N\(_3\)O\(_7\)Na requires 446.1890.
3.2 Preparation of Organozinc Reagents

Stock solutions of the following organozincs have been prepared according to the procedures reported in the literature, from the corresponding commercially available Grignard reagents\textsuperscript{11}. Tridecylmagnesium bromide has been prepared from the corresponding 1-bromotridecane following a reported procedure.\textsuperscript{12} All the solutions of Grignard reagents and the organolithium compounds used for the synthesis, were titrated before use, according to the procedure reported in the literature.\textsuperscript{13}

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\text{R}_2\text{Zn}
\]
4 Umpolung N-Arylations and Cyclization–Cascades

4.1 Reactions Optimization

| Entry | [M] (equiv.) | [Ni] (mol%) | Ligand (mol%) | Additive (eq.) | Solvent (M) | T (ºC) | Yield (%) |
|-------|-------------|-------------|---------------|----------------|-------------|--------|-----------|
| 1     | ZnPh (1.5)  | NiCl₃glyme (20) | –             | –              | DMF–THF (1.1.) (0.1) | rt     | –         |
| 2     | ZnPh (1.5)  | NiCl₃glyme (20) | dtbpy (20)    | –              | DMF–THF (1.1.) (0.1) | rt     | 90        |
| 3     | ZnPh (1.5)  | NiCl₃glyme (10) | dtbpy (10)    | –              | DMF–THF (1.1.) (0.1) | rt     | 74        |
| 4     | ZnPh (1.5)  | NiCl₃glyme (5)  | dtbpy (5)     | –              | DMF–THF (1.1.) (0.1) | rt     | 69        |
| 5     | ZnPh (1.5)  | NiCl₂•6H₂O (5) | dtbpy (5)     | –              | DMF–THF (1.1.) (0.1) | rt     | 99        |
| 6     | ZnPh (1.5)  | NiCl₂•6H₂O (5) | bpy (5)       | –              | DMF–THF (1.1.) (0.1) | rt     | 84        |
| 7     | ZnPh (1.5)  | NiCl₂•6H₂O (5) | dMeObpy (5)   | –              | DMF–THF      | rt     | 79        |
|   |   |   |   |   |
|---|---|---|---|---|
| 8 | ZnPh (1.5) | NiCl₂•6H₂O (5) | batophen (5) | DMF–THF (1.1) (0.1) | rt | 71 |
| 9 | ZnPh (1.5) | NiCl₂•6H₂O (2) | dtbpy (4) | DMF–THF (1.1) (0.1) | rt | 81 |
| 10 | ZnPh (1.5) | NiCl₂•6H₂O (1) | dtbpy (2) | DMF–THF (1.1) (0.1) | rt | 61 |
| 11 | ZnCl (1.5) | NiCl₂•6H₂O (5) | dtbpy (10) | DMF–THF (1.1) (0.1) | rt | 85 |
| 12 | ZnPh (1.5) | (dtbpy)NiCl₂ (5) |   | DMF–THF (1.1) (0.1) | rt | 92 |
| 13 | B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | 1,4-dioxane–DMF (9:1) (0.05 M) | rt | – |
| 14 | B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | 1,4-dioxane–DMF (9:1) (0.05 M) | 75 | – |
| 15 | B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | Et₃N (3.5) | 1,4-dioxane–DMF (9:1) (0.05 M) | 75 | traces |
| 16 | B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | Et₃N (3.5) | THF–DMF (1:1) (0.05 M) | 75 | – |
| 17 | B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | Et₃N (3.5) | MTBE–DMF (9:1) (0.05 M) | 75 | 75 |
|   | B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | Et₃N (2.0) | toluene–DMF (9:1) (0.05 M) |   |   |
|---|--------------|-----------------|-----------|-----------|---------------------------|---|---|
| 18| B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | Et₃N (2.0) | toluene–DMF (9:1) (0.05 M) | 75| 31|
| 19| B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | Cs₂CO₃ (2.0) | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| 85|
| 20| B(OH)₂ (2.0) | NiCl₂glyme (5)  | dtbpy (5)  | Cs₂CO₃ (2.0) | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| 62|
| 21| B(OH)₂ (2.0) | NiCl₂glyme (5)  | dtbpy (5)  | Cs₂CO₃ (2.0) | MTBE (0.05 M)             | 75| 90|
| 22| B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | K₂CO₃ (2.0) | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| 17|
| 23| B(OH)₂ (2.0) | NiCl₂glyme (20) | dtbpy (20) | CsF        | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| 13|
| 24| B(OH)₂ (2.0) | NiCl₂•6H₂O (20) | dtbpy (20) | Cs₂CO₃ (3.5)| 1,4-dioxane–DMF (9:1) (0.05 M) | 75| 50|
| 25| B(OH)₂ (2.0) | –               | –          | –          | toluene                   | 50| – |
| 26| Si(OEt)₃ (2.0)| NiCl₂glyme (20) | dtbpy (20) | –          | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| – |
| 27| Si(OEt)₃ (2.0)| NiCl₂glyme (20) | dtbpy (20) | TBAF (2.0) | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| – |
| 28| Si(OEt)₃ (2.0)| NiCl₂glyme (20) | dtbpy (20) | CsF (2.0)  | 1,4-dioxane–DMF (9:1) (0.05 M) | 75| – |
| 29| Si(OEt)₃ (2.0)| NiCl₂glyme (20) | dtbpy (20) | TBAT (2.0) | 1,4-dioxane–DMF            | 75| 20|
|   | Si(OEt)$_3$ (2.0) | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMSO–DMF (9:1) (0.05 M) |   |
|---|------------------|-------------------|------------|------------|------------------------|---|
| 30 | Si(OEt)$_3$ (2.0) | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMSO–DMF (9:1) (0.05 M) | 75 | 48 |
| 31 | Si(OEt)$_3$ (2.0) | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMF (0.05 M)           | 75 | 32 |
| 32 | Si(OEt)$_3$ (2.0) | –                 | –          | TBAT (2.0) | DMSO–DMF (9:1) (0.05 M) | 75 | –  |
| 33 | Si(OEt)$_3$ (2.0) | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMSO (0.05 M)          | 75 | 68 |
| 34 | Si(OEt)$_3$ (2.0) | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMSO (0.05 M)          | 50 | 88 |
| 35 | Si(OEt)$_3$ (2.0) | NiCl$_2$glyme (5) | dtbpy (5)  | TBAT (2.0) | DMSO (0.05 M)          | 50 | 86 |
| 36 | SiMe$_3$         | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMSO (0.05 M)          | 50 | –  |
| 37 | SiMeCB           | NiCl$_2$glyme (20) | dtbpy (20) | TBAT (2.0) | DMSO (0.05 M)          | 50 | –  |
Table S2.

| Entry | [M] (equiv.) | [Ni] (mol%) | Ligand (mol%) | Additive (eq.) | Solvent (M)                  | T (ºC) | Yield (%) |
|-------|-------------|-------------|---------------|----------------|-------------------------------|--------|-----------|
| 1     | ZnPh (1.5)  | NiCl₂•6H₂O (20) | dtbpy (20) | –              | THF–DMF (1:1) (0.1)          | rt     | 61        |
| 2     | ZnPh (1.5)  | NiBr₂•6H₂O (20)  | dtbpy (20) | –              | THF–DMF (1:1) (0.1)          | rt     | 71        |
| 3     | ZnPh (1.5)  | (dtbpy)NiBr₂ (20) | –            | –              | THF–DMF (1:1) (0.1)          | rt     | 76        |
| 4     | ZnPh (1.5)  | (dtbpy)NiBr₂ (5)  | –            | –              | THF–DMF (1:1) (0.1)          | rt     | 52        |
| 5     | B(OH)₂ (2.0) | (dtbpy)NiBr₂ (20) | –            | Cs₂CO₃ (2.0)   | THF–DMF (1:1) (0.1)          | 75     | 47        |
| 6     | B(OH)₂ (2.0) | (dtbpy)NiBr₂ (20) | –            | Cs₂CO₃ (2.0)   | MTBE (0.05 M)                | 75     | 83        |
| 7     | Si(OEt)₃ (2.0) | (dtbpy)NiBr₂ (20) | –            | TBAT (2.0)     | DMSO (0.05 M)                | 50     | 51        |
### Table S3.

| Entry | [M] (equiv.) | [Ni] (mol%) | Ligand (mol%) | Additive (eq.) | Solvent (M)       | T (ºC) | Yield (%) |
|-------|--------------|-------------|---------------|---------------|-------------------|--------|-----------|
| 1     | ZnEt (1.5)   | NiCl₂·6H₂O (20) | dtbpy (20) | –             | THF–DMF (1:1) (0.1) | rt     | 34        |
| 2     | ZnEt (1.5)   | NiBr₂·6H₂O (20) | dtbpy (20) | –             | THF–DMF (1:1) (0.1) | rt     | 39        |
| 3     | ZnEt (1.5)   | (dtbpy)NiBr₂ (20) | –         | –             | THF–DMF (1:1) (0.1) | rt     | 60        |
| 4     | ZnEt (1.5)   | NiI₂ (20)   | dtbpy (20) | –             | THF–DMF (1:1) (0.1) | rt     | 33        |
| 5     | ZnEt (1.5)   | Ni(acac)₂·4H₂O (20) | dtbpy (20) | –             | THF–DMF (1:1) (0.1) | rt     | 32        |
| 6     | ZnEt (1.5)   | NiBr₂·6H₂O (20) | dtbpy (20) | –             | THF–DMF (1:1) (0.1) | rt     | 39        |
| 7     | B(OH)₂ (2.0) | NiCl₂glyme (5) | dtbpy (5)   | Cs₂CO₃ (2.0)  | MTBE (0.05 M)     | 75     | –         |
| 8     | B(OH)₂ (2.0) | (dtbpy)NiBr₂ (20) | –         | Cs₂CO₃ (2.0)  | THF–DMF (1:1) (0.1) | rt     | –         |
| 9 | B(OH)$_2$ (2.0) | (dtbpy)NiBr$_2$ (20) | – | Cs$_2$CO$_3$ (2.0) | MTBE (0.05 M) | rt | – |
4.2 GP3 – General Procedure for N-arylation and cyclization-arylation with organozincs

\[
\begin{align*}
R_1^N\text{R}^1 &\quad + \quad \text{Ar}-\text{ZnAr} &\quad \text{NiCl}_2\cdot6\text{H}_2\text{O (2 mol%), dtbpy (2 mol%) } \\
\text{THF:DMF 1:1 (0.1 M)} &\quad 1\text{h, r.t.} &\quad R_1^N\text{R}^1
\end{align*}
\]

- **N-Arylation:** An oven-dried 10 mL crimp-cap microwave vial equipped with a stirring bar was charged with the aryloxyamine (0.1 mmol, 1.0 equiv.), sealed, evacuated and refilled with N\textsubscript{2} for three times. Then a solution of NiCl\textsubscript{2}·6H\textsubscript{2}O:dtbpy 1:1 in DMF (0.2 µmol, 2 mol%) and a solution of organozinc in THF (0.1 mmol, 1.0 equiv.) were added (DMF:THF 1:1, 0.1 M). The reaction was stirred at room temperature for 1h, the crude was then absorbed on silica and purified on silica gel column.

- **Cyclization-arylation–alkylation:** An oven-dried 10 mL crimp-cap microwave vial equipped with a stirring bar was charged with the aryloxyamide (0.1 mmol, 1.0 equiv.), and the catalyst C2 (2 µmol, 20 mol%), sealed, evacuated and refilled with N\textsubscript{2} for three times. Then DMF and a solution of organozinc in THF (0.1 mmol, 1.0 equiv.) were added (DMF:THF 1:1, 0.025M). The reaction was stirred at room temperature for 15 h, the crude was absorbed on silica and purified on silica gel column.

4.3 GP4 – General Procedure for N-arylation and cyclization-arylation with arylboronic acids

\[
\begin{align*}
R_1^N\text{R}^1 &\quad + \quad \text{Ar-B(OH)}_2 (3.0 \text{ equiv.}) &\quad \text{C1 (20 mol%), Cs}_2\text{CO}_3 (3.5 \text{ equiv.}) \\
\text{THF--DMF (9:1) (0.1 M), 15 h, 75 \text{ °C}} &\quad R_1^N\text{R}^1
\end{align*}
\]

\[
\begin{align*}
\text{R}_1^N\text{OAr} &\quad + \quad \text{R}^2\text{-ZnR}^2 &\quad \text{C2 (20 mol %), THF--DMF 1:1 (0.05 M)} \\
\text{15 h, r.t.} &\quad R^2
\end{align*}
\]

Unless otherwise stated, an oven-dried 10 mL crimp-cap microwave vial equipped with a stirring bar was charged with nickel(II)-catalyst C1 (2 µmol, 20 mol%), the appropriate aryloxyamine/amide (0.1 mmol, 1.0 equiv.), the appropriate arylboronic acid (0.3 mmol, 3.0 equiv.) and Cs\textsubscript{2}CO\textsubscript{3} (0.35 equiv.). The vial was sealed, evacuated and refilled with N\textsubscript{2} (3×),
and the following anhydrous solvents were added. The reaction was stirred at the stated temperature for 15 h.

- **N-Arylation**: THF:DMF (9:1, 0.1 M), 75 °C.
- **Cyclization-arylation/1,5-HAT-arylation**: DCE:DMF (9:1, 0.025 M), 95 °C.

Upon completion, the crude was diluted with water and extracted with EtOAc (3×) and then purified by column chromatography.

### 4.4 GP5 – General Procedure for N-arylation and cyclization-arylation with organo silanes

A dry tube equipped with a stirring bar was charged with the aryloxyamine/amide (0.1 mmol, 1.0 equiv.), sealed, evacuated and refilled with N₂ for three times. Then a stock solution of NiCl₂·6H₂O:dtbpy 1:1 in DMF were added (1.0 µmol, 10 mol%), followed by the addition of a stock solution of the arylsilane and TBAT in DMSO (0.2 mmol, 2.0 equiv.). The reaction was stirred at 50 °C for 15h, the crude was then absorbed on silica and purified on silica gel column.
5 Analysis of Chan-Lam Couplings with Heteroaromatic Organometallics

As the use of arylboronic acids and, to a lesser extent, arylsilanes and arylzincs in this methodology would deliver products identical to the widely used Chan-Lam coupling, we performed a literature survey to identify potential areas of complementarity (Figure S1). We realized that amination of C-3 and C-4-zincated pyridines and C-2-zincated 5-membered ring heterocycles (e.g. thiophene) has not been reported. In the case of aryl boronic acids no precedent was found to access C-4 aminated pyridines. Aryl silanes are considerably less used in aromatic amination.
6 Mechanistic Considerations

The following experiments using substrates 3–5 were performed following the general procedures GP3, GP4 or GP5. As shown in Table S4, although the N-arylation product 6 was obtained in several cases, product 7, which would result from a radical 5-exo-trig cyclisation, was exclusively obtained when using 3, regardless from the nature of the organometallic partner (entries 1–6). The presence of both 6 and 7 in these reactions suggests that the rates of cyclisation (1.9 \times 10^5 \text{s}^{-1}) and N-arylation are comparable.\(^1\)

![Diagram](image)

| Entry | X   | [M]        | 6 (%) | 7 (%) |
|-------|-----|------------|-------|-------|
| 1     | OAr | ZnPh       | 30    | 22    |
| 2     | OBz | ZnPh       | 13    | –     |
| 3     | Cl  | ZnPh       | 31    | –     |
| 4     | OAr | B(OH)\(_2\) | 8     | 9     |
| 5     | OBz | B(OH)\(_2\) | traces| –     |
| 6     | Cl  | B(OH)\(_2\) | –     | –     |

Indeed, the ratio between 6 and 7 varies in favor of 7 at low Ni-catalyst loading (Table S5, entries 1–4) and also at higher dilution (entries 5–8), which further supports the intermediacy of a N-radical in our process.

\(^1\) The C-radical formed upon N-radical cyclization could intercept the Ni(II)-aryl complex. However, as this radical is di-benzylic we believe other pathways might be operative (e.g. 1,5-HAT, oxidation…). Furthermore, the addition of benzylic radicals to Ni-complexes has been described to be reversible, see: O. Gutierrez, J. C. Tellis, D. N. Primer, G. A. Molander, M. C. Kozlowski, \textit{J. Am. Chem. Soc.} \textbf{2015}, \textit{137}, 4896.
Table S5.

| Entry | [ ] (M) | [Ni] (mol%) | 6 (%) | 7 (%) |
|-------|---------|-------------|-------|-------|
| 1     | 0.08    | 20          | 45    | 9     |
| 2     | 0.05    | 20          | 34    | 22    |
| 3     | 0.03    | 20          | 25    | 29    |
| 4     | 0.01    | 20          | 19    | 38    |
| 5     | 0.05    | 10          | 18    | 22    |
| 6     | 0.05    | 5           | 9     | 22    |
| 7     | 0.05    | 2           | 4     | 23    |
| 8     | 0.05    | 1           | traces| 29    |

We subjected precursors 3 and 4 to the optimum conditions identified in Table S5 favouring cyclization over N-arylation (Table S5, entry 8). As shown in Table S6 precursor 3 only led to the cyclized product 7 (entry 1) while 6 underwent N-arylation in poor yield. (entry 2).

Table S6.

| Entry | X        | 6 (%) | 7 (%) |
|-------|----------|-------|-------|
| 1     | OAr      | –     | 29    |
| 2     | OBz      | 10    | –     |

Using precursor 3 product 7 was detected in 29% yield and no 6 was found. Using precursor 2 no cyclization was found and only 10% of N-arylated product 6 was found.
7 Products Characterization

1-Phenylpiperidine (2)

S1 (27 mg, 0.1 mmol) gave 2 following GP3 (99%), GP4 (85%) and GP5 (86%). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.28–7.19 (2H, m), 6.93 (2H, d, $J$ = 8.2 Hz), 6.81 (1H, t, $J$ = 7.3 Hz), 3.17–3.10 (4H, m), 1.70 (4H, p, $J$ = 5.7 Hz), 1.56 (2H, dtd, $J$ = 9.0, 5.3, 4.8, 2.2 Hz); $^{13}$C NMR (125 MHz, CDCl$_3$) $\delta$ 152.5, 129.2, 119.4, 116.8, 50.9, 26.1, 24.5. Data in accordance with the literature.$^{14}$

N-(5,5-diphenylpent-4-en-1-yl)-N-methylaniline (6)

3 gave 6 following GP3 (30%) and GP4 (8%) as an oil. FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2961, 2788, 1597, 1491, 1448, 1377, 1313, 1258, 1173, 1082, 1031; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.37 (2H, t, $J$ = 7.3 Hz), 7.31 (1H, t, $J$ = 7.2 Hz), 7.28 – 7.13 (10H, m), 6.75 – 6.60 (3H, m), 6.09 (1H, t, $J$ = 7.4 Hz), 3.35 – 3.20 (2H, m), 2.87 (3H, s), 2.15 (2H, q, $J$ = 7.5 Hz), 1.72 (2H, p, $J$ = 7.5 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 149.3, 142.8, 142.3, 140.2, 130.0, 129.3, 129.2, 128.3, 128.2, 127.4, 127.1, 127.0, 116.1, 112.3, 52.5, 38.5, 27.5, 27.0; HRMS (ASAP): Found MH$^+$ 328.2062 C$_{24}$H$_{26}$N requires 328.2060.

2-Benzhydryl-1-methylpyrrolidine (7)

Following GP3, 3 gave 7 (22%) as an oil. FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2917, 2361, 1598, 1574, 1504, 1442, 1361, 1259, 1192, 1116, 1073, 1031; $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.64 (2H, d, $J$ = 8.2 Hz), 7.53 (2H, d, $J$ = 8.2 Hz), 7.27 (4H, t, $J$ = 7.7 Hz), 7.14 (2H, t, $J$ = 7.2 Hz), 3.68 (1H, dd, $J$ = 9.6, 4.3 Hz), 3.17 (1H, t, $J$ = 6.3 Hz), 2.48 (1H, q, $J$ = 9.5 Hz), 1.87 (3H, s), 1.99 – 1.88 (1H, m) 1.79 – 1.57 (3H, m), 1.35 – 1.19 (1H, m); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 146.7, 128.3 & 128.2, 126.4 & 126.3, 125.6 & 125.5, 72.4, 59.3, 43.2, 29.9, 24.1, 1.2.
4.4-Difluoro-1-phenylpiperidine (8)

Following GP3, S2 (37 mg, 0.1 mmol) gave 8 (73%) as an oil. FT-IR ν<sub>max</sub> (film)/cm<sup>-1</sup> 3617, 2962, 1634, 1050, 997 cm<sup>-1</sup>; <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.28 (2H, t, J = 7.9 Hz), 6.95 (2H, d, J = 8.1 Hz), 6.89 (1H, t, J = 7.3 Hz), 3.66–3.13 (4H, m), 2.10 (4H, tt, J = 13.3, 5.6 Hz); <sup>13</sup>C NMR (126 MHz, CDCl<sub>3</sub>) δ 129.4, 124.0, 122.1 (t, J = 241.7 Hz), 120.3, 117.0, 46.9 (t, J = 5.2 Hz), 33.8 (t, J = 22.8 Hz); <sup>19</sup>F NMR (CDCl<sub>3</sub>, 376 MHz) δ -97.6; HRMS (HESI): Found MH<sup>+</sup> 198.1089 C<sub>11</sub>H<sub>14</sub>NF<sub>2</sub> requires 198.1089.

4-Phenylmorpholine (9)

Following GP3 for 3h, S10 (27 mg, 0.1 mmol) gave 9 (95%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.31–7.25 (2H, m), 6.95–6.83 (3H, m), 3.93–3.82 (4H, m), 3.23–3.10 (4H, m); <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 151.5, 129.4, 120.3, 115.9, 67.2, 49.6. Data in accordance with the literature.<sup>14</sup>

4-Phenylthiomorpholine (10)

Following GP3 with 5 mol% of C1 for 3h, S3 (0.1 mmol) gave 10 (85%). <sup>1</sup>H NMR (500 MHz, CDCl<sub>3</sub>) δ 7.33–7.21 (2H, m), 7.03–6.81 (3H, m), 3.57–3.49 (4H, m), 2.76–2.70 (4H, m); <sup>13</sup>C NMR (101 MHz, CDCl<sub>3</sub>) δ 151.5, 129.4, 120.0, 117.3, 52.3, 27.0. Data in accordance with the literature.<sup>15</sup>
Benzyl 4-phenylpiperazine-1-carboxylate (11)

Following GP3 for 3h, S4 (40 mg, 0.1 mmol) gave 11 (95%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.43–7.32 (2H, m), 6.98–6.86 (3H, m), 3.71–3.63 (4H, m), 3.15 (4H, br s); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 155.0, 151.0, 136.4, 129.0, 128.4, 127.9, 127.8, 120.3, 116.6, 67.2, 49.5, 43.8. Data in accordance with the literature.\(^{16}\)

Furan-2-yl(4-phenylpiperazin-1-yl)methanone (12)

Following GP3, S5 (36 mg, 0.1 mmol) gave 12 (83%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.50 (1H, s), 7.29 (2H, t, J = 7.8 Hz), 7.05 (1H, d, J = 2.8 Hz), 6.95 (2H, d, J = 8.0 Hz), 6.91 (1H, t, J = 7.3 Hz), 6.55–6.46 (1H, m), 3.97 (4H, s), 3.32–3.21 (4H, m); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 159.2, 151.0, 148.0, 143.9, 129.4, 120.6, 116.7, 116.7, 111.5, 49.8. Data in accordance with the literature.\(^{17}\)

$N,N$-Diethylaniline (13)

Following GP3, S6 (25 mg, 0.1 mmol) gave 13 (88%). $^1$H NMR (400 MHz, CDCl$_3$) $\delta$ 7.19 (2H, t, J = 7.9 Hz), 6.67 (2H, d, J = 8.4 Hz), 6.62 (1H, t, J = 7.2 Hz), 3.34 (4H, q, J = 7.0 Hz), 1.15 (6H, t, J = 7.1 Hz); $^{13}$C NMR (400 MHz, CDCl$_3$) $\delta$ 146.8, 128.2, 114.3, 110.9, 43.3, 11.5. Data in accordance with the literature.\(^{18}\)

$N$-Methyl-$N$-phenethylaniline (14)

Following GP3, S7 (32 mg, 0.1 mmol) gave 14 (95%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.38–7.06 (7H, m), 6.87–6.62 (3H, m), 3.57 (2H, t, J = 7.8 Hz), 2.92–2.76 (5H, m); $^{13}$C NMR (101
MHz, CDCl$_3$) $\delta$ 148.8, 139.8, 129.2, 128.8, 128.5, 126.2, 116.1, 112.1, 54.7, 38.4, 32.9. Data in accordance with the literature.$^{19}$

$N,N$-Dibenzylaniline (15)

Following **GP3**, S8 (38 mg, 0.1 mmol) gave 15 (88%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.33 (4H, t, $J$ = 7.7 Hz, 4H), 7.27–7.23 (6H, m), 7.17 (2H, t, $J$ = 7.7 Hz), 6.75 (2H, d, $J$ = 7.7 Hz), 6.70 (1H, t, $J$ = 7.7 Hz), 4.66 (4H, s); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 149.3, 138.8, 129.4, 128.8, 127.0, 126.8, 116.9, 112.6, 54.3. Data in accordance with the literature.$^{20}$

2-(Piperidin-1-yl)pyridine (16)

A solution of 2-bromopyridine (316 mg, 2.0 mmol, 1.0 equiv.) in THF (8.0 ml) was cooled at –78 °C and $n$-BuLi (1.25 ml of a solution 1.6 M in hexane, 2.0 mmol, 1.0 equiv.) was added by dropwise over 20 min. The mixture was stirred at –78 °C for 30 minutes and a solution of ZnCl$_2$ (1.0 ml of a solution 1.0 M in THF, 1.0 mmol, 0.5 equiv.) was added. The mixture was stirred for 30 minutes at –78 °C, then at room temperature for 30 minutes. The solution was titrated as 0.1 M, and used for the reaction. Following **GP3**, in DMF:THF 1:2 (0.06 M), and with 10 mol% of catalyst, S1 (27 mg, 0.1 mmol) gave 16 (41%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 8.16 (1H, dd, $J$ = 5.2, 1.9 Hz), 7.42 (1H, ddd, $J$ = 8.8, 7.1, 2.0 Hz), 6.62 (1H, d, $J$ = 8.6 Hz), 6.54 (1H, dd, $J$ = 7.1, 4.9 Hz), 3.51 (4H, br s), 1.63 (6H, s); $^{13}$C NMR, (101 MHz, CDCl$_3$) $\delta$ 159.8, 148.0, 137.5, 112.5, 107.3, 46.5, 25.7, 24.9. Data in accordance with the literature.$^{21}$

3-(Piperidin-1-yl)pyridine (17)

A dry, nitrogen charged round bottomed flask was charged with iPrMgCl·LiCl (1.0 ml of a titrated solution 1.0 M in THF, 1.0 mmol, 0.5 equiv.) and diluted with 1.0 ml of anhydrous
THF. The mixture was cooled at 0 °C and 3-bromopyridine (316 mg, 2.0 mmol, 1.0 equiv.) was added in one portion. The solution was stirred at r.t. for 30 min before a solution of ZnCl₂ in THF (1.0 ml of a solution 1.0 M, 1.0 mmol, 0.5 equiv.) was added in. After 30 min stirring, the solution was titrated as 0.1 M.

Following GP3 in DMF:THF 1:2 (0.06 M), and with 10 mol% of catalyst, S1 (27 mg, 0.1 mmol) gave 17 (37%). ¹H NMR (500 MHz, CDCl₃) δ 8.31 (1H, d, J = 2.7 Hz), 8.06 (1H, dd, J = 4.5, 1.3 Hz), 7.14–7.20 (2H, m), 3.19 (4H, t, J = 5.4 Hz), 1.71–1.75 (4H, m), 1.61–1.69 (2H, m); ¹³C NMR (101 MHz, CDCl₃) δ 147.7, 140.0, 139.0, 123.3, 122.6, 49.9, 25.6, 24.1. Data in accordance with the literature.

4-(Piperidin-1-yl)pyridine (18)

![Image of 4-(Piperidin-1-yl)pyridine](image)

A dry flask was charged with 4-iodopyridine (102 mg, 0.5 mmol, 1.0 equiv.) and THF (2.0 ml) and was cooled at −78 °C. n-BuLi (0.31 ml of a solution 1.6 M in hexane, 0.5 mmol, 1.0 equiv.) was then added by dropwise over 20 min. The mixture was stirred for 30 min at −78 °C and a solution of ZnCl₂ (0.5 ml of a solution 1.0 M in THF, 0.5 mmol, 1 equiv.) was added. After stirring for 30 min at −78 °C the solution was warmed up at room temperature, and used for the reaction.

Following GP3 in DMF:THF 1:2 (0.06 M), and with 10 mol% of catalyst, S1 (27 mg, 0.1 mmol) gave 18 (29%). ¹H NMR (500 MHz, CDCl₃) δ 8.25 (2H, br s), 6.74 (2H, br d, J = 5.80 Hz), 3.51–3.39 (4H, m), 1.77–1.56 (6H, m); ¹³C NMR (101 MHz, CDCl₃) δ 155.6, 146.2, 107.5, 47.3, 25.2, 24.0. Data in accordance with the literature.

2-Methoxy-4-(piperidin-1-yl)pyridine (19)

![Image of 2-Methoxy-4-(piperidin-1-yl)pyridine](image)

Following GP4, S1 (27 mg, 0.1 mmol) gave 19 (49%). ¹H NMR (400 MHz, CDCl₃) δ 7.83 (1H, d, J = 6.1 Hz), 6.36 (1H, dd, J = 6.2, 2.4 Hz), 6.02 (1H, d, J = 2.3 Hz), 3.87 (3H, s), 3.27 (4H, t, J = 4.5 Hz), 1.67–1.53 (6H, m); ¹³C NMR (101 MHz, CDCl₃) δ 165.9, 157.5, 146.8, 104.2, 92.6, 53.1, 47.5, 25.0, 24.3. Data in accordance with the literature.
1-(Thiophen-2-yl)piperidine (20)

S1 (27 mg, 0.1 mmol) gave 20 (83%) following GP3 with 10 mol% of catalyst and following GP5 (29%). ¹H NMR (500 MHz, CDCl₃) δ 6.75 (1H, dd, J = 5.5, 3.7 Hz), 6.56 (1H, dd, J = 5.5, 1.3 Hz), 6.09 (1H, dd, J = 5.2, 1.3 Hz), 3.13–3.09 (4H, m), 1.72 (4H, p, J = 5.8 Hz), 1.62–1.52 (2H, m); ¹³C NMR (101 MHz, CDCl₃) δ 160.4, 126.2, 111.8, 104.9, 53.0, 25.55, 23.94. Data in accordance with the literature.²⁵

1-(Thiophen-3-yl)piperidine (21)

Following GP4, S1 (27 mg, 0.1 mmol) gave 21 (38%). ¹H NMR (500 MHz, CDCl₃) δ 7.22 (1H, dd, J = 5.2, 3.0 Hz), 6.89 (1H, dd, J = 5.2, 1.7 Hz), 6.18 (1H, dd, J = 3.0, 1.7 Hz), 3.07 (4H, t, J = 7.0 Hz), 1.76–1.68 (4H, m), 1.60–1.52 (2H, m); ¹³C NMR, (101 MHz, CDCl₃) δ 153.5, 125.1, 120.7, 100.1, 51.9, 25.8, 24.3. Data in accordance with the literature.²⁶

1-(p-Tolyl)piperidine (22)

Following GP5, S1 (27 mg, 0.1 mmol) gave 22 (71%). ¹H NMR (500 MHz, CDCl₃) δ 7.16 (2H, d, J = 8.4 Hz), 6.96 (2H, d, J = 8.4 Hz), 3.18 (4H, t, J = 5.4 Hz), 2.37 (3H, s), 1.85–1.77 (4H, m), 1.69–1.61 (2H, m); ¹³C NMR (125 MHz, CDCl₃) δ 150.2, 129.5, 128.7, 116.9, 51.3, 25.9, 24.2, 20.4. Data in accordance with the literature.²⁷
1-(4-Chlorophenyl)piperidine (23)

Following GP5, S1 (27 mg, 0.1 mmol) gave 23 (83%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.19–7.28 (2H, m), 6.85–6.88 (2H, m), 3.14 (4H, t, $J = 5.4$ Hz), 1.69–1.75 (4H, m), 1.58–1.61 (2H, m); $^{13}$C NMR (101 MHz, CDCl$_3$) $\delta$ 150.8, 128.8, 123.9, 117.6, 50.6, 25.7, 24.2. Data in accordance with the literature.$^{28}$

1-Methyl-6-phenylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (29)

28 (33 mg, 0.1 mmol) gave 29 following GP6 (76%) with C1, GP4 (83%) with 10 mol% of C1 and GP5 (45%) as a white solid. FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2962, 2360, 1682, 1400, 1257, 1018; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 7.34 (2H, t, $J = 7.7$ Hz), 7.22 (1H, t, $J = 7.4$ Hz), 7.18 (2H, d, $J = 7.7$ Hz), 3.76 (1H, d, $J = 4.8$ Hz), 3.12–3.01 (1H, m), 2.89 (3H, s), 2.69 (1H, br s), 2.69–2.66 (1H, m), 2.47 (1H, dd, $J = 10.8$, 4.5 Hz), 2.04–1.96 (1H, m), 1.87 (1H, d, $J = 10.9$ Hz), 1.72 (1H, d, $J = 13.0$ Hz), 1.49 (1H, d, $J = 11.0$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 179.6, 142.9, 128.7, 127.3, 126.4, 68.3, 52.1, 45.2, 43.4, 42.4, 35.5, 34.6, 29.0; HRMS (HESI): Found MH$^+$ 282.1380 C$_{15}$H$_{18}$NO requires 228.1383.

6-(4-Methoxyphenyl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (30)

Following GP4 at 75 ºC, 28 (33 mg, 0.1 mmol) gave 30 (52%) as a grey solid. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$2953, 1692, 1610, 1512, 1464, 1431, 1396, 1307, 1266,
1243, 1179, 1111, 1065, 1032, 1018; \textsuperscript{1}H NMR, (500 MHz, CDCl$_3$) $\delta$ 7.09 (2H, d, $J = 8.6$ Hz), 6.87 (2H, d, $J = 8.6$ Hz), 3.80 (3H, s), 3.71 (1H, d, $J = 4.4$ Hz), 3.04 (1H, tq, $J = 4.8, 1.6$ Hz), 2.88 (3H, s), 2.63 (1H, br s), 2.62 (1H, br s), 2.46 (1H, dd, $J = 10.7, 4.8$ Hz), 2.00 (1H, ddd, $J = 13.0, 10.9, 4.1$ Hz), 1.84 (1H, dd, $J = 11.0, 1.9$ Hz), 1.74–1.68 (1H, m), 1.47 (1H, dq, $J = 11.0, 1.8$ Hz); \textsuperscript{13}C NMR (126 MHz, CDCl$_3$) $\delta$ 179.6, 158.1, 135.0, 128.3, 114.1, 68.5, 55.4, 51.3, 45.1, 43.6, 42.4, 35.5, 34.6, 29.0; HRMS (HESI): Found M$^{+}$Na$^{+}$ 279.9174 C$_{16}$H$_{19}$NO$_2$Na requires 279.9175.

6-(4-Fluorophenyl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (31)

Following \textbf{GP4}, 28 (33 mg, 0.1 mmol) gave 31 (78%) as a solid. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2962, 2924, 2362, 1412, 1259, 1024; \textsuperscript{1}H NMR (500 MHz, CDCl$_3$) $\delta$ 7.13 (2H, dd, $J = 8.3, 5.3$ Hz), 7.02 (2H, t, $J = 8.4$ Hz), 3.70 (1H, d, $J = 4.7$ Hz), 3.16–3.01 (1H, m), 2.89 (3H, s), 2.66 (1H, br s), 2.63 (1H, br s), 2.47 (1H, dd, $J = 11.1, 4.5$ Hz), 2.09–1.96 (1H, m), 1.82 (1H, d, $J = 11.0$ Hz), 1.71 (1H, d, $J = 13.0$ Hz), 1.50 (1H, d, $J = 11.0$ Hz); \textsuperscript{13}C NMR (126 MHz, CDCl$_3$) $\delta$ 179.5, 161.4 (d, $J = 245.2$ Hz), 138.6 (d, $J = 3.3$ Hz), 128.7 (d, $J = 7.8$ Hz), 115.5 (d, $J = 21.1$ Hz), 68.5, 51.4, 45.1, 43.5, 42.3, 35.5, 34.6, 29.0; \textsuperscript{19}F NMR (376 MHz, CDCl$_3$): $\delta$ –116.8; HRMS (HESI): Found MH$^+$ 246.1289 C$_{15}$H$_{17}$FNO requires 246.1287.

6-(4-Chlorophenyl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (32)

Following \textbf{GP4} in THF:DMF (9:1, 0.025 M) at 75 °C, 28 (33 mg, 0.1 mmol) gave 32 (73%) as a pale yellow solid. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2962, 1679, 1532,
1494, 1477, 1398, 1317, 1259, 1238, 1219, 1160; $^1$H NMR (500 MHz, CDCl$_3$) δ 7.28 (2H, d, $J = 8.3$ Hz), 7.09 (2H, d, $J = 8.2$ Hz), 3.68 (1H, d, $J = 4.3$ Hz), 3.05 (1H, br s), 2.86 (3H, s), 2.63 (1H, br s), 2.62 (1H, br s), 2.45 (1H, dd, $J = 10.4$, 3.5 Hz), 2.00 (1H, td, $J = 12.9$, 4.1 Hz), 1.79 (1H, d, $J = 10.8$ Hz), 1.69 (1H, d, $J = 13.0$ Hz), 1.48 (1H, d, $J = 11.5$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) δ 179.4, 141.2, 132.1, 128.7, 128.6, 68.3, 51.5, 45.1, 43.3, 42.2, 35.3, 34.5, 29.0; HRMS (HESI): Found MH$^+$ 262.0993 C$_{15}$H$_{17}$NOCl requires 262.0989.

4-(1-Methyl-2-oxooctahydro-3,5-methanocyclopenta[b]pyrrol-6-yl)benzonitrile (33)

Following GP4 in THF:DMF (9:1, 0.025 M) at 75 °C, 28 (33 mg, 0.1 mmol) gave 33 (74%) as a yellow solid. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2961, 2357, 2227, 1695, 1606, 1505, 1479, 1432, 1398, 1319, 1260, 1092, 1066, 1011; $^1$H NMR (500 MHz, CDCl$_3$) δ 7.60 (2H, d, $J = 8.1$ Hz), 7.27 (2H, d, $J = 8.1$ Hz), 3.72 (1H, d, $J = 4.4$ Hz), 3.08 (1H, dt, $J = 4.7$, 2.4 Hz), 2.87 (3H, s), 2.71 (1H, br s), 2.66 (1H, d, $J = 3.2$ Hz), 2.47 (1H, dd, $J = 10.8$, 4.6 Hz), 2.02 (1H, ddd, $J = 12.4$, 11.0, 4.1 Hz), 1.77 (1H, dq, $J = 11.1$, 1.9 Hz), 1.72 (1H, dt, $J = 13.1$, 2.1 Hz), 1.52 (1H, dq, $J = 11.1$, 1.7 Hz); $^{13}$C NMR (CDCl$_3$, 126 MHz) δ 179.2, 148.2, 132.4, 128.1, 118.7, 110.3, 68.0, 52.2, 45.1, 43.1, 42.0, 35.2, 34.5, 29.0; HRMS (HESI): Found MH$^+$ 235.1335 C$_{16}$H$_{16}$N$_2$O requires 235.1333.

6-(2-Methoxyphenyl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (34)

Following GP4 with C2, 28 (33 mg, 0.1 mmol) gave 34 (26%) as an oil. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2959, 2362, 1620, 1598, 1585, 1526, 1435, 1398, 1311, 1165, 1103; $^1$H NMR (500 MHz, CDCl$_3$) δ 7.23 (1H, td, $J = 7.9$, 1.4 Hz), 7.14 (1H, d, $J = 7.5$ Hz), 6.97–6.90 (1H, m), 6.88 (1H, d, $J = 8.2$ Hz), 3.84 (3H, s), 3.60 (1H, d, $J = 4.3$ Hz), 3.04–
2.97 (1H, m), 2.93 (3H, br s), 2.85 (1H, br s), 2.68 (1H, d, J = 3.3 Hz), 2.44 (1H, dd, J = 10.9, 4.5 Hz), 2.00 (1H, ddd, J = 13.0, 10.9, 4.2 Hz), 1.91 (1H, br dq, J = 10.8, 1.8 Hz), 1.72 (1H, dt, J = 13.0, 2.2 Hz), 1.52 (1H, dd, J = 10.8, 1.8 Hz); 13C NMR (126 MHz, CDCl₃) δ 179.8, 157.3, 130.7, 127.5, 126.8, 120.2, 110.3, 68.1, 54.9, 46.5, 45.7, 42.6, 41.7, 35.2, 35.2, 29.4; HRMS (HESI): Found MH⁺ 258.1488 C₁₆H₂₀NO₂ requires 258.1489.

6-(3-Fluorophenyl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (35)

Following GP4, 28 (33 mg, 0.1 mmol) gave 35 (84%) as an off-white solid. [Petrol:EtOAc (20:80)]; FT-IR νmax (film)/cm⁻¹ 2961, 2360, 1684, 1411, 1257, 1016; 1H NMR (500 MHz, CDCl₃) δ 7.30 (1H, td, J = 8.0, 6.2 Hz), 6.98–6.94 (1H, m), 6.94–6.83 (2H, m), 3.72 (1H, dd, J = 5.0, 1.4 Hz), 3.07 (1H, tq, J = 4.8, 1.5 Hz), 2.89 (3H, s), 2.70–2.63 (2H, m), 2.48 (1H, dd, J = 10.9, 4.7 Hz), 2.02 (1H, ddd, J = 13.0, 10.9, 4.1 Hz), 1.83 (1H, br dq, J = 11.0, 1.9 Hz), 1.71 (1H, dt, J = 12.9, 2.1 Hz), 1.51 (1H, dq, J = 11.2, 1.8 Hz); 13C NMR (126 MHz, CDCl₃) δ 179.4, 163.1 (d, J = 246.0 Hz), 145.5 (d, J = 6.8 Hz), 130.2 (d, J = 8.3 Hz), 123.0 (d, J = 2.7 Hz), 114.3 (d, J = 21.6 Hz), 113.3 (d, J = 21.1 Hz), 68.4, 51.9, 45.1, 43.3, 42.2, 35.4, 34.6, 29.02; 19F (376 MHz, CDCl₃) δ –112.7; HRMS (HESI): Found MH⁺ 246.1287 C₁₅H₁₇FNO requires 246.1289.

1-Methyl-6-(3-nitrophenyl)hexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (36)

Following GP4, 28 (33 mg, 0.1 mmol) gave 36 (43%) as a pale yellow solid. [Petrol:EtOAc (20:80)]; FT-IR νmax (film)/cm⁻¹ 2961, 1691, 1524, 1479, 1433, 1347, 1320, 1258, 1082, 1019; 1H NMR (500 MHz, CDCl₃) δ 8.10 (1H, ddd, J = 5.8, 4.1, 2.4 Hz), 8.05 (1H, s), 7.54–7.51 (2H, m), 3.78 (1H, d, J = 4.5 Hz), 3.18–3.09 (1H, m), 2.91 (3H, s), 2.78 (1H, br s), 2.72 (1H, d, J = 3.9 Hz), 2.52 (1H, dd, J = 11.0, 4.7 Hz), 2.07 (1H, ddd, J = 13.1, 10.9, 4.1 Hz), 1.81 (1H, dd, J = 11.3, 1.9 Hz), 1.76 (1H, dt, J = 13.2, 2.3 Hz), 1.57 (1H, dd, J = 11.2, 1.7 Hz); 13C NMR (126 MHz, CDCl₃) δ 179.2, 148.6, 144.9, 133.8, 129.7, 122.0, 121.6, 68.1,
51.8, 45.2, 43.4, 42.1, 35.3, 34.5, 29.1; HRMS (HESI): Found MH+ 273.1230. C15H17N2O3 requires 273.1234.

1-Methyl-6-(naphthalen-2-yl)hexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (37)

Following GP4 with THF:DMF (9:1, 0.025 M) at 75 °C, 28 (33 mg, 0.1 mmol) gave 37 (65%) as a white solid. [Petrol:EtOAc (20:80)]; FT-IR νmax (film)/cm–1 2959, 1696, 1689, 1682, 1674, 1668, 1599, 1529, 1435, 1259, 1019; 1H NMR (500 MHz, CDCl3) δ 7.87–7.77 (3H, m), 7.49 (1H, td, J = 7.0, 1.5 Hz), 7.46 (1H, td, J = 7.0, 1.3 Hz), 7.31 (1H, dd, J = 8.5, 1.9 Hz), 3.89 (1H, d, J = 4.7 Hz), 3.11 (1H, td, J = 4.7, 1.5 Hz), 2.94 (3H, s), 2.84 (1H, br s), 2.78 (1H, br s), 2.51 (1H, dd, J = 10.7, 4.4 Hz), 2.06 (1H, ddd, J = 13.0, 11.0, 4.1 Hz), 1.95 (1H, dd, J = 11.0, 1.9 Hz), 1.78 (1H, d, J = 13.0 Hz), 1.53 (1H, dd, J = 11.0, 1.8 Hz); 13C NMR (126 MHz, CDCl3) δ 179.6, 140.2, 133.4, 132.0, 128.3, 127.8, 127.7, 126.7, 126.5, 125.9, 124.9, 68.0, 52.2, 45.2, 43.5, 42.4, 35.5, 34.6, 29.1; HRMS (HESI): Found MH+ 278.1539. C19H20NO2 requires 278.1535.

6-(Dibenzo[b,d]furan-4-yl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (38)

Following GP4, 28 (33 mg, 0.1 mmol) gave 38 (27%) as a yellow solid. [Petrol:EtOAc (20:80)]; FT-IR νmax (film)/cm–1 2959, 1682, 1475, 1451, 1184, 1020; 1H NMR (500 MHz, CDCl3) δ 7.96 (1H, d, J = 7.4 Hz), 7.87–7.82 (1H, m), 7.57 (1H, d, J = 8.2 Hz), 7.53–7.44 (1H, m), 7.41–7.34 (1H, m), 7.31 (1H, t, J = 7.6 Hz), 7.26 (1H, d, J = 7.4 Hz), 3.92 (1H, d, J = 4.4 Hz), 3.22 (1H, br s), 3.13 (3H, s), 3.11–3.08 (1H, m), 2.88 (1H, d, J = 3.7 Hz), 2.53 (1H, dd, J = 10.6, 4.4 Hz), 2.09 (1H, ddd, J = 13.1, 10.9, 4.1 Hz), 2.01 (1H, ddd, J = 10.7, 2.1 Hz), 1.87 (1H, dt, J = 13.1, 2.1 Hz), 1.62–1.58 (1H, m); 13C NMR (126 MHz, CDCl3) δ 179.8, 156.0, 154.3, 127.4, 126.9, 124.4, 124.4, 124.3, 123.0, 122.8, 120.9, 119.0, 111.7,
67.7, 46.9, 45.5, 42.4, 42.0, 35.3, 35.2, 29.4; HRMS (HESI): Found MH$^+$ 318.1479 C$_{21}$H$_{20}$NO$_2$ requires 318.1489.

6-(2-Methoxypyridin-4-yl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (39)

Following GP4 with THF:DMF (9:1, 0.025 M) at 75 ºC, 28 (33 mg, 0.1 mmol) gave 39 (60%) as a solid. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 2974, 2876, 2360, 1695, 1607, 1553, 1480, 1447, 1393, 1318, 1241, 1217, 1187, 1154, 1046; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 8.10 (1H, d, $J$ = 5.4 Hz), 6.69 (1H, dd, $J$ = 5.4, 1.2 Hz), 6.53 (1H, s), 3.93 (3H, s), 3.70 (1H, d, $J$ = 4.4 Hz), 3.14–2.99 (1H, m), 2.88 (3H, s), 2.67 (1H, d, $J$ = 3.2 Hz), 2.59 (1H, br s), 2.47 (1H, dd, $J$ = 10.8, 4.5 Hz), 2.02 (1H, ddd, $J$ = 13.1, 10.9, 4.3 Hz), 1.78 (1H, dq, $J$ = 11.1, 1.9 Hz), 1.71 (1H, dt, $J$ = 13.1, 2.1 Hz), 1.51 (1H, dq, $J$ = 11.2, 1.8 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 179.2, 164.6, 154.2, 147.0, 116.2, 109.1, 67.6, 53.4, 51.3, 44.9, 42.6, 42.0, 35.2, 34.6, 28.8; HRMS (HESI): Found MNa$^+$ 281.1258 C$_{15}$H$_{18}$N$_2$O$_2$Na requires 281.1260.

6-(6-Fluoropyridin-3-yl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (40)

Following GP4 with MTBE:DMF (9:1, 0.025 M) at 75 ºC, 28 (33 mg, 0.1 mmol) gave 40 (67%) as a yellow oil. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{max}$ (film)/cm$^{-1}$ 2962, 2361, 2353, 2342, 2339, 1694, 1593, 1485, 1435, 1398, 1257; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 8.03 (1H, s), 7.58 (1H, td, $J$ = 8.1, 2.5 Hz), 6.90 (1H, dd, $J$ = 8.5, 3.0 Hz), 3.69 (1H, d, $J$ = 4.7 Hz), 3.10 (1H, t, $J$ = 4.1 Hz), 2.87 (3H, s), 2.68 (1H, br s), 2.64 (1H, br s), 2.48 (1H, dd, $J$ = 10.7, 4.4 Hz), 2.03 (1H, ddd, $J$ = 13.1, 11.1, 4.1 Hz), 1.78 (1H, d, $J$ = 11.2 Hz), 1.73 (1H, d, $J$ = 13.1 Hz), 1.54 (1H, d, $J$ = 11.3 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 179.2, 162.4 (d, $J$ = 238.7 Hz), 146.3 (d, $J$ = 14.5 Hz), 140.1 (d, $J$ = 7.9 Hz), 135.8 (d, $J$ = 4.6 Hz), 109.5 (d, $J$ = 37.4
Hz), 68.1, 49.4, 45.2, 43.3, 42.0, 35.3, 34.4, 29.0; $^{19}$F NMR (376 MHz, CDCl$_3$) δ –71.20; HRMS (HESI): Found MH$^+$ 247.1241 C$_{14}$H$_{16}$N$_2$OF requires 247.1242.

6-(6-Chloropyridin-3-yl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (41)

Following GP4, 28 (33 mg, 0.1 mmol) gave 41 (32%) as a yellow oil. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2961, 2361, 2339, 2330, 1260, 1088, 1026; $^1$H NMR (500 MHz, CDCl$_3$) δ 8.18 (1H, d, $J = 2.5$ Hz), 7.41 (1H, dd, $J = 8.3$, 2.5 Hz), 7.23 (1H, d, $J = 6.3$ Hz), 3.65 (1H, dd, $J = 4.7$ Hz), 3.06 (1H, td, $J = 4.8$, 1.3 Hz), 2.82 (3H, s), 2.63 (1H, br s), 2.61–2.58 (1H, m), 2.44 (1H, dd, $J = 10.8$, 4.5 Hz), 1.99 (1H, ddd, $J = 13.0$, 10.9, 4.1 Hz), 1.70 (2H, br t, $J = 13.0$ Hz), 1.50 (1H, d, $J = 11.1$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) δ 179.1, 149.6, 148.8, 137.7, 137.1, 124.2, 67.9, 49.5, 45.1, 43.2, 41.9, 35.2, 34.4, 29.0; HRMS (HESI): Found MH$^+$ 263.0942 C$_{14}$H$_{16}$N$_2$OCl requires 263.0946.

1-Methyl-6-(quinolin-3-yl)hexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (42)

Following GP4, 28 (33 mg, 0.1 mmol) gave 42 (77%) as a yellow oil. [Petrol:EtOAc (20:80)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2963, 2370, 2366, 2355, 2340, 1649, 1259, 1022; $^1$H NMR (500 MHz, CDCl$_3$) δ 8.80 (1H, s), 8.09 (1H, d, $J = 8.4$ Hz), 7.86 (1H, s), 7.80 (1H, d, $J = 8.1$ Hz), 7.70 (1H, ddd, $J = 8.4$, 6.8, 1.5 Hz), 7.57 (1H, t, $J = 7.4$ Hz), 3.88 (1H, d, $J = 5.3$ Hz), 3.21–3.12 (1H, m), 2.93 (3H, s), 2.89 (1H, br s), 2.78 (1H, d, $J = 4.0$ Hz), 2.53 (1H, dd, $J = 5.1$, 4.5 Hz), 2.09 (1H, ddd, $J = 13.1$, 10.9, 4.1 Hz), 1.90 (1H, d, $J = 10.9$ Hz), 1.82 (1H, d, $J = 13.1$ Hz), 1.57 (1H, d, $J = 12.2$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) δ 179.2, 151.4, 146.8, 135.2, 132.5, 129.2, 129.2, 127.6, 127.5, 127.1, 67.6, 49.9, 45.2, 43.1, 42.0, 35.2, 34.3, 29.0; HRMS (HESI): Found MH$^+$ 279.1484 C$_{18}$H$_{19}$N$_2$O requires 279.1492.
1-Methyl-6-(thiophen-3-yl)hexahydro-3,5-methanocyclopenta[b]pyrrolo[2(1H)]one (43)

Following GP4 with THF:DMF (9:1, 0.025 M) at 75 °C, 28 (33 mg, 0.1 mmol) gave 43 (60%) as a yellow oil. [Petrol:EtOAc (20:80)]; FT-IR ν_{max} (film)/cm\(^{-1}\) 2360, 1694, 1477, 1432, 1398, 1260, 1240, 1093, 1066, 1019; \(^1\)H NMR (500 MHz, CDCl\(_3\)) δ 7.30 (1H, dd, J = 4.9, 2.9 Hz), 6.94–6.92 (1H, m), 6.91 (1H, dd, J = 3.2, 1.7 Hz), 3.67 (1H, d, J = 4.7 Hz), 3.02 (1H, dt, J = 4.7, 2.4 Hz), 2.86 (3H, s), 2.66 (1H, br s), 2.62 (1H, br s), 2.42 (1H, br s), 1.97 (1H, ddd, J = 13.0, 10.9, 4.1 Hz), 1.86–1.77 (1H, m), 1.67 (1H, d, J = 13.0 Hz), 1.49–1.43 (1H, m); \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) δ 179.4, 143.9, 127.4, 126.1, 119.5, 68.2, 48.2, 44.8, 43.6, 42.1, 35.1, 34.7, 28.9; HRMS (HESI): Found MH\(^+\) 234.0947 C\(_{13}\)H\(_{16}\)NOS requires 234.0947.

1-Methyl-6-(thiophen-2-yl)hexahydro-3,5-methanocyclopenta[b]pyrrolo[2(1H)]one (44)

Following GP3 with 10 mol% of C2 and for 1h, 28 (33 mg, 0.1 mmol) gave 44 (64%) as a yellow oil. [Petrol:EtOAc (50:50)]; FT-IR ν_{max} (film)/cm\(^{-1}\) 2957, 1691, 1532, 1475, 1432, 1397, 1238, 1065, 1092, 1017 cm\(^{-1}\); \(^1\)H NMR (500 MHz, CDCl\(_3\)) δ 7.16 (1H, d, J = 5.0 Hz), 6.97–6.91 (1H, m), 6.78 (1H, d, J = 3.2 Hz), 3.71 (1H, d, J = 4.5 Hz), 3.11–2.93 (1H, m), 2.86 (3H, s), 2.83 (1H, br s), 2.65 (1H, br s), 2.45 (1H, dd, J = 10.6, 4.1 Hz), 1.97 (1H, ddd, J = 13.0, 10.9, 4.1 Hz), 1.90 (1H, d, J = 10.9 Hz), 1.68 (1H, d, J = 13.1 Hz), 1.51 (1H, d, J = 10.9 Hz); \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) δ 179.4, 143.7, 127.0, 123.6, 123.3, 69.5, 48.1, 44.9, 44.7, 41.9, 35.0, 34.9, 29.0; HRMS (HESI): Found MH\(^+\) 234.0947 C\(_{13}\)H\(_{16}\)NOS requires 234.0947.
1-Methyl-6-(1-methyl-1H-indol-5-yl)hexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (45)

Following **GP4** 75 °C, 28 (33 mg, 0.1 mmol) gave 45 (23%) as a yellow oil. [Petrol:EtOAc (20:80)]; FT-IR ν max (film)/cm⁻¹ 2959, 2923, 2854, 1727, 1691, 1512, 1480, 1444, 1431, 1394, 1328, 1318, 1261, 1248, 1241, 1118, 1087, 1069, 1019; ¹H NMR (500 MHz, CDCl₃) δ 7.40 (1H, br s), 7.30 (1H, d, J = 8.5 Hz), 7.09–7.02 (2H, m), 6.45 (1H, d, J = 2.9 Hz), 3.85 (1H, d, J = 4.7 Hz), 3.79 (3H, s), 3.07 (1H, t, J = 4.2 Hz), 2.91 (3H, s), 2.81 (1H, br s), 2.70 (1H, d, J = 3.9 Hz), 2.48 (1H, dd, J = 10.8, 4.6 Hz), 2.08–1.92 (2H, m), 1.74 (1H, dt, J = 13.1, 2.1 Hz), 1.48 (1H, d, J = 10.9 Hz); ¹³C NMR (126 MHz, CDCl₃) δ 179.7, 135.4, 133.9, 129.5, 128.6, 121.8, 118.6, 109.5, 100.9, 68.7, 52.1, 45.2, 44.0, 42.5, 35.7, 34.6, 33.0, 29.1; HRMS (HESI): Found M 280.1304 C₁₈H₂₀N₂O requires 280.1376.

5-Benzyl-1-methylpyrrolidin-2-one (46)

Following **GP6** with MTBE:DMF (9:1, 0.025 M) at 75 °C, S13 (29 mg, 0.1 mmol) gave 46 (73%) as a pale yellow oil. [Petrol:EtOAc (20:80)]; FT-IR ν max (film)/cm⁻¹ 2925, 1683, 1453, 1423, 1399, 1308, 1253, 1113; ¹H NMR (400 MHz, CDCl₃) δ 7.35–7.27 (2H, m), 7.26–7.21 (1H, m), 7.18–7.10 (2H, m), 3.74 (1H, hept, J = 4.3 Hz), 3.02 (1H, dd, J = 13.5, 4.4 Hz), 2.87 (3H, s), 2.63 (1H, dd, J = 13.5, 8.2 Hz), 2.24–2.07 (2H, m), 1.98 (1H, ddt, J = 13.0, 9.9, 7.6 Hz), 1.73 (1H, dddd, J = 13.2, 9.1, 5.9, 4.2 Hz); ¹³C NMR (100 MHz, CDCl₃) δ 175.3, 137.0, 129.3, 128.7, 126.8, 61.2, 39.5, 29.8, 28.3, 23.6. HRMS (HESI): Found MNa⁺ 212.1043 C₁₂H₁₅NONa requires 212.1046.
5-Benzyl-1-phenethylpyrrolidin-2-one (47)

Following GP4 with C2 in MTBE:DMF (9:1, 0.025 M) at 70 °C, S14 (39 mg, 0.1 mmol) gave 47 (20.5 mg, 76%) as an oil. [Petrol:EtOAc (50:50)]; FT-IR νₘₐₓ (film)/cm⁻¹ 2924, 1679, 1496, 1453, 1418, 1367, 1270, 1154, 1030; ¹H NMR (400 MHz, CDCl₃) δ 7.39–7.23 (8H, m), 7.12 (2H, d, J = 7.1 Hz), 4.04 (1H, dt, J = 13.9, 7.1 Hz), 3.69–3.59 (1H, m), 3.20 (1H, dt, J = 14.3, 7.4 Hz), 3.02–2.81 (3H, m), 2.57 (1H, dd, J = 13.1, 8.6 Hz), 2.28–2.13 (2H, m), 1.98–1.81 (1H, m), 1.78–1.67 (1H, m); ¹³C NMR (100 MHz, CDCl₃) δ 175.2, 139.1, 137.1, 129.3, 128.9, 128.7, 128.7, 126.9, 126.6, 59.2, 42.3, 39.5, 34.2, 29.9, 24.0.; HRMS (APCI): Found MH⁺ 280.1703 C₁₉H₂₂NO requires 280.1696.

tert-Butyl 8-benzyl-7-methyl-6-oxo-1,7-diazaspiro[4.4]nonane-1-carboxylate (48)

Following GP4 with C2 in MTBE:DMF (9:1, 0.025 M) at 70 °C, S15 (59 mg, 0.13 mmol) gave 48 (26 mg, 58%) as an amorphous solid. d.r 2.5:1 [Petrol:EtOAc (10:90)]; FT-IR νₘₐₓ (film)/cm⁻¹ 2924, 1686, 1479, 1447, 1390, 1360, 1281, 1168, 1144, 1089; ¹H NMR (500 MHz, CDCl₃, diastereomers and rotamers) δ 7.37–7.25 (2.4H, m), 7.25–7.23 (0.5H, m), 7.21 (0.6H, d, J = 7.6 Hz), 7.17 (0.9H, d, J = 7.4 Hz), 7.13 (0.6H, d, J = 7.3 Hz), 3.94 (0.1H, tt, J = 8.3, 3.8 Hz), 3.74 (0.2H, dq, J = 9.5, 3.8 Hz), 3.57 – 3.40 (2.7H, m), 3.33 (0.9H, td, J = 12.9, 4.5 Hz), 3.01 (0.3H, ddd, J = 25.2, 13.8, 4.5 Hz), 2.95 (0.4H, s), 2.93 (0.7H, s), 2.93 (0.6H, s), 2.91 (1.3H, s), 2.70 (0.3H, t, J = 11.4 Hz), 2.68–2.59 (0.2H, m), 2.55 – 2.44 (0.6H, m), 2.39 (0.2H, dd, J = 13.5, 9.7 Hz), 2.26 (0.3H, dd, J = 12.5, 8.6 Hz), 2.06 (0.5H, dd, J = 12.5, 9.2 Hz), 2.05–1.95 (1H, m), 1.94–1.84 (1H, m), 1.79–1.63 (3.5H, m), 1.46 (6.5H, s), 1.40 (1H, d, J = 1.5 Hz, s); ¹³C NMR (126 MHz, CDCl₃, diastereomers and rotamers) δ 175.2M & 175.1M, 175.1m & 175.0m, 153.5M & 153.3m, 153.5m & 153.3M, 137.6M & 136.8M, 137.2m & 136.9m, 129.6m & 129.6m, 129.3M & 129.2M, 128.9M & 128.7M, 128.7m & 128.7m, 127.1m & 126.8m, 127.0M & 126.7M, 80.4M, 79.6M, 79.8m & 79.6m, 66.8M & 66.8M, 66.2m & 66.1m, 57.9m & 57.9m, 57.5M & 57.1M, 47.9M & 47.6M, 47.8m & 47.5m, 40.7M & 40.1M, 40.2m &
39.8 m, 39.7 m & 39.5 m, 38.5 M & 37.1 M, 36.8 M & 36.5 M, 36.3 m & 35.9 m, 29.8 M & 28.8 M, 29.2 m & 28.6 m, 28.7 M & 28.5 m, 23.7 m & 23.1 m, 23.5 M & 22.7 M.; HRMS (APCI): Found MH⁺ 345.2166 C₂₀H₂₉O₃N₂ requires 345.2173.

1-(1,1-Dioxidotetrahydrothiophen-3-yl)-5-methylpyrrolidin-2-one (49)

Following GP4 with C2 in MTBE:DMF (9:1, 0.025 M) at 70 °C, S16 (34 mg, 0.10 mmol) gave 49 (96%) as an oil. dr 4:1. [Petrol:EtOAc (50:50)]; FT-IR νmax (film)/cm⁻¹ 2936, 1687, 1601, 1456, 1395, 1284, 1263, 1236, 1108, 1083; ¹H NMR (400 MHz, CDCl₃, diastereomers) δ 7.33–7.23 (3.5H, m), 7.22–7.14 (1.5H, m), 3.76 (0.2H, d, J = 5.9 Hz), 3.61 (0.8H, br s), 3.24 (0.8H, br s), 2.95–2.91 (2.4H, m), 2.76 (0.2H, d, J = 4.2 Hz), 2.47 (0.2H, s (br)), 2.44 (1.2H, s, (br)), 2.33–1.93 (2H, m), 1.92–1.68 (4H, m), 1.63–1.47 (1.2H, m), 1.19–1.06 (0.7H, m), 0.84 (0.7H, dq, J = 12.6, 7.1 Hz); ¹³C NMR (101 MHz, CDCl₃, diastereomers) δ 177.8 M & 176.1 m, 143.3 m & 142.6 M, 128.8 M & 128.7 m, 127.8 M & 127.2 m, 126.7 m & 126.4 M, 65.2 m & 63.7 M, 43.3 m & 40.7 M, 39.3 m & 37.1 M, 30.7 M & 29.8 m, 27.7 M & 25.5 m, 24.2 M & 23.0 m, 21.8 M & 20.9 m.; HRMS (APCI): Found MH⁺ 229.1470 C₁₅H₁₉NO requires 229.1467.

4-Benzyl-3-cyclohexyloxazolidin-2-one (50)

Following GP4 with C2 in MTBE:DMF (9:1, 0.025 M) at 70 °C, S17 (37 mg, 0.1 mmol) gave 50 (19 mg, 73%) as an oil. [Petrol:EtOAc (75:25)]; FT-IR νmax (film)/cm⁻¹ 2931, 2855, 1742, 1496, 1447, 1423, 1288, 1081; ¹H NMR (500 MHz, CDCl₃) δ 7.33 (2H, t, J = 7.3 Hz), 7.30–7.23 (1H, m), 7.17 (2H, d, J = 6.8 Hz), 4.06–3.95 (3H, m), 3.55–3.47 (1H, m), 3.23 (1H, dd, J = 13.5, 3.2 Hz), 2.70–2.62 (1H, m), 2.04–1.95 (1H, m), 1.92–1.75 (4H, m), 1.72–1.65 (1H, m), 1.62 (1H, td, J = 12.7, 3.7 Hz), 1.41–1.28 (2H, m), 1.19 (1H, tt, J = 13.1, 3.5 Hz); ¹³C NMR (101 MHz, CDCl₃) δ 157.8, 136.0, 129.2, 129.1, 127.3, 66.8, 56.0, 54.5, 40.9, 32.0, 30.6, 26.1, 26.0, 25.5; HRMS (ESI): Found MH⁺ 260.1642 C₁₆H₂₂O₂N: requires 260.1645.
4-Benzyl-3-methylthiazolidin-2-one (51)

Following \( \text{GP4} \) with \( \text{C2} \) in DCE:DMF (9:1, 0.025 M) at 70 °C, \( \text{S18} \) (31 mg, 0.10 mmol) gave \( \text{S18} \) (10 mg, 48%) as an oil. [Petrol:EtOAc (50:50)]; FT-IR \( \nu_{\text{max}} \) (film)/cm\(^{-1}\) 2924, 1665, 1604, 1527, 1497, 1454, 1418, 1386, 1343, 1285, 12227, 1069; \(^1\)H NMR (500 MHz, CDCl\(_3\)) \( \delta \) 7.36–7.27 (3H, m), 7.20 (2H, d, \( J = 7.4 \) Hz), 3.92–3.85 (1H, m), 3.23 (1H, dd, \( J = 11.3, 7.4 \) Hz), 3.15 (1H, dd, \( J = 13.5, 4.5 \) Hz), 2.95 (1H, dd, \( J = 11.2, 4.1 \) Hz), 2.93 (3H, s), 2.81 (1H, dd, \( J = 13.5, 9.6 \) Hz); \(^{13}\)C NMR (126 MHz, CDCl\(_3\)) \( \delta \) 171.7, 136.4, 129.4, 129.1, 127.3, 62.7, 37.6, 30.8, 30.3; HRMS (ESI): Found M\(^+\) 207.0715 \( \text{C}_{11}\text{H}_{13}\text{NOS} \) requires 207.0718.

tert-Butyl 2-Benzylpyrrolidine-1-carboxylate (53)

Following \( \text{GP4} \) with MTBE:DMF (9:1, 0.025 M), \( \text{S18} \) (37 mg, 0.1 mmol) gave \( \text{S18} \) (73%) as a pale yellow oil. [Petrol:CH\(_2\)Cl\(_2\) (20:80)]; FT-IR \( \nu_{\text{max}} \) (film)/cm\(^{-1}\) 2962, 1697, 1392, 1257, 1015; \(^1\)H NMR (500 MHz, CDCl\(_3\), rotamers) \( \delta \) 7.33–7.23 (2H, m), 7.25–7.13 (3H, m), 4.03 (0.4H, br s), 3.95 (0.6H, br s), 3.36 (1.2H, br s), 3.28 (0.8H, s), 3.16 (0.4H, d, 12.9 Hz), 3.05 (0.6H, d, 12.1 Hz), 2.62–2.46 (1H, m), 1.82–1.61 (4H, m), 1.51 (9H, s); \(^{13}\)C NMR (126 MHz, CDCl\(_3\), rotamers) \( \delta \) 154.7, 139.3, 129.7 \& 129.5, 128.5 \& 128.4, 126.3 \& 126.2, 79.4 \& 79.2, 59.0 \& 58.8, 47.0 \& 46.4, 40.7 \& 39.7, 29.9 \& 29.8, 28.8, 22.8; HRMS (HESI): Found MH\(^+\) 262.1800 \( \text{C}_{16}\text{H}_{24}\text{NO}_2 \) requires 262.1802. Data in accordance with the literature\(^{30}\).

tert-Butyl 2-(4-Methoxybenzyl)pyrrolidine-1-carboxylate (54)

Following \( \text{GP4} \) with MTBE:DMF (9:1, 0.025 M), \( \text{S18} \) (37 mg, 0.1 mmol) gave \( \text{S18} \) (61%) as a pale yellow oil. [Petrol:CH\(_2\)Cl\(_2\) (20:80)]; FT-IR \( \nu_{\text{max}} \) (film)/cm\(^{-1}\) 2962, 1695, 1512, 1393, 1258, 1172, 1016; \(^1\)H NMR (500 MHz, CDCl\(_3\), rotamers) \( \delta \) 7.16–6.98 (2H, m), 6.83 (2H, d,
$J = 7.9$ Hz), 3.99 (0.4H, br s), 3.90 (0.6H, s), 3.78 (3H, s), 3.35 (1.2H, br s), 3.27 (0.8H, br s), 3.07 (0.4H, d, $J = 12.1$ Hz), 2.97 (0.6H, d, $J = 12.3$ Hz), 2.51 (1H, m), 1.78 – 1.69 (4H, m), 1.51 (9H, s); $^{13}$C NMR (126 MHz, CDCl$_3$, rotamers) δ 158.2, 154.7, 131.4, 130.6 & 130.4, 113.9 & 113.8, 79.3 & 79.1, 59.1 & 58.9, 55.4, 46.9 & 46.5, 39.7 & 38.73, 29.7, 28.8, 23.6 & 22.8; HRMS (HESI): Found M$^+$ 292.1905 C$_{17}$H$_{26}$NO$_3$ requires 292.1907. Data in accordance with the literature.$^{31}$

**tert-Butyl 2-Benzylpyrrolidine-1-carboxylate (55)**

Following GP4 with MTBE:DMF (9:1, 0.025 M), 52 (37 mg, 0.1 mmol) gave 55 (75%) as a pale yellow oil. [Petrol:CH$_2$Cl$_2$ (20:80)]; FT-IR $v_{\text{max}}$ (film)/cm$^{-1}$ 2961, 1674, 1410, 1258, 1016; $^1$H NMR (500 MHz, CDCl$_3$, rotamers) δ 7.24 (2H, s), 7.11 (2H, dd, $J = 20.7$, 8.1 Hz), 4.00 (0.5H, br s), 3.91 (0.5H, br s), 3.35 (1H, br s), 3.27 (1H, br s), 3.10 (0.5H, d, $J = 13.3$ Hz), 2.99 (0.5H, d, $J = 13.1$ Hz), 2.54 (1H, dt, $J = 21.8$, 11.7 Hz), 1.70 (4H, m), 1.49 (9H, s); $^{13}$C NMR (126 MHz, CDCl$_3$, rotamers) δ 154.6, 137.8, 132.2 & 132.0, 131.0 & 130.8, 128.7 & 128.5, 79.6 & 79.2, 58.8 & 58.6, 47.0 & 46.5, 40.1 & 39.1, 29.9, 28.7, 22.8. HRMS (HESI): Found M+H-tBu 240.0780 C$_{12}$H$_{15}$NO$_2$Cl requires 240.0786.

**tert-Butyl 2-(4-Cyanobenzyl)pyrrolidine-1-carboxylate (56)**

Following GP4 with MTBE:DMF (9:1, 0.025 M), 52 (37 mg, 0.1 mmol) gave 56 (73%) as a pale yellow oil. [Petrol:CH$_2$Cl$_2$ (20:80)]; FT-IR $v_{\text{max}}$ (film)/cm$^{-1}$ 2970, 2931, 2873, 2227, 1725, 1689, 1608, 1454, 1392, 1365, 1342, 1256, 1169, 1109; $^1$H NMR (500 MHz, CDCl$_3$, rotamers) δ 7.56 (2H, s), 7.37 – 7.21 (2H, m), 4.02 (0.5H, br s), 3.95 (0.5H, br s), 3.43–3.21 (2H, m), 3.18 (0.5H, d, $J = 14.0$ Hz), 3.06 (0.5H, d, $J = 11.3$ Hz), 2.64 (1H, p, $J = 10.7$ Hz), 1.90–1.66 (3H, m), 1.64–1.56 (1H, m), 1.47 (9H, s); $^{13}$C NMR (126 MHz, CDCl$_3$, rotamers) δ 154.7 & 154.4, 145.0, 132.3 & 132.2, 130.4 & 130.3, 119.0, 110.3 & 110.2, 79.7 & 79.4, 58.5 & 58.4, 47.0 & 46.4, 41.0 & 40.0, 30.0 & 29.2, 28.7, 23.6 & 22.8; HRMS (HESI):
Found $\text{MNa}^+ 309.1568\text{ C}_{17}\text{H}_{22}\text{N}_2\text{O}_2\text{Na}$ requires 309.1573. Data in accordance with the literature.\textsuperscript{32}

**tert-Butyl 2-(Quinolin-3-ylmethyl)pyrrolidine-1-carboxylate (57)**

Following GP4 with MTBE:DMF (9:1, 0.025 M), $\textbf{52}$ (37 mg, 0.1 mmol) gave $\textbf{57}$ (55%) as a pale yellow oil. [CH\textsubscript{2}Cl\textsubscript{2}:Et\textsubscript{2}O (95:5)]; FT-IR $\nu_{\text{max}}$ (film)/cm\textsuperscript{-1} 2959, 2927, 2874, 1725, 1691, 1494, 1391, 1365, 1259, 1168, 1116, 1089, 1071; $^1$H NMR (500 MHz, CDCl\textsubscript{3}, rotamers) $\delta$ 8.77 (1H, d, $J = 2.1$ Hz), 8.07 (1H, d, $J = 8.4$ Hz), 8.02–7.84 (1H, m), 7.76 (1H, d, $J = 8.1$ Hz), 7.66 (1H, t, $J = 7.8$ Hz), 7.52 (1H, t, $J = 7.6$ Hz), 4.13 (0.5H, br s), 4.05 (0.5H, br s), 3.51–3.14 (3H, m), 2.97–2.85 (0.5H, m), 2.81–2.70 (0.5H, m), 1.93–1.55 (4H, m), 1.48 (9H, s); $^{13}$C NMR (126 MHz, CDCl\textsubscript{3}, rotamers) $\delta$ 154.8 & 154.6, 152.5 & 152.3, 147.1, 136.0 & 135.6, 132.0, 129.3, 129.0 & 128.9, 128.2, 127.5, 126.8 & 126.7, 79.8 & 79.4, 58.7 & 58.4, 47.0 & 46.5, 38.3 & 36.9, 30.1 & 29.2, 28.7, 23.7 & 22.9; HRMS (HESI): Found M$\text{Na}^+$ 335.1726 C\textsubscript{19}H\textsubscript{24}N\textsubscript{2}O\textsubscript{2}Na requires 335.1730.

**tert-Butyl 2-((1-methyl-1H-indol-5-yl)methyl)pyrrolidine-1-carboxylate (58)**

Following GP4, $\textbf{52}$ (37 mg, 0.1 mmol) gave $\textbf{58}$ (28%) as a pale yellow oil. [Petrol:CH\textsubscript{2}Cl\textsubscript{2} (5:95)]; FT-IR $\nu_{\text{max}}$ (film)/cm\textsuperscript{-1} 2957, 2929, 2870, 2857, 1726, 1696, 1393, 1271, 1119; $^1$H NMR (500 MHz, CDCl\textsubscript{3}, rotamers) $\delta$ 7.54–7.36 (1H, m), 7.25 (1H, d, $J = 9.1$ Hz), 7.18–6.94 (2H, m), 6.42 (1H, s, 1H), 4.08 (0.4H, br s), 3.98 (0.6H, br s), 3.47–3.10 (3H, m), 2.68–2.53 (1H, m), 1.75 (4H, br s), 1.55 & 1.52 (9H, s); $^{13}$C NMR (126 MHz, CDCl\textsubscript{3}, rotamers) $\delta$ 154.8, 135.7, 130.1 & 129.1, 128.9 & 128.7, 123.7 & 123.3, 121.5 & 121.3, 109.2 & 109.0, 100.6, 79.3 & 79.0, 59.7 & 59.6, 47.0 & 46.5, 40.6, 38.3, 33.0 & 31.4, 29.8 & 29.6, 28.8, 23.5 & 22.8; HRMS (HESI): Found M$\text{Na}^+$ 337.1883 C\textsubscript{19}H\textsubscript{26}N\textsubscript{2}O\textsubscript{2}Na requires 337.1886.
tert-Butyl 2-(Benzo[b]thiophen-2-ylmethyl)pyrrolidine-1-carboxylate (59)

Following GP4, 52 (37 mg, 0.1 mmol) gave 59 (30%) as a pale yellow oil. [Petrol:CH₂Cl₂ (10:90)]; FT-IR ν<sub>max</sub> (film)/cm⁻¹ 2962, 1698, 1259, 1094, 1081, 1072, 1059, 1037, 1023; ¹H NMR (500 MHz, CDCl₃, rotamers) δ 7.77 (1H, d, J = 7.9 Hz), 7.68 (1H, d, J = 7.7 Hz), 7.36–7.22 (2H, m), 7.03 (1H, d, J = 10.7 Hz), 4.14 (0.4H, br s), 4.05 (0.6H, br s), 3.47–3.19 (3H, m), 3.12–3.03 (0.4H, m), 3.01–2.92 (0.6H, m), 1.84–1.67 (3H, m), 1.58 (1.5H, s), 1.52 (7.5H, s); ¹³C NMR (126 MHz, CDCl₃, rotamers) δ 154.6, 142.4, 140.1 & 140.0, 124.3 & 124.1, 123.8 & 123.6, 122.9, 122.5 & 122.3, 122.2, 79.7 & 79.4, 58.5 & 58.1, 47.2 & 46.7, 35.8 & 34.6, 30.4 & 29.6, 28.8, 23.7 & 23.0; HRMS (HESI): Found MNa⁺ 340.1338 C<sub>18</sub>H<sub>23</sub>NO₂SNa requires 340.1342.

1,6-Dimethylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (60)

Following GP3, 28 (35 mg, 0.1 mmol) gave 60 (88%) as a pale yellow oil. [Et₂O:EtOAc (95:5)]; FT-IR ν<sub>max</sub> (film)/cm⁻¹ 2958, 1694, 1683, 1455, 1429, 1396, 1261, 1239, 1063, 1009; ¹H NMR (500 MHz, CDCl₃) δ 3.01 (1H, d, J = 4.7 Hz), 2.90 (1H, t, J = 4.0 Hz), 2.77 (3H, s), 2.33 (1H, dd, J = 10.7, 4.2 Hz), 2.09 (1H, br s), 1.84 (1H, ddd, J = 12.8, 10.9, 4.0 Hz), 1.74 (1H, d, J = 12.3 Hz), 1.55–1.44 (2H, m), 1.38 (1H, d, J = 10.9 Hz), 0.91 (3H, d, J = 7.4 Hz); ¹³C NMR (126 MHz, CDCl₃) δ 179.9, 68.8, 44.8, 43.9, 41.9, 41.5, 35.4, 33.7, 28.9, 19.2; HRMS (HESI): Found MH⁺ 166.1227 C<sub>10</sub>H<sub>16</sub>NO requires 166.1226.

6-Ethyl-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (61)

Following GP3, 28 (35 mg, 0.1 mmol) gave 61 (60%) as a pale yellow oil. [Et₂O:EtOAc (95:5)]; FT-IR ν<sub>max</sub> (film)/cm⁻¹ 2960, 2873, 2363, 1699, 1456, 1429, 1397, 1259, 1237, 1221,
1062, 1010; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 3.06 (1H, d, $J$ = 4.8 Hz), 2.93–2.86 (1H, m), 2.75 (3H, s), 2.35 (1H, dd, $J$ = 10.8, 4.5 Hz), 2.20 (1H, br s), 1.85 (1H, ddd, $J$ = 12.8, 10.8, 4.0 Hz), 1.68 (1H, dd, $J$ = 10.9, 1.9 Hz), 1.48 (1H, dt, $J$ = 12.8, 2.1 Hz), 1.37 (1H, d, $J$ = 10.9 Hz), 1.34–1.07 (3H, m), 0.91 (3H, t, $J$ = 7.1 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 179.6, 66.8, 49.7, 44.8, 42.4, 42.2, 35.6, 34.2, 28.6, 25.7, 11.8; HRMS (HESI): Found MH$^+$ 180.1383 C$_{11}$H$_{18}$NO requires 180.1383.

6-Isopentyl-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (62)

Following GP3, 28 (35 mg, 0.1 mmol) gave 62 (56%) as a pale yellow oil. [Et$_2$O:EtOAc (95:5)]; FT-IR $v_{\text{max}}$ (film)/cm$^{-1}$ 2957, 1703, 1427, 1396, 1258, 1017; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 3.05 (1H, d, $J$ = 4.8 Hz), 2.89 (1H, tq, $J$ = 4.7, 1.5 Hz), 2.75 (3H, s), 2.34 (1H, dd, $J$ = 10.8, 4.6 Hz), 2.18 (1H, d, $J$ = 3.0 Hz), 1.84 (1H, ddd, $J$ = 12.8, 10.9, 4.0 Hz), 1.69 (1H, dq, $J$ = 10.8, 1.9 Hz), 1.54–1.43 (2H, m), 1.37 (1H, dd, $J$ = 10.9, 1.7 Hz), 1.25–1.06 (5H, m), 0.86 (3H, d, $J$ = 6.6 Hz), 0.85 (3H, d, $J$ = 6.6 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 179.6, 67.3, 48.0, 44.8, 42.7, 42.2, 36.6, 35.6, 34.2, 30.8, 28.7, 28.1, 22.7; HRMS (HESI): Found MH$^+$ 222.1851 C$_{14}$H$_{23}$NO requires 222.1852.

6-(3,7-Dimethyloctyl)-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (63)

Following GP3, 28 (35 mg, 0.1 mmol) gave 63 (57%) as a pale yellow oil. [Et$_2$O:EtOAc (95:5)]; dr 1:1. FT-IR $v_{\text{max}}$ (film)/cm$^{-1}$ 2955, 2938, 2366, 2357, 2339, 1704, 1259, 1096, 1025; $^1$H NMR (500 MHz, CDCl$_3$, diastereomers) $\delta$ 3.05 (1H, d, $J$ = 4.8 Hz), 2.89 (1H, br t, $J$ = 4.8 Hz), 2.74 (3H, s), 2.34 (1H, dd, $J$ = 10.7, 4.5 Hz), 2.18 (1H, br s), 1.84 (1H, ddd, $J$ = 12.8, 11.0, 4.0 Hz), 1.69 (1H, d, $J$ = 10.9 Hz), 1.56–1.45 (2H, m), 1.39–1.02 (13H, m), 0.84 (6H, d, $J$ = 6.7 Hz), 0.83 (3H, d, $J$ = 6.5 Hz), 0.82 (3H, d, $J$ = 6.5 Hz); $^{13}$C NMR (126 MHz, CDCl$_3$, diastereomers) $\delta$ 179.6, 67.4 & 67.3, 48.1 & 48.0, 44.8 & 44.7, 42.8 & 42.6, 42.2,
39.4, 37.3, 35.6, 34.8 & 34.7, 34.2, 32.9 & 32.8, 30.4, 28.7, 28.0, 24.9 & 24.8, 22.8 & 22.7, 19.8; HRMS (HESI): Found MH$^+$ 292.2625 C$_{19}$H$_{34}$NO requires 292.2635.

6-Cyclopropyl-1-methylhexahydro-3,5-methanocyclopenta[b]pyrrol-2(1H)-one (65)

Following GP3, 28 (35 mg, 0.1 mmol) gave 65 (83%) as a pale yellow oil. [Et$_2$O:EtOAc (95:5)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 2960, 1699, 1428, 1397, 1257, 1015; $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 3.28 (1H, d, $J = 4.8$ Hz), 2.97–2.89 (1H, m), 2.72 (3H, s), 2.35 (2H, br q, $J = 5.5$ Hz), 1.90–1.72 (3H, m), 1.49–1.37 (2H, m), 0.63–0.46 (3H, m), 0.23–0.10 (1H, m), 0.06–0.02 (1H, m); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 179.6, 67.7, 53.8, 44.6, 43.1, 42.2, 35.4, 34.7, 28.6, 14.2, 5.3, 4.3; HRMS (HESI): Found MH$^+$ 192.1383 C$_{12}$H$_{18}$NO requires 192.1383.

tert-Butyl 2-ethylpyrrolidine-1-carboxylate (66)

Following GP3, 52 (37 mg, 0.1 mmol) gave 66 (44%). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 3.95–3.56 (1H, m), 3.55–3.12 (m, 2H), 2.15–1.74 (m, 4H), 1.74–1.90 (m, 2H), 1.59–1.40 (s, 9H), 0.80 (t, $J = 7.7$ Hz, 3H); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 154.8, 78.8, 58.7, 46.6, 46.2, 30.2, 29.3, 28.6, 27.5, 26.8, 23.8, 23.1, 10.6. Data in accordance with the literature.$^{33}$

tert-Butyl 2-propylpyrrolidine-1-carboxylate (67)

Following GP3, 52 (37 mg, 0.1 mmol) gave 67 (58%). $^1$H NMR (500 MHz, CDCl$_3$, rotamers) $\delta$ 3.59–3.83 (1H, m), 3.36 (0.55H, br s), 3.29 (1.45H, br s), 1.56–1.95 (5H, m), 1.45 (9H, s), 1.28–1.36 (3H, m), 0.91 (3H, t, $J = 7.2$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$) $\delta$ 154.7, 78.8, 57.2, 56.9, 46.4, 46.0, 36.9, 36.3, 30.6, 29.8, 23.8, 23.0, 19.5, 14.1. Data in accordance with the literature.$^{34}$

tert-Butyl 2-(cyclopropylmethyl)pyrrolidine-1-carboxylate (68)
Following **GP3**, 52 (37 mg, 0.1 mmol) gave 68 (72%) as a pale yellow oil. [Petrol:CH₂Cl₂ (20:80)]; FT-IR νₘₐₓ (film)/cm⁻¹ 2967, 2930, 1694, 1454, 1390, 1364, 1259, 1168, 1103, 1017; ¹H NMR (500 MHz, CDCl₃, rotamers) δ 3.88 (0.4H, br s), 3.80 (0.6H, br s), 3.42–3.33 (2H, m), 2.06–1.73 (4H, m), 1.44 (9H, s), 1.42–1.10 (2H, m), 0.60 (1H, m), 0.41 (2H, m), 0.20–0.00 (2H, m); ¹³C NMR (126 MHz, CDCl₃, rotamers) δ 154.7, 78.9, 57.7, 46.7, 46.2, 39.5, 38.5, 30.7, 30.0, 28.7, 24.0, 23.2, 8.0, 4.9, 4.0; HRMS (HESI): Found MNa⁺ 248.1616 C₁₃H₂₃NO₂Na requires 248.1621.

**tert-Butyl 2-tetradecylpyrrolidine-1-carboxylate (69)**

Following **GP3**, 52 (37 mg, 0.1 mmol) gave 69 (57%) as an oil. [Petrol:acetone (90:10)]; FT-IR νₘₐₓ (film)/cm⁻¹ 2960, 2923, 2853, 1697, 1455, 1390, 1364, 1259, 1171, 1099, 1023; ¹H NMR (500 MHz, CDCl₃) δ 3.75 (0.4H, br s), 3.69 (0.6H, br s), 3.38 (0.8H, br s), 3.29 (1.2H, br s), 1.96–1.69 (3H, m), 1.69–1.56 (3H, m), 1.46 (9H, s), 1.38–1.16 (26H, m), 0.88 (3H, t, J = 6.8 Hz); ¹³C NMR (126 MHz, CDCl₃, rotamers) δ 32.1, 29.9, 29.8, 29.7, 29.5, 28.7, 22.8, 14.3; HRMS (HESI): Found MH+ t-Bu⁺ 326.3055 C₂₀H₄₀NO₂ requires 326.3054. Further deprotection using TFA (1.0 equiv.) in CH₂Cl₂ (0.1 M), at room temperature, 1h, gave the corresponding 2-pentadecylpyrrolidin-1-ium ion. ¹H NMR (400 MHz, CDCl₃) δ 10.21 (1H, br s), 3.51 (1H, br s), 2.31–1.94 (3H, m), 1.89–1.57 (4H, m), 1.41–1.17 (27H, m), 0.87 (3H, t, J = 6.7 Hz). Data in accordance with the literature.⁴⁶

**1-Methyl-2-tetradecylpyrrolidine (70)**

¹H NMR (500 MHz, CDCl₃) δ 3.07–3.01 (1H, m), 2.29 (3H, s), 2.12 (1H, app dd, J = 17.6, 8.5 Hz), 1.97–1.85 (2H, m), 1.80–1.62 (3H, m), 1.46–1.39 (1H, m), 1.32–1.15 (25H, m), 0.87 (3H, t, J = 6.8 Hz). Data in accordance with the literature.⁴⁶
**tert-Butyl 2-Isopropylpyrrolidine-1-carboxylate (71)**

Following GP3, S19 (38 mg, 0.1 mmol) gave 71 (53%) as an oil. $^1$H NMR (400 MHz, CDCl$_3$, rotamers) δ 3.76–3.32 (2H, m), 3.23–3.12 (1H, m), 2.23–1.63 (5H, m), 1.44 (9H, s), 0.83 (3H, d, $J = 7.1$ Hz), 0.77 (3H, d, $J = 6.9$ Hz); $^{13}$C NMR (126 MHz, CDCl$_3$, diastereomers and rotamers) δ 154.6, 79.0, 62.3, 47.7, 30.8, 30.2, 28.9, 26.9, 26.2, 24.8, 23.8, 20.0, 17.8. Data in accordance with the literature.

**tert-Butyl 2-butyl-5-propylpyrrolidine-1-carboxylate (73)**

Following GP3, 72 (42 mg, 0.1 mmol) gave 73 (70%) as an oil. d.r 1:1. $^1$H NMR (400 MHz, CDCl$_3$, rotamers) δ 3.80–3.63 (1.4H, m), 3.63–3.52 (0.6H, m), 1.96–1.70 (3H, m), 1.67–1.49 (3H, m), 1.41 (9H, s), 1.35–1.02 (6H, m), 0.93–0.77 (6H, m); $^{13}$C NMR (126 MHz, CDCl$_3$, diastereomers and rotamers) δ 154.0, 78.8, 57.8 & 57.7, 34.1 & 33.8, 32.9 & 32.7, 32.0, 29.2 & 29.1, 28.8, 28.7 & 28.6, 27.7, 26.8, 26.7 & 26.6, 22.9, 22.8, 14.4 & 14.3, 14.2. Data in accordance with the literature.

**tert-Butyl 2-butyl-5-pentylpyrrolidine-1-carboxylate (74)**

Following GP3, 72 (42 mg, 0.1 mmol) gave 74 (70%) as an oil. d.r 1:1. [CH$_2$Cl$_2$:EtO (95:5)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 3342, 2960, 1694, 1668, 1388, 1365, 1258, 1016; $^1$H NMR (500 MHz, CDCl$_3$, diastereomers and rotamers) δ 3.74–3.67 (1H, m), 3.64–3.57 (1H, m), 2.04–1.76 (3H, m), 1.74–1.52 (2H, m), 1.45 (9H, s), 1.38–1.10 (13H, m), 0.99–0.79 (6H, m); $^{13}$C NMR (126 MHz, CDCl$_3$, diastereomers and rotamers) δ 154.0, 78.8, 57.8 & 57.7, 34.1 & 33.8, 32.9 & 32.7, 32.0, 29.2 & 29.1, 28.8, 28.7 & 28.6, 27.7, 26.8, 26.7 & 26.6, 22.9, 22.8, 14.4 & 14.3, 14.2; HRMS (HESI): Found MH–t-Bu$^+$ 242.2113 C$_{14}$H$_{28}$NO$_2$ requires 242.2115.
**tert-**Butyl 2-butyl-5-heptylpyrrolidine-1-carboxylate (75)

Following **GP3**, 72 (42 mg, 0.1 mmol) gave 75 (70%) as an oil. d.r 1:1; [CH$_2$Cl$_2$:Et$_2$O (95:5)]; FT-IR $\nu_{\text{max}}$ (film)/cm$^{-1}$ 3387, 2959, 2927, 1694, 1389, 1258, 1173, 1019; $^1$H NMR (500 MHz, CDCl$_3$, diastereomers and rotamers) $\delta$ 3.75–3.67 (1H, m) 3.65–3.56 (1H, m), 2.03–1.76 (3H, m), 1.77–1.60 (2H, m), 1.45 (9H, s), 1.40–1.09 (17H, m), 0.88 (6H, m); $^{13}$C NMR (126 MHz, CDCl$_3$, diastereomers and rotamers) $\delta$ 153.9, 78.6, 57.6, 34.0 & 33.7, 32.8 & 32.5, 31.8, 29.7 & 29.6, 29.4 & 29.3, 29.1 & 29.0, 28.6, 28.5, 27.6, 26.9 & 26.8, 26.7, 22.7, 22.6, 14.2 & 14.1, 14.1; HRMS (HESI): Found MH–t-Bu$^+$ 270.2422 C$_{16}$H$_{32}$NO$_2$ requires 270.2425.

**2-Butyl-5-propylpyrrolidine (76)**

TFA (10 equiv.) was added to a solution of 73 in CH$_2$Cl$_2$ (0.1 M) at room temperature. The mixture was stirred for 2 h and NaOH (1 M in H$_2$O) was added until pH = 14. The layers were separated and the aqueous layer was washed with CH$_2$Cl$_2$ (x 4). The combined organic layers were dried (MgSO$_4$) and evaporated to give 76 (quant). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 3.66–3.44 (1H, m), 3.07–2.91 (1H, m) 1.99–1.86 (2H, m), 1.55–1.22 (14H, m), 0.94 (3H, t, $J$ = 7.3 Hz), 0.90 (3H, t, $J$ = 7.4 Hz). Data in accordance with the literature. 47

**2-Butyl-5-pentylpyrrolidine (77)**

TFA (10 equiv.) was added to a solution of 74 in CH$_2$Cl$_2$ (0.1 M) at room temperature. The mixture was stirred for 2 h and NaOH (1 M in H$_2$O) was added until pH = 14. The layers were separated and the aqueous layer was washed with CH$_2$Cl$_2$ (x 4). The combined organic layers were dried (MgSO$_4$) and evaporated to give 77 (quant). $^1$H NMR (500 MHz, CDCl$_3$) $\delta$ 3.44–2.99 (2H, m), 2.14 (1H, br s), 2.12–1.84 (2H, m), 1.61–1.44 (16H, m), 0.91 (3H, t, $J$ = 7.4 Hz), 0.86 (3H, t, $J$ = 7.1 Hz). Data in accordance with the literature. 48
2-Butyl-5-heptylpiprrolidine (78)

\[
\text{\begin{tikzpicture}
\node (A) at (0,0) {	ext{Me}};
\node (B) at (0.5,0) {	ext{Me}};
\node (C) at (1,0) {	ext{N}};
\node (D) at (1.5,0) {	ext{Me}};
\node (E) at (2,0) {	ext{Me}};
\end{tikzpicture}}
\]

TFA (10 equiv.) was added to a solution of 75 in CH\(_2\)Cl\(_2\) (0.1 M) at room temperature. The mixture was stirred for 2 h and NaOH (1 M in H\(_2\)O) was added until pH = 14. The layers were separated and the aqueous layer was washed with CH\(_2\)Cl\(_2\) (x 4). The combined organic layers were dried (MgSO\(_4\)) and evaporated to give 78 (quant). \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 3.29–3.19 (1H, m), 3.06–2.99 (1H), 2.05–1.89 (2H, m), 1.71–1.55 (2H, m), 1.48–1.21 (18H, m), 0.91–0.82 (6H, m), 0.88 (3H, \(t\), J = 7.5 Hz), 0.86 (3H, \(t\), J = 7.4 Hz). Data in accordance with the literature.\(^{49}\)
8 Computational Studies

8.1 Computational Methods

Density functional theory (DFT)\textsuperscript{37} calculations were performed using Gaussian 09 (revision E.01)\textsuperscript{38} and the Gaussview\textsuperscript{39} was used to generate input geometries and visualize output structures. Regarding geometry optimizations and frequency calculations for the nitrogen radicals addition and subsequent reductive elimination, B3LYP functional\textsuperscript{40-43} was used with the UB3LYP/6-31G(d)-LANL2DZ (for Ni and Br) basis set.\textsuperscript{44} All stationary points were characterized as minima or transitions states based on normal vibrational mode analysis. Thermal corrections were computed from unscaled frequencies, assuming a standard state of 298.15 K and 1 atm. For substrates having more than one conformations, low energy conformation of the transition state could possibly be different from the low energy ground state.\textsuperscript{45} The structures described herein are the lowest energy-optimized conformers.
## 8.2 Activation Energy ($\Delta G^\ddagger$) and Reaction Energy ($\Delta G$) for Radical Additions and Reductive Elimination Reactions

**DFT Method:** UB3LYP/6-31G(d)-LANL2DZ (for Ni and Br) [values are in Kcal mol$^{-1}$]

| No. | Radical Additions and corresponding Reductive Elimination Reactions | $\Delta G^\ddagger$ | $\Delta G$ |
|-----|---------------------------------------------------------------|---------------------|------------|
| 1   | ![Radical Addition 1](image1) ![Reductive Elimination 1](image2) | 6.7                 | 5.0        |
| 2   | ![Radical Addition 2](image3) ![Reductive Elimination 2](image4) | 2.1                 | -58.6      |
| 3   | ![Radical Addition 3](image5) ![Reductive Elimination 3](image6) | 11.7                | -2.6       |
| 4   | ![Radical Addition 4](image7) ![Reductive Elimination 4](image8) | 10.3                | -58.9      |
**Computed Energies** [values are in Hartree]

| No. | Species | Total Electronic Energy | Sum of Electronic and Zero-point Energies | Sum of Electronic and Thermal Enthalpies | Gibbs Free Energy |
|-----|---------|--------------------------|------------------------------------------|------------------------------------------|-------------------|
| 1   | ![Species 1](image1) | -1224.0875973           | -1223.608936                              | -1223.579239                              | -1223.671024      |
| 2   | ![Species 2](image2) | -251.2503264            | -251.104655                               | -251.098082                               | -251.134045       |
| 3   | ![Species 3](image3) | -1475.3489696           | -1474.723617                              | -1474.687127                              | -1474.794432      |
| 4   | ![Species 4](image4) | -1475.3493639           | -1474.724244                              | -1474.686747                              | -1474.797033      |
| 5   | ![Species 5](image5) | -1475.3509824           | -1474.724436                              | -1474.688343                              | -1474.793710      |
| 6   | ![Species 6](image6) | -992.4688836            | -992.081943                               | -992.057176                               | -992.139638       |
| 7   | ![Species 7](image7) | -482.9557153            | -482.715047                               | -482.704079                               | -482.750721       |
| 8   | ![Species 8](image8) | -247.851032             | -247.763155                               | -247.755772                               | -247.794013       |
| No. | Species | Optimized Structure |
|-----|---------|---------------------|
| 9   | ![Image](image9.png) | -1471.9443233 -1471.375827 -1471.339200 -1471.446345 |
| 10  | ![Image](image10.png) | -1471.9684674 -1471.398339 -1471.361257 -1471.469115 |
| 11  | ![Image](image11.png) | -1471.9539625 -1471.383700 -1471.347648 -1471.452672 |
| 12  | ![Image](image12.png) | -479.5683878 -479.385072 -479.373311 -479.423381 |

**Optimized Structures and Cartesian Coordinates**

| No. | Species | Optimized Structure |
|-----|---------|---------------------|
| 1   | ![Image](image1.png) | ![Image](image1.png) |

| Cartesian Coordinates |
|-----------------------|
| C 1.40980000 -0.28870600 -0.00010600 |
| C 1.19690000 -2.58919800 -0.00123600 |
| C 2.57593900 -2.75776900 -0.00061400 |
| C 3.42817000 -1.64319900 0.00043100 |
| C 2.80491000 -0.39069600 0.00068000 |
| C 2.57593900 0.99476700 -0.00019000 |
| C 1.19690000 3.42790500 -0.00107700 |
| C 0.55894400 3.42790500 -0.00068000 |
| C 2.57593900 2.24388400 -0.00026400 |
| C 2.01021000 -3.90696000 0.00068000 |
| C 1.30354100 -3.76739900 -0.00090900 |
| C 0.55894400 4.13234900 -0.00150600 |
| N 0.61544400 -1.38073100 -0.00097000 |
Cartesian Coordinates

C  -1.70732400  -0.27110700  -0.32754000
C  -1.12783300  -2.49303200  -0.58360500
C  -2.45769800  -2.89191800  -0.53053600
C  -3.47534000  -1.94057300  -0.36332500
C  -3.06515200  -0.60721300  -0.26489800
C  -1.20883700  1.12532700  -0.22568100
C  0.66013900  2.48075200  -0.13512200
C  -0.11287900  3.62987500  -0.03357500
C  -1.51423900  3.53296200  -0.03020000
C  -2.04765800  2.24404300  -0.13241600
H  -0.31855200  -3.20079800  -0.72907500
H  -2.68610300  -3.94850000  -0.62030800
H  1.74561100  2.51185500  -0.14256400
H  0.38434900  4.59111100  0.04095500
N  -0.75469300  -1.21085100  -0.48146400
N  0.13167000  1.25550900  -0.23007000
Ni  1.27328400  -0.58183100  -0.30739300
Br  2.09375700  -2.45544900  -1.85421200
H  -3.11976100  2.10308500  -0.14158700
H  -3.79984000  0.17495000  -0.13137600
C  -2.38297100  4.79541600  0.07041700
C  -4.94700100  -2.37398600  -0.29476800
C  -5.90168500  -1.18008800  -0.10448400
C  -5.32356600  -3.09691100  -1.61062200
C  -5.13265100  -3.34273000  0.89807400
C  -2.07321200  5.72116500  -1.13090000
C  -2.04872800  5.53284100  1.38982900
C  -3.88947200  4.47446700  0.06110800
H  -4.51168000  -4.23864600  0.79729800
H  -4.86985800  -2.85756000  1.84478100
H  -6.17829300  -3.66650400  0.95929700
H  -4.70427600  -3.98313000  -1.78145800
H  -6.36977200  -3.42224000  -1.57366400
H  -5.20422100  -2.43262600  -2.47418100
H  -5.70232600  -0.64118500  0.82920000
H  -5.83838700  -0.46770800  -0.93557100
H  -6.93519700  -1.54022600  -0.06055600
H  -4.17851000  3.83967900  0.90667600
H  -4.46188200  5.40497000  0.13900000
H  -4.19674600  3.97747300  -0.86626500
H  -2.30749400  5.22706900  -0.20805620
H  -2.67552200  6.63474700  -1.06554700
H  -1.01971000  6.01817100  -1.15771800
H  -0.99742700  5.83525900  1.45353600
H  -2.65987600  6.43858100  1.47716100
H  -2.25419000  4.89886400  2.25964800
C  1.35588900  -1.13734000  1.62436200
C  0.93713600  -0.29919000  2.66857900
C  1.79707600  -2.42763900  1.95593000
C  0.95552000  -0.73099700  4.00138800
H  0.59644900  0.71433700  2.45760000
C  1.81640000  -2.86581300  3.28580200
H  2.13602900  -3.09886300  1.16956200
C  1.39566900  -2.01857100  4.31354300
H  0.62731400  -0.06043200  4.79423700
H  2.16487400  -3.87066400  3.51849700
H  1.41253900  -2.35747600  5.34696000
C  4.02559900  0.32234500  0.73543900
C  3.77487000  0.44287500  -1.65157700

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Cartesian Coordinates

C   -1.72209300 -0.30961300 -0.35100200
C   -1.12821200 -2.53005900 -0.59124700
C   -2.45688400 -2.93541400 -0.55995300
C   -3.48122100 -1.98767700 -0.31154700
C   -1.22929900 1.08852000 -0.24173200
C   -0.31251900 3.24264000 -0.72058400
C   -2.67958200 -3.93130000 -0.65120100
N   0.11096800 1.22561300 -0.23143600
Ni  1.24963000 -0.59001400 -0.25545700
Br  2.21354100 -2.47957100 -1.67692400
H   -3.14494600 2.05806000 -0.19493400
H   -0.31251900 -3.23426400 -0.72058400
C   -4.49187000 -2.42774000 -0.36339000
C   -5.91547800 -1.23637200 -0.20162200
C   -5.30387600 -3.16714700 -1.6767300
C   -5.15174500 -3.38407400 0.83724800
C   -2.10313200 5.68411500 -1.12949500
C   -2.10905000 5.48491900 1.39069600
C   -3.92832900 4.42341000 0.03480700
H   -4.52518400 -4.27091000 0.75602100
H   -4.90573600 -2.88721400 1.78238400
H   -6.19673700 -3.71206100 0.89604400
H   -4.67744000 -4.05213800 -1.82757500
H   -6.34876700 -3.49801000 -1.65254300
H   -5.17450400 -2.51210500 -2.54572800
H   -5.73497800 -0.68794500 0.72998500
C   -5.84112300 -0.53222600 -1.03849300
H   -6.94777200 -1.60183200 -0.17202400
H   -4.22452900 3.78403800 0.87369600
H   -4.50579200 5.35188800 0.11045900
H   -4.22220800 3.93067000 -0.89704000
H   -2.32454400 5.19328800 -2.08400500
H   -2.70941600 6.59526300 -1.06741500
H   -1.05041300 5.98490800 -1.14257400
H   -1.05991800 5.79223500 1.45060200
H   -2.72556000 6.38736800 1.47448600
Cartesian Coordinates

C -1.6207000 -0.45712700 -0.14994100
C -0.65429100 -2.48481000 -0.66587600
C -1.85818700 -3.15751500 -0.49962300
C -3.01290300 -2.45549900 -0.11952800
C -2.87082700 -1.07426800  0.04847600
C -1.41779400  1.00978500 -0.09201200
C  0.12501100  2.72449500 -0.05698600
C -0.86959900  3.69193600  0.00110600
C -2.21921400  3.30698000  0.04750200
C -2.47098600  1.93181600  0.01849100
H  0.25261500 -2.99526800 -0.97436400
H -1.88178000 -4.22949600 -0.66365200
H  1.17268600  3.00122500 -0.11247800
H -0.58212200  4.73793700  0.00031300
N -0.53527200 -1.16381700 -0.48635200
N -0.13014900  1.40928800 -0.06017300
Ni 1.32098400 -0.18070300 -0.44177500
Br  2.04834300 -1.31536900 -2.63160800
H  3.48965900  1.56855200  0.01374800
H -3.71966000 -0.47315500  0.34554100
C -3.33173400  4.36406200  0.10271600
C -4.34273700 -3.19060800  0.08909400
C -5.48195300 -2.24693500  0.50888200
C -4.74694000 -3.88920500 -1.23396400
C -4.16050700 -4.26042900  1.19717400
C -3.23911800  5.26144000 -1.15522500
C -3.14170800  5.23076200  1.37113400
C -4.73685600  3.73502900  0.14939400
H -3.38927100 -4.99251400  0.93700300
H -3.87514300 -3.79569800  2.14773700
H -5.09926200 -4.80487200  1.35233900
\[
\begin{array}{cccc}
H & -3.99370400 & -4.61218200 & -1.56301900 \\
H & -5.69199700 & -4.42875900 & -1.10106100 \\
H & -4.88281800 & -3.15752700 & -2.03826900 \\
H & -5.26828700 & -1.74494900 & 1.45975900 \\
H & -5.67822900 & -1.48143100 & -0.25013400 \\
H & -6.40550200 & -2.82070700 & 0.64169800 \\
H & -4.87300200 & 3.10171400 & 1.03371200 \\
H & -5.49111900 & 4.52787600 & 0.19439600 \\
H & -4.94636400 & 3.34132200 & -0.74220100 \\
H & -2.24728000 & 5.77532700 & -1.12752400 \\
H & -3.37002700 & 4.67281200 & -2.07011300 \\
H & -4.02375500 & 6.02634000 & -1.12752400 \\
H & -2.17266000 & 5.74038200 & -0.25013400 \\
H & -2.03169000 & 4.88281800 & 1.03371200 \\
C & 1.43261000 & 2.03160900 & 1.19960100 \\
C & 1.48782000 & 2.77484700 & 2.10770400 \\
C & 1.43261000 & 2.77484700 & 2.10770400 \\
H & 0.90740500 & 0.19921100 & 2.56781900 \\
C & 1.16020000 & -0.74699500 & 0.00013700 \\
C & 0.93824000 & -2.62530200 & 0.00058100 \\
C & -0.16020000 & -3.47365300 & 0.00042000 \\
C & -1.46190800 & -2.94333200 & 0.00006800 \\
C & -1.56145900 & -1.54814400 & -0.00006500 \\
C & -0.43697000 & 0.73642500 & 0.00002200 \\
C & 0.85662400 & 2.65562300 & -0.00018100 \\
C & -0.26305000 & 3.46797900 & -0.00016200 \\
C & -1.55205200 & 2.89959000 & -0.00002600 \\
C & -1.60839300 & 1.50200700 & 0.00006500 \\
H & 1.95263100 & -3.01246900 & 0.00082700 \\
H & 0.00958900 & -4.54499400 & 0.00005500 \\
H & 1.85851300 & 3.07410100 & -0.00027500 \\
H & -0.13035500 & 4.54585000 & -0.00024200 \\
N & 0.82599400 & -1.28745000 & 0.00043200 \\
N & 0.78584900 & 1.31486100 & -0.00008700 \\
Ni & 2.34277200 & 0.03810600 & 0.00014000 \\
\end{array}
\]
**Cartesian Coordinates**

**7**

![Image of a molecular structure](image1)

| Element | Coordinates          |
|---------|----------------------|
| C       | -2.5664600 0.9999270 0.00020600 |
| H       | -2.53465900 -1.07581600 -0.00036800 |
| C       | -2.80246500 3.79104400 0.00003700 |
| C       | -2.68397100 -3.87354600 -0.00016500 |
| C       | -4.01319400 -3.09330900 -0.00036400 |
| C       | -2.64033100 -4.76650900 -1.26393000 |
| C       | -2.64075000 -4.76658100 1.26356200 |
| C       | -2.78693400 4.68498600 -1.26373200 |
| C       | -2.78671600 4.68510900 1.26371600 |
| C       | -4.10652500 2.97140900 0.00019100 |
| H       | -1.73509300 -5.38063200 1.30830800 |
| H       | -2.67338300 -4.16097100 2.17623200 |
| H       | -3.50261000 -5.44390200 1.27370800 |
| H       | -1.73470400 -5.38061900 -1.30037500 |
| H       | -3.50225300 -5.44376900 -1.27444000 |
| H       | -2.67258100 -4.16084100 -2.17657400 |
| H       | -4.11796000 -2.46306000 0.88898700 |
| H       | -4.11756700 -2.46285000 -0.88961200 |
| H       | -4.85058600 -3.80123900 -0.00062900 |
| H       | -4.19077300 2.33604000 0.88951200 |
| H       | -4.96574200 3.65050600 0.00022500 |
| H       | -4.19092000 2.33594200 -0.88904700 |
| H       | -2.79933000 4.07867900 -2.17642700 |
| H       | -3.66987600 5.33459400 -1.27472900 |
| H       | -1.90132600 5.32768800 -1.29961600 |
| H       | -1.90111200 5.32731000 1.29937500 |
| H       | -3.66967000 5.33470100 1.27481500 |
| H       | -2.79893000 4.07888800 2.17647100 |
| Br      | 4.69413800 0.06594200 -0.00018000 |

**8**

![Image of another molecular structure](image2)

| Element | Coordinates          |
|---------|----------------------|
| C       | 0.466691200 0.14545300 -0.03392800 |
| O       | 0.37244300 1.37211000 -0.03905100 |
| N       | -0.63296100 -0.65709900 -0.29608000 |
| C       | 1.77967300 -0.59073700 0.10317000 |
Cartesian Coordinates

|          | X             | Y             | Z             |
|----------|---------------|---------------|---------------|
| C        | -1.33500400   | -0.71630900   | -0.21065100   |
| C        | 0.15516500    | -2.45038400   | -0.55879600   |
| C        | -0.86597700   | 3.39145100    | -0.67460200   |
| C        | -2.19491800   | 2.98841500    | -0.33290000   |
| C        | -1.49791400   | 2.75467300    | -0.07589700   |
| C        | 0.39209800    | 2.78424000    | 0.00525400    |
| C        | 1.58842300    | 3.48806900    | 0.06702800    |
| C        | 2.81098600    | 2.79675400    | 0.06040300    |
| H        | 1.18902300    | -2.72732700   | -0.05375000   |
| H        | 0.57506000    | 3.27648900    | -0.21065100   |
| H        | 0.57506000    | 3.27648900    | -0.21065100   |
| N        | 0.06871000    | -1.13961200   | -0.39775700   |
| N        | -0.34518400   | 1.44838100    | -0.04820900   |
| Ni       | 1.47229400    | 0.27905500    | -0.25178600   |
| Br       | 2.82128600    | -0.91106800   | -2.07798800   |
| C        | -3.64631700   | 0.81474600    | -0.05375000   |
| C        | -3.07665000   | -1.23797100   | -0.01085100   |
| C        | -4.14018800   | 3.56431400    | 0.11919700    |
| C        | -3.32912000   | -4.02320400   | -0.30299000   |
| C        | -4.70740900   | -3.37716500   | -0.06808600   |
| C        | -3.36363000   | -4.77121700   | -1.65779800   |
| C        | 3.06182500    | 5.03402600    | 0.83849600    |
| C        | -4.23332400   | 4.50512400    | -1.10669800   |
| C        | -4.18139700   | 4.40393400    | 1.41897600    |
| C        | -5.36129800   | 2.62550200    | 0.10730700    |
| H        | -2.11316200   | -5.50636700   | 0.70469400    |
| H        | -3.03367300   | -4.53193400   | 1.81215400    |
| H        | -3.35620000   | -5.78631800   | 0.86219900    |
| H        | -2.42293000   | -5.29152200   | -1.86183800   |
| H        | -4.16437900   | -5.51984800   | -1.65145600   |
| H        | -3.55102700   | -4.07946400   | -2.48667600   |
| H        | -4.75599900   | -2.85316500   | 0.89360800    |
| H        | -4.96848400   | -2.66866400   | -0.86279100   |
| H        | -5.47876000   | -4.15465100   | -0.55685300   |
| H        | -5.36326000   | 1.94509100    | 0.96686600    |
| H        | -6.27996700   | 3.21961800    | 0.15478500    |
| H        | -5.40849900   | 2.02629000    | -0.80929100   |
| H        | -4.20420500   | 3.93727900    | -2.04335300   |
| H        | -5.17465200   | 5.06603300    | -1.07776400   |
| H        | -3.41363000   | 5.23032600    | -1.12538600   |
| H        | -3.35765100   | 5.12345200    | 1.46719700    |
| H        | -5.11972400   | 4.96812100    | 1.47079500    |
| H        | -4.12117000   | 3.76306000    | 2.30596400    |
| C        | -1.98221400   | -0.44397900   | 1.51662900    |
| C        | 1.20296000    | -0.15957400   | 2.64136300    |
| C        | 3.06838200    | -1.31560600   | 1.62991700    |
| C        | 1.50783900    | -0.74128300   | 3.87728700    |
| H        | 0.35508100    | 0.51925300    | 2.57138300    |
| C        | 3.37162600    | -1.89789900   | 2.86804900    |
Cartesian Coordinates

| Atm  | X      | Y      | Z      |
|------|--------|--------|--------|
| C    | -1.55022400 | -0.46585000 | 0.03975800 |
| C    | -0.84633400 | -2.62019000 | -0.39589800 |
| C    | -2.14190900 | -3.11286300 | -0.31907200 |
| C    | -3.20724200 | -2.24493500 | 0.02830200 |
| C    | -2.87769400 | 0.52343600  | 0.35006500  |
| C    | -1.60445900 | 3.37255000  | 0.28987000  |
| C    | -2.04576500 | 2.01312000  | 0.20228000  |
| C    | -0.00701900 | -3.27686900 | -0.59965300 |
| C    | -2.30725900 | -4.17296800 | -0.47734500 |
| C    | 1.71339000  | 2.55296500  | 0.34443300  |
| C    | 0.21805300  | 4.51618900  | 0.40413300  |
| N    | -0.55321800 | -1.32793000 | -0.22397000 |
| N    | 0.19656000  | 1.16403200  | 0.25859000  |
| Ni   | 1.40785800  | -0.54798500 | -0.16165000 |
| C    | 4.23157700  | -0.13164300 | -0.84174000 |
| C    | 4.78427500  | 1.54372300  | 1.32681200  |
| C    | 5.50692300  | 0.42255800  | -0.67970300 |
| C    | 4.02691900  | -0.75670100 | -1.70290100 |
| C    | 5.78005100  | 1.26462600  | 0.39767000  |
| C    | 4.99141800  | 2.18115300  | 2.18339200  |
| H    | 6.27833000  | 0.19911400  | -1.41297100 |
| Br   | 1.31792000  | -0.19825000 | -2.62084500 |
| C    | 3.51030300  | 0.98009500  | 1.17954100  |
| C    | 2.75929000  | 1.17743100  | 1.93804100  |
| C    | 3.22019700  | 0.16379900  | 0.08315800  |
| C    | -3.10240300 | 1.79951000  | 0.11784200  |
| H    | -3.64972000 | -0.18114000 | 0.39888700  |
| H    | 6.77789700  | 1.69297000  | 0.51588600  |
| C    | -2.55588500 | 4.54129400  | 0.30119500  |
| C    | -4.64162000 | -2.78087900 | 0.08156700  |
| C    | -5.65765000 | -1.67248400 | 0.41703900  |
| C    | -5.04535700 | -3.42145100 | -1.26870000 |
| C    | -4.69901300 | -3.85022200 | 1.19947700  |
| C    | -2.23613600 | 5.44783500  | -0.91282300 |
| C    | -2.34383400 | 5.33769600  | 1.61186300  |
| C    | -4.03533300 | 4.12149400  | 0.21954200  |
| C    | -4.02823900 | -4.69128500 | 0.99726500  |
| C    | -4.41896900 | -3.42310000 | 2.16906300  |
| C    | -5.71561600 | -4.24894100 | 1.28470300  |
| C    | -4.38537900 | -4.24903500 | -1.54425300 |
Cartesian Coordinates

|   |   |   |
|---|---|---|
| C | 1.16776900 | 0.89212500 | 0.09500000 |
| C | -0.62524800 | 2.35115500 | 0.00807700 |
| C | 0.21340300 | 3.44995700 | -0.09927100 |
| C | 1.60546200 | 3.27727300 | -0.12657300 |
| C | 2.06369600 | 1.96190000 | -0.02745400 |
| C | 1.60286200 | -0.52161600 | 0.18033800 |
| C | -0.91735800 | 2.72344700 | 0.18058500 |
| C | 2.22413200 | -3.17510500 | 0.32250800 |
| C | 3.28540400 | -2.26076100 | 0.39629100 |
| C | 2.94084400 | -0.90713300 | 0.32602600 |
| H | -1.70074700 | 2.46472500 | -0.00091300 |
| H | -0.23460400 | 4.43412300 | -0.17972400 |
| H | 0.08629500 | -3.40736100 | 0.09005300 |
| H | 2.44019600 | -4.24493000 | 0.36768800 |
| N | -0.16716400 | 1.09317300 | 0.11528100 |
| N | 0.56663500 | -1.42324100 | 0.10786800 |
| Ni | -1.39573000 | -0.55104800 | 0.03747900 |
| Br | -2.02056700 | 2.74153500 | -2.34086400 |
| H | 3.70892500 | -0.14894300 | 0.39545700 |
| H | 3.12380100 | 1.75346600 | -0.06608100 |
| C | 4.73245200 | -2.75169400 | 0.54808700 |
| C | 2.54066000 | 4.48551400 | -0.27406100 |
| C | 4.02593700 | 4.07877300 | -0.29071400 |
| C | 2.21720100 | 5.21336200 | -1.60154600 |
| C | 2.30960300 | 5.45067700 | 0.91398000 |
| C | 5.08766900 | -3.65367700 | -0.65881400 |
| C | 4.85537700 | -3.56751300 | 1.85766300 |
| C | 5.74311200 | -1.59082600 | 0.60208500 |
| H | 1.27607500 | 5.80965200 | 0.95487400 |
| C | 2.53470300 | 4.96324500 | 1.86947300 |
| C | 2.96245100 | 6.32583000 | 0.81705900 |
| H | 1.18257700 | 5.56958000 | -1.63144000 |
| H | 2.87379400 | 6.08318400 | -1.71952100 |
| H | 2.36856600 | -4.55189800 | -2.46159600 |
| Element | X Coordinates | Y Coordinates | Z Coordinates |
|---------|---------------|---------------|---------------|
| C       | 2.04294300    | -0.45946900   | 0.04995700    |
| O       | 3.23789700    | -0.19268600   | 0.01794200    |
| N       | 1.07147700    | 0.52222500    | -0.04962700   |
| C       | 1.54837400    | -1.89068100   | 0.20250900    |
| C       | 1.47665800    | 1.91964600    | -0.19267200   |
| H       | 1.07872200    | 2.52367800    | 0.63139900    |
| H       | 2.56603200    | 1.95065100    | -0.17922800   |
| H       | 1.10658000    | 2.33584700    | -1.13742400   |
| H       | 0.97320000    | -2.21122400   | -0.67292500   |
| C       | 2.42335100    | -2.52052000   | 0.31435000    |
| H       | 0.89716500    | -2.00369000   | 1.07530100    |
| C       | -0.33586500   | 0.25055100    | -0.02549100   |
| C       | -1.04382500   | 0.31796000    | 1.18029800    |
| C       | -1.01852900   | -0.40601000   | -1.21220600   |
| C       | -2.41915300   | 0.08258000    | 1.19975800    |
| H       | -0.50761700   | 0.55039800    | 2.09638200    |
| C       | -2.39375700   | -0.27698700   | -1.19006800   |
| H       | -0.46326600   | -0.08130500   | -2.14534600   |
| C       | -3.09580200   | -0.21578400   | 0.01533100    |
| H       | -2.96151500   | 0.13272900    | 2.14004600    |
| H       | -2.91629000   | -0.50721800   | -2.11456200   |
| H       | -4.16658700   | -0.39924800   | 0.03158700    |

Cartesian Coordinates

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9  NMR Spectra

S9 $^1$H NMR (400 MHz, CDCl$_3$)

S9 $^{13}$C NMR (101 MHz, CDCl$_3$)
4 $^1$H NMR (400 MHz, CDCl$_3$)

$^1$H NMR (400 MHz, CDCl$_3$)

4 $^{13}$C NMR (101 MHz, CDCl$_3$)

$^{13}$C NMR (101 MHz, CDCl$_3$)

S12 $^1$H NMR (400 MHz, CDCl$_3$)
S12 $^{13}$C NMR (101 MHz, CDCl$_3$)

3 $^1$H NMR (400 MHz, CDCl$_3$)
$^3$C NMR (101 MHz, CDCl$_3$)

$^1$H NMR (400 MHz, CDCl$_3$)
$^{13}$C NMR (101 MHz, CDCl$_3$)

$^1$H NMR (400 MHz, CDCl$_3$)
$^{13}$C NMR (101 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (400 MHz, CDCl$_3$)
$^6$^{13}$C NMR (101 MHz, CDCl$_3$)

$^7$H NMR (400 MHz, CDCl$_3$)
$^7$C NMR (101 MHz, CDCl$_3$)

$^8$H NMR (400 MHz, CDCl$_3$)
$^1$H NMR (400 MHz, CDCl$_3$)

$^13$C NMR (101 MHz, CDCl$_3$)

$^19$F NMR (376 MHz, CDCl$_3$)
29 $^1$H NMR (400 MHz, CDCl$_3$)

29 $^{13}$C NMR (101 MHz, CDCl$_3$)

30 $^1$H NMR (400 MHz, CDCl$_3$)
$^{13}$C NMR (101 MHz, CDCl$_3$)

$^1$H NMR (400 MHz, CDCl$_3$)
$^{31}$C NMR (101 MHz, CDCl$_3$)

$^{19}$F NMR (376 MHz, CDCl$_3$)
32 $^1$H NMR (500 MHz, CDCl$_3$)

32 $^{13}$C NMR (126 MHz, CDCl$_3$)

33 $^1$H NMR (500 MHz, CDCl$_3$)
33 $^{13}$C NMR (126 MHz, CDCl$_3$)

178.19  142.44  128.13  74.74  52.26  46.67  42.91  36.28  34.98

34 $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^{19}$F NMR (376 MHz, CDCl$_3$)
36 $^1$H NMR (500 MHz, CDCl$_3$)

36 $^{13}$C NMR (126 MHz, CDCl$_3$)

37 $^1$H NMR (500 MHz, CDCl$_3$)
$^{37}$\textsuperscript{13}C NMR (126 MHz, CDCl$_3$)

$^{38}$\textsuperscript{1}H NMR (500 MHz, CDCl$_3$)
38 $^{13}$C NMR (126 MHz, CDCl$_3$)

39 $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^{19}$F NMR (376 MHz, CDCl$_3$)
41 $^1$H NMR (500 MHz, CDCl$_3$)

41 $^{13}$C NMR (126 MHz, CDCl$_3$)

42 $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
\[ 43 \text{ } ^{13}C \text{ NMR (126 MHz, CDCl}_3) \]

\[ 44 \text{ } ^{1}H \text{ NMR (500 MHz, CDCl}_3) \]
44 $^{13}$C NMR (126 MHz, CDCl$_3$)

45 $^1$H NMR (500 MHz, CDCl$_3$)
45 $^{13}$C NMR (126 MHz, CDCl$_3$)

46 $^1$H NMR (500 MHz, CDCl$_3$)
46 $^{13}$C NMR (126 MHz, CDCl$_3$)

47 $^1$H NMR (500 MHz, CDCl$_3$)
47 $^{13}$C NMR (126 MHz, CDCl$_3$)

48 $^1$H NMR (500 MHz, CDCl$_3$)
$^1$H NMR (500 MHz, CDCl$_3$)
49 $^{13}$C NMR (126 MHz, CDCl$_3$)

50 $^1$H NMR (500 MHz, CDCl$_3$)
50 $^{13}$C NMR (126 MHz, CDCl$_3$)

51 $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
53 $^{13}$C NMR (126 MHz, CDCl₃)

54 $^1$H NMR (500 MHz, CDCl₃)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
57 $^{13}$C NMR (126 MHz, CDCl$_3$)

58 $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
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59 $^{13}$C NMR (126 MHz, CDCl$_3$)

61 $^1$H NMR (500 MHz, CDCl$_3$)
**61** $^{13}$C NMR (126 MHz, CDCl$_3$)

**62** $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
67 $^{13}$C NMR (126 MHz, CDCl$_3$)

68 $^1$H NMR (500 MHz, CDCl$_3$)
68 $^{13}$C NMR (126 MHz, CDCl$_3$)

69 $^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
$^{13}$C NMR (126 MHz, CDCl$_3$)

$^1$H NMR (500 MHz, CDCl$_3$)
76 $^{13}$C NMR (126 MHz, CDCl$_3$)

80 $^1$H NMR (500 MHz, CDCl$_3$)
$^1$H NMR (500 MHz, CDCl$_3$)

$^{13}$C NMR (126 MHz, CDCl$_3$)
$\text{Me} \quad \text{Boc} \quad \text{Me}$

$\text{^13C NMR (126 MHz, CDCl}_3)$

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