Supporting Information

for

Formal [3+3] Cycloaddition of Indol-2-yl Carbinol with Azadiene and the Subsequent Oxidative Ring Expansion Reaction for the Synthesis of Indole Azepinones

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General information

The 1H-NMR spectra were recorded at 600 MHz, 400 MHz or 300MHz in CDCl3 or DMSO-d6, and the 13C-NMR spectra were recorded at 150 MHz in CDCl3 or DMSO-d6 with TMS as internal standard. All shifts were given in ppm. All coupling constants (J values) were reported in Hertz (Hz). High resolution mass spectra (HRMS) were obtained on an IonSpec Ultima 7.0 T FT-ICR-MS (IonSpec, USA) with a Waters Z-spray source. Column chromatography was performed on silica gel 200-300 mesh. All reagents were commercial grades and were used without any purification unless otherwise noted. Anhydrous triethylamine, 1,2-dichloroethane, dichloromethane, and acetonitrile were obtained by distillation from calcium hydride under nitrogen. Anhydrous tetrahydrofuran was distilled according to the standard procedure. All other solvents were used without further purification.
Experimental Procedures and Characterization Data

General procedures for one-pot [3+3] Cyclization:

To a solution of the tertiary alcohol 6 (0.42 mmol) and aza-Danishefsky’s diene (7) (4.0 eq.) in dry MeCN (4 mL) was added Hf(OTf)₄ (5 mol%) at -40 °C. The reaction mixture was stirred at the same temperature until 6 had disappeared as monitored by TLC. Then TfOH (1.5 eq.) was recharged to the reaction vessel and the reaction mixture was stirred at 15 °C for 36 h. The reaction mixture was diluted with dichloromethane (50 mL) and washed sequentially with saturated aqueous Na₂CO₃ (15 mL) and NaHCO₃ (15 mL). The organic phase was dried over anhydrous Na₂SO₄, filtered, concentrated, and purified by flash column chromatography on silica gel to give the desired products.

¹H-NMR (400 MHz, CD₃OD) δ: 8.08 (d, J = 7.6 Hz, 1H), 7.29–7.16 (m, 2H), 7.06 (t, J = 6.8 Hz, 1H), 4.52 (s, 1H), 4.03 (s, 3H), 3.81 (s, 3H), 3.30–3.14 (m, 2H), 2.73–2.22 (m, 6H), 1.11 (t, J = 6.8 Hz, 3H). ¹³C-NMR (100 MHz, DMSO) δ: 192.47, 166.96, 160.98, 149.28, 140.69, 134.70, 131.63, 127.95, 124.32, 123.62, 115.51, 114.83, 64.52, 52.77, 43.53, 37.31, 31.71, 23.82, 23.09, 12.26.
\[\text{1H-NMR (400 MHz, CDCl}_3\text{)} \delta: 8.48 (d, J = 7.6 \text{ Hz}, 1\text{H}), 7.47 (d, J = 7.2 \text{ Hz}, 1\text{H}), 7.41–7.17 (m, 2\text{H}), 6.30 (s, 1\text{H}), 3.84 (s, 3\text{H}), 3.80 (s, 3\text{H}), 3.46 (d, J = 14.4 \text{ Hz}, 1\text{H}), 3.04–2.79 (m, 3\text{H}), 2.13 (t, J = 6.0 \text{ Hz}, 2\text{H}), 1.96 (q, J = 7.2 \text{ Hz}, 2\text{H}), 0.97 (t, J = 7.2 \text{ Hz}, 3\text{H}). \]

\[\text{13C-NMR (100 MHz, CDCl}_3\text{)} \delta: 193.22, 168.75, 161.36, 150.17, 142.35, 135.24, 129.45, 124.63, 124.16, 120.27, 116.55, 105.89, 64.51, 52.71, 42.69, 38.20, 30.44, 30.15, 29.90, 8.34. \]

HRMS Calcd for \(\text{C}_{20}\text{H}_{22}\text{N}_{2}\text{NaO}_5\) (M+Na\(^+\)): 393.1426; Found: 393.1439.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane, and EtOAc as eluent (v/v/v = 15:1:1, then 10:1:1) to give \(3a\) in 85.3% yield (cis-\(3a\)/trans-\(3a\) = 2.24:1).

\[\text{1H-NMR of cis-3a (400 MHz, CDCl}_3\text{)} \delta: 8.47 (d, J = 8.0 \text{ Hz}, 1\text{H}), 7.65 (d, J = 7.6 \text{ Hz}, 1\text{H}), 7.37 (t, J = 7.6 \text{ Hz}, 1\text{H}), 7.30 (t, J = 7.6 \text{ Hz}, 1\text{H}), 3.68 (s, 3\text{H}), 3.12 (s, 3\text{H}), 3.03 (d, J = 14.0 \text{ Hz}, 1\text{H}), 2.99–2.78 (m, 3\text{H}), 2.30–2.19 (m, 1\text{H}), 2.11–1.96 (m, 1\text{H}), 1.96–1.80 (m, 1\text{H}), 1.80–1.65 (m, 1\text{H}), 0.97 (t, J = 7.2 \text{ Hz}, 3\text{H}). \]

\[\text{13C-NMR (100 MHz, CDCl}_3\text{)} \delta: 203.22, 168.16, 166.69, 144.16, 135.30, 127.47, 125.35, 124.66, 120.05, 116.61, 111.58, 73.17, 62.96, 53.53, 48.00, 36.53, 30.56, 30.11, 28.76, 8.35. \]

HRMS Calcd for \(\text{C}_{20}\text{H}_{22}\text{N}_{2}\text{NaO}_5\) (M+Na\(^+\)): 393.1426; Found: 393.1433.
$^1$H-NMR of trans-3a (400 MHz, CDCl$_3$) $\delta$: 8.46 (d, $J = 8.0$ Hz, 1H), 7.67 (d, $J = 7.6$ Hz, 1H), 7.36 (t, $J = 7.6$ Hz, 8.0Hz, 1H), 7.29 (t, $J = 7.6$ Hz, 1H), 6.91–6.66 (br, 1H), 3.67 (s, 3H), 3.21 (s, 3H), 3.06 (d, $J = 14.8$ Hz, 1H), 3.03–2.78 (m, 2H), 2.62 (d, $J = 14.8$ Hz, 1H), 2.32–2.20 (m, 1H), 2.13–1.82 (m, 2H), 1.81–1.64 (m, 1H), 0.98 (t, $J = 7.6$ Hz, 3H). $^{13}$C-NMR of trans-3a (100 MHz, CDCl$_3$) $\delta$: 206.68, 168.23 (2C), 143.63, 135.48, 127.41, 125.39, 124.62, 120.27, 116.64, 111.37, 71.22, 63.31, 53.28, 49.74, 36.29, 30.62, 30.34, 29.26, 8.39.

The products were purified by flash column chromatography on silica gel with mixture of petroleum ether, dichloromethane, and EtOAc as eluent (v/v/v = 10:1:1) to give 3b in 69.7% yield (cis/trans = 2.21:1).

$^1$H-NMR (400 MHz, CDCl$_3$, cis-3b) $\delta$: 8.47 (d, $J = 8.0$ Hz, 1H), 7.62 (d, $J = 7.6$ Hz, 1H), 7.37 (t, $J = 7.6$ Hz, 1H), 7.30 (t, $J = 7.6$ Hz, 1H), 7.23–7.01 (br, 1H), 3.68 (s, 3H), 3.11 (s, 3H), 3.08–2.98 (m, 2H), 2.96–2.86 (m, 1H), 2.82 (d, $J = 14.0$ Hz, 1H), 2.31–2.15 (m, 1H), 2.08–1.97 (m, 1H), 1.44 (s, 3H). $^{13}$C-NMR (100 MHz, CDCl$_3$, cis-3b) $\delta$: 203.12, 167.93, 166.51, 143.17, 135.17, 127.33, 125.26, 124.58, 119.79, 116.52, 111.49, 72.92, 62.81, 53.35, 52.50, 34.85, 33.34, 30.74, 24.99.

$^1$H-NMR (400 MHz, CDCl$_3$, mixture of diastereoisomers) $\delta$: 8.46 (d, $J = 8.0$ Hz, 1H of both isomers), 7.71 (d, $J = 7.6$ Hz, 1H of major isomer), 7.62 (d, $J = 7.6$ Hz, 1H of major isomer), 7.36 (t, $J = 7.6$ Hz, 1H of both isomers), 7.33–7.27 (m, 1H of both isomers), 7.19–6.59 (br, 1H of both isomers), 3.68 (s, 3H of major isomer), 3.67 (s,
The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 15:1:1) to give $3c$ in 73.6% yield ($cis/trans = 2.24:1$). HRMS Calcd for C$_{22}$H$_{26}$N$_2$NaO$_5$ (M$+$Na$^+$): 421.1739; Found: 421.1744.
\[ \text{trans-3c} \]

$^1$H-NMR (300 MHz, CDCl$_3$, trans-3c) $\delta$: 8.46 (d, $J = 7.8$ Hz, 1H), 7.68 (d, $J = 7.2$ Hz, 1H), 7.36 (m, 1H), 7.29 (m, 1H), 6.76 (br, 1H), 3.67 (s, 3H), 3.21 (s, 3H), 3.07 (d, $J = 14.7$ Hz, 1H), 3.02–2.79 (m, 2H), 2.63 (d, $J = 14.7$ Hz, 1H), 2.31–2.20 (m, 1H), 2.09–1.93 (m, 1H), 1.91–1.78 (m, 1H), 1.74–1.60 (m, 1H), 1.43–1.25 (m, 4H), 0.90 (t, $J = 6.6$ Hz, 3H). $^{13}$C-NMR (150 MHz, CDCl$_3$, trans-3c) $\delta$: 206.64, 168.17 (2C), 143.56, 135.38, 127.33, 125.29, 124.53, 120.20, 116.56, 111.17, 71.37, 63.22, 53.11, 50.37, 36.32, 36.08, 30.95, 30.66, 25.96, 23.00, 13.93.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 5:1:1) to give 3d in 47.4% yield (cis/trans = 2.84:1). $^1$H-NMR (400 MHz, CDCl$_3$, mixture of diastereoisomers) $\delta$: 8.46 (d, $J = 8.0$ Hz, 1H of both isomers), 7.65 (d, $J = 7.6$ Hz, 1H of both isomers), 7.36 (t, $J = 7.6$ Hz, 1H of both isomers), 7.32 (t, $J = 7.6$ Hz, 1H of both isomers), 3.68 (s, 3H of both isomers), 3.46-3.33 (m, 1H of both isomers), 3.33–3.25 (m, 4H of both isomers), 3.21 (s, 3H of minor isomer), 3.13 (s, 3H of major isomer), 3.07–2.79 (m, 4H of major isomer and 3H of minor isomer), 2.66 (d, $J = 16.4$ Hz, 1H of minor isomer), 2.31–2.19 (m, 1H of both isomers), 2.14–1.87 (m, 2H of both isomers), 1.76–1.63 (m, 2H of both isomers), 1.63–1.49 (m, 1H of both isomers). $^{13}$C-NMR (100 MHz, CDCl$_3$, mixture of diastereoisomers) $\delta$: 206.25 (1C of minor isomer), 203.04 (1C of major isomer), 168.11 (1C of major isomer and 2C of minor isomer).
isomer), 166.58 (1C of major isomer), 143.74 (1C of major isomer), 142.97 (1C of minor isomer), 135.22 (1C of both isomers), 127.31 (1C of both isomers), 125.32 (1C of both isomers), 124.58 (1C of both isomers), 120.15 (1C of minor isomer), 119.97 (1C of major isomer), 116.55 (1C of both isomers), 111.53 (1C of major isomer), 111.27 (1C of minor isomer), 73.07 (1C of minor isomer), 72.21 (1C of major isomer), 63.20 (1C of minor isomer), 62.88 (1C of major isomer), 58.68 (1C of both isomers), 53.46 (1C of major isomer), 53.10 (1C of minor isomer), 50.26 (1C of minor isomer), 48.58 (1C of major isomer), 36.20 (1C of major isomer), 35.90 (1C of minor isomer), 33.11 (1C of minor isomer), 32.58 (1C of major isomer), 31.00 (1C of minor isomer), 30.80 (1C of major isomer), 30.51 (1C of both isomers), 24.22 (1C of both isomers). HRMS Calcd for C_{22}H_{26}N_{2}NaO_{6} (M+Na^+): 437.1689; Found: 437.1699.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 15:1:1, 10:1:1) to give 3e in 90.0% yield \((cis/trans = 2.44:1)\). \(^1\)H-NMR (400 MHz, CDCl\(_3\), mixture of diastereoisomers) \(\delta\): 8.45 (d, \(J = 8.0\) Hz, 1H of both isomers), 7.64 (d, \(J = 7.6\) Hz, 1H of minor isomer), 7.57 (d, \(J = 7.6\) Hz, 1H of major isomer), 7.35 (t, \(J = 7.6\) Hz, 8.0 Hz, 1H of both isomers), 7.31–7.19 (m, 5H of both isomers), 7.15–7.06 (m, 2H of both isomers), 6.91–6.69 (br, 1H of minor isomer), 5.23–5.13 (m, 1H of both isomers), 5.10–4.97 (m, 1H of both isomers), 3.21 (s, 3H of minor isomer), 3.11 (s, 3H of major isomer), 3.07–2.96 (m, 1H of both isomers), 2.96–2.76 (m, 3H of major isomer, 2H of minor isomer), 2.58 (d, \(J = 14.8\) Hz, 1H of minor isomer), 2.27–2.15 (m, 1H of both isomers), 2.05–1.91 (m, 1H of both isomers), 1.91-1.53 (m, 4H of both isomers), 0.95 (t, \(J = 7.6\) Hz, 1H of major isomer), 0.82 (t, \(J = 7.6\) Hz, 1H of minor isomer). \(^{13}\)C-NMR (100 MHz, CDCl\(_3\), mixture of diastereoisomers) \(\delta\): 206.55 (1C of both isomers), 202.88 (1C of both isomers), 167.98 (2C of minor isomer), 167.32 (1C of major isomer), 165.81 (1C of major isomer), 143.85 (1C of major isomer), 143.40 (1C of minor isomer), 135.18 (1C of minor isomer), 135.04 (1C of major isomer),
134.49 (1C of both isomers), 128.50 (3C of major isomer), 128.33 (3C of minor isomer), 128.07 (2C of minor isomer), 127.97 (2C of major isomer), 127.18 (1C of major isomer), 127.10 (1C of minor isomer), 125.10 (1C of both isomers), 124.35 (1C of major isomer), 124.32 (1C of minor isomer), 120.17 (1C of minor isomer), 116.30 (1C of both isomers), 111.42 (1C of major isomer), 111.08 (1C of minor isomer), 73.20 (1C of major isomer), 71.07 (1C of minor isomer), 67.96 (1C of major isomer), 67.77 (1C of minor isomer), 63.06 (1C of minor isomer), 62.72 (1C of major isomer), 49.54 (1C of minor isomer), 47.79 (1C of major isomer), 36.28 (1C of major isomer), 35.96 (1C of minor isomer), 30.33 (1C of both isomers), 30.01 (1C of minor isomer), 29.90 (1C of major isomer), 28.91 (1C of minor isomer), 28.57 (1C of major isomer), 8.11 (1C of major isomer), 7.98 (1C of minor isomer). HRMS Calcd for C_{26}H_{26}N_{2}NaO_{5} (M+Na\textsuperscript{+}): 469.1739; Found: 469.1732.

![Chemical structure](image)

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 10:1:1) to give 3f in 67.0% yield (cis/trans = 1.86:1). \(^1\)H-NMR (400 MHz, CDCl\textsubscript{3}, mixture of diastereoisomers) \(\delta\): 8.45 (d, \(J = 8.0\) Hz, 1H of both isomers), 7.67 (d, \(J = 7.6\) Hz, 1H of minor isomer), 7.53 (d, \(J = 7.6\) Hz, 1H of major isomer), 7.35 (t, \(J = 7.6\) Hz, 1H of both isomers), 7.31–7.18 (m, 4H of both isomers), 7.15–7.04 (m, 2H of both isomers), 5.25–5.11 (m, 1H of both isomers), 5.11–4.95 (m, 1H of both isomers), 3.22 (s, 3H of minor isomer), 3.10 (s, 3H of major isomer), 3.08–2.72 (m, 4H of both isomers), 2.25–2.11 (m, 1H of both isomers), 2.08–1.96 (m, 1H of both isomers), 1.43 (s, 3H of major isomer), 1.34 (m, 3H of minor isomer). \(^{13}\)C-NMR (100 MHz, CDCl\textsubscript{3}, mixture of diastereomers) \(\delta\): 206.52 (1C of minor isomer), 202.88 (1C of major isomer), 167.86 (2C of minor isomer), 167.28 (1C of major isomer), 165.74 (1C of major isomer), 143.04 (1C of major isomer), 142.56 (1C of minor isomer), 135.13 (1C of minor isomer), 134.96 (1C of major isomer), 134.51 (1C of minor isomer), 134.44
(1C of minor isomer), 128.44 (3C of major isomer), 128.28 (3C of minor isomer), 127.93 (2C of major isomer), 127.87 (1C of minor isomer), 127.13 (1C of major isomer), 127.06 (1C of minor isomer), 125.06 (1C of both isomers), 124.33 (1C of major isomer), 124.28 (1C of minor isomer), 120.16 (1C of minor isomer), 119.84 (1C of major isomer), 116.27 (1C of both isomers), 111.35 (1C of major isomer), 111.07 (1C of minor isomer), 73.02 (1C of major isomer), 71.08 (1C of minor isomer), 67.88 (1C of major isomer), 67.64 (1C of minor isomer), 62.98 (1C of minor isomer), 62.65 (1C of major isomer), 53.88 (1C of minor isomer), 52.36 (1C of major isomer), 34.64 (1C of both isomers), 33.17 (1C of major isomer), 32.86 (1C of minor isomer), 30.58 (1C of both isomers), 25.14 (1C of minor isomer), 24.87 (1C of major isomer).

HRMS Calcd for C_{25}H_{24}N_{2}NaO_{5} (M+Na^+): 455.1583; Found: 455.1574.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 20:1:1, then 15:1:1) to give 3g in 86.3% yield (cis/trans = 2.12:1).

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\text{cis-}3g: \delta: 8.45 (d, J = 8.0 \text{ Hz}, 1H), 7.57 (d, J = 7.6 \text{ Hz}, 1H), 7.35 (t, J = 7.6 \text{ Hz}, 1H), 7.30–7.06 (m, 6H), 5.11 (dd, J_{1} = 41.6 \text{ Hz}, J_{2} = 12.0 \text{ Hz}, 2H), 3.12 (s, 3H), 3.06–2.76 (m, 4H), 2.26–2.10 (m, 1H), 2.07–1.88 (m, 1H), 1.88–1.73 (m, 1H), 1.73–1.60 (m, 1H), 1.44–1.15 (m, 4H), 0.88 (t, J = 7.2 \text{ Hz}, 3H).
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\text{trans-}3g: \delta: 8.45 (d, J = 8.0 \text{ Hz}, 1H), 7.65 (d, J = 7.6 \text{ Hz}, 1H), 7.36 (t, J = 7.6 \text{ Hz}, 1H), 7.30–7.04 (m, 6H), 6.99–6.57 (br, 1H), 5.25–4.93 (m, 2H), 3.21 (s, 3H), 3.09–3.00 (d, J = 14.8 \text{ Hz}, 1H), 3.00–2.77 (m, 2H), 2.67–2.56 (d, J
= 14.8 Hz, 1H), 2.29–2.13 (m, 1H), 2.06–1.91 (m, 1H), 1.82–1.64 (m, 1H), 1.56–1.44 (m, 1H), 1.36–0.94 (m, 4H), 0.76 (t, J = 7.6 Hz, 3H). 13C-NMR (150 MHz, CDCl3, trans-3g) δ: 206.41, 168.03, 167.41, 143.52, 135.19, 134.60, 128.35, 128.29, 128.05, 127.13, 125.04, 124.32, 120.14, 116.30, 110.90, 71.01, 67.66, 63.04, 50.07, 35.94, 35.88, 30.51, 30.44, 25.70, 22.55, 13.80. HRMS Calcd for C28H30N2NaO5 (M+Na+): 497.2052; Found: 497.2043.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 10:1:1) to give 3h in 78.9% yield (cis/trans = 2.73:1). 1H-NMR (400 MHz, CDCl3, mixture of diastereoisomers) δ: 8.48 (d, J = 8.0 Hz, 1H of both isomers), 7.53 (d, J = 7.6 Hz, 1H of both isomers), 7.37 (t, J = 7.6 Hz, 1H of both isomers), 7.29 (t, J = 7.6 Hz, 1H of both isomers), 3.22 (s, 3H of minor isomer), 3.14 (s, 3H of major isomer), 3.04 (d, J = 14.4 Hz, 1H of both isomers), 3.00–2.80 (m, 2H of both isomers), 2.72 (d, J = 14.4 Hz, 1H of both isomers), 2.31–2.17 (m, 4H of major isomer and 1H of minor isomer), 2.12–1.97 (m, 1H of major isomer and 4H of minor isomer), 1.93–1.78 (m, 1H of both isomers), 1.78–1.65 (m, 1H of both isomers), 0.86 (t, J = 7.6 Hz, 3H of both isomers). 13C-NMR (100 MHz, CDCl3, mixture of diastereoisomers) δ: 203.30 (1C of major isomer), 200.15 (1C of major isomer), 167.91 (1C of major isomer), 143.91 (1C of major isomer), 135.39 (1C of minor isomer), 135.19 (1C of major isomer), 127.08 (1C of major isomer), 126.19 (1C of minor isomer), 125.61 (1C of minor isomer), 125.20 (1C of major isomer), 124.78 (1C of minor isomer), 124.44 (1C of major isomer), 119.83 (1C of both isomers), 116.52 (1C of major isomer), 116.12 (1C of minor isomer), 112.00 (1C of major isomer), 109.5 (1C of minor isomer), 80.28 (1C of both isomers), 63.46 (1C of minor isomer), 62.59 (1C of major isomer), 48.94 (1C of minor isomer), 48.06 (1C of major isomer), 36.33 (1C of major isomer), 35.61 (1C of minor isomer), 30.31 (1C of minor isomer), 30.59 (1C of minor isomer), 30.31 (1C
of major isomer), 30.17 (1C of minor isomer), 30.06 (1C of major isomer), 28.70 (1C of both isomers), 27.01 (1C of both isomers), 8.45 (1C of minor isomer), 8.11 (1C of major isomer). HRMS Calcd for C_{20}H_{22}N_{2}O_{4} (M+Na\(^{+}\)): 377.1477; Found: 377.1489.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 8:1:1) to give 3i in 77.6% yield (cis/trans = 1.64:1). \(^{\text{\textsuperscript{1}}}\)H-NMR (300 MHz, CDCl\(_3\), mixture of diastereoisomers) \(\delta\): 8.48 (d, \(J = 7.8\) Hz, 1H of both isomers), 7.56 (d, \(J = 7.5\) Hz, 1H of both isomers), 7.50 (d, \(J = 7.5\) Hz, 1H of major isomer), 7.38 (t, \(J = 7.2\) Hz, 1H of both isomers), 7.33–7.28 (m, 2H of both isomers and 1H of major isomer), 6.84 (br, 1H of minor isomer), 3.23 (s, 3H of minor isomer), 3.12 (s, 3H of major isomer), 3.09–2.80 (m, 4H of both isomers), 2.31–2.15 (m, 1H of both isomers and 3H of major isomer), 2.15–2.01 (m, 1H of both isomers and 3H of minor isomer), 1.50 (s, 3H of minor isomer), 1.44 (s, 3H of major isomer). \(^{\text{\textsuperscript{13}}}\)C-NMR (150 MHz, CDCl\(_3\), mixture of isomers) \(\delta\): 207.35 (1C of minor isomer), 203.51 (1C of major isomer), 201.98 (1C of minor isomer), 200.09 (1C of major isomer), 168.07 (1C of minor isomer), 167.97 (1C of major isomer), 143.38 (1C of major isomer), 142.67 (1C of minor isomer), 135.61 (1C of minor isomer), 135.38 (1C of major isomer), 127.27 (1C of major isomer), 127.02 (1C of minor isomer), 125.62 (1C of minor isomer), 125.45 (1C of major isomer), 124.77 (1C of minor isomer), 124.70 (1C of major isomer), 120.14 (1C of minor isomer), 119.90 (1C of major isomer), 116.76 (1C of major isomer), 116.71 (1C of minor isomer), 112.15 (1C of major isomer), 111.36 (1C of minor isomer), 80.38 (1C of major isomer), 76.51 (1C of minor isomer), 63.01 (1C of minor isomer), 62.78 (1C of major isomer), 53.76 (1C of minor isomer), 52.85 (1C of major isomer), 35.44 (1C of minor isomer), 35.01 (1C of major isomer), 33.56 (1C of minor isomer), 33.49 (1C of major isomer), 30.88 (1C of minor isomer), 30.83 (1C of major isomer), 27.42 (1C of minor isomer), 27.19 (1C of major isomer), 25.86 (1C of major isomer).

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 15:1:1) to give $\textbf{3j}$ in 86.3% yield (cis/trans = 2.10:1). $^1$H-NMR (400 MHz, CDCl$_3$, mixture of diastereoisomers) $\delta$: 8.48 (d, $J = 8.0$ Hz, 1H of both isomers), 7.53 (d, $J = 7.6$ Hz, 1H of both isomers), 7.37 (t, $J = 7.6$ Hz, 1H of both isomers), 7.29 (t, $J = 7.6$ Hz, 1H of both isomers), 6.82 (br, 1H of minor isomer), 3.21 (s, 3H of minor isomer), 3.14 (s, 3H of major isomer), 3.04 (d, $J = 14.8$ Hz, 1H of both isomers), 3.01–2.81 (m, 2H of both isomers), 2.81–2.67 (m, 1H of both isomers), 2.34–1.99 (m, 5H of both isomers), 1.99–1.89 (m, 1H of minor isomer), 1.85–1.74 (m, 1H of major isomer), 1.71–1.61 (m, 1H of major isomer), 1.57–1.47 (m, 1H of minor isomer), 1.45–1.18 (m, 4H of both isomers), 0.97–0.82 (m, 3H of both isomers). $^{13}$C-NMR (100 MHz, CDCl$_3$, mixture of diastereoisomers) $\delta$: 207.20 (1C of minor isomer), 203.44 (1C of major isomer), 202.09 (1C of minor isomer), 200.31 (1C of major isomer), 168.21 (1C of minor isomer), 168.10 (1C of major isomer), 144.08 (1C of major isomer), 143.61 (1C of minor isomer), 135.55 (1C of minor isomer), 135.36 (1C of major isomer), 127.27 (1C of major isomer), 127.00 (1C of minor isomer), 125.53 (1C of minor isomer), 125.35 (1C of major isomer), 124.71 (1C of minor isomer), 124.61 (1C of major isomer), 119.99 (1C of both isomers), 116.69 (1C of major isomer), 116.29 (1C of minor isomer), 112.10 (1C of major isomer), 111.10 (1C of minor isomer), 80.39 (1C of major isomer), 76.32 (1C of minor isomer), 62.98 (1C of minor isomer), 62.70 (1C of major isomer), 49.76 (1C of minor isomer), 48.94 (1C of major isomer), 36.63 (1C of major isomer), 36.57 (1C of minor isomer), 36.39 (1C of minor isomer), 35.94 (1C of major isomer), 30.93 (1C of both isomers), 30.61 (1C of both isomers), 27.45 (1C of minor isomer), 27.15 (1C of major isomer), 25.97 (1C of both isomers), 22.91 (1C of...
of both isomers), 13.92 (1C of both isomers). HRMS Calcd for C_{22}H_{26}N_{2}NaO_{4} (M+Na\(^{+}\)): 405.1790; Found: 405.1800.

The products were purified by flash column chromatography on silica gel with a mixture of petroleum ether, dichloromethane and EtOAc as eluent (v/v/v = 4:1:1) to give 3k in 41.8% yield (cis/trans = 3.93:1). \(^1\)H-NMR (300 MHz, CDCl\(_3\), mixture of diastereoisomers) \(\delta\): 8.48 (d, \(J = 7.8\) Hz, 1H of both isomers), 7.53 (d, \(J = 7.8\) Hz, 1H of both isomers and 1H of major isomer), 6.83 (br, 1H of minor isomer), 3.47–3.34 (m, 1H of both isomers), 3.34–3.23 (m, 4H of both isomers), 3.22 (s, 3H of minor isomer), 3.15 (s, 3H of major isomer), 3.07–2.92 (m, 2H of both isomers), 2.92–2.72 (m, 2H of both isomers), 2.33–2.19 (m, 1H of both isomers and 3H of major isomer), 2.15–2.02 (m, 1H of both isomers and 3H of minor isomer), 2.02–1.86 (m, 1H of both isomers), 1.75–1.52 (m, 3H of both isomers). \(^{13}\)C-NMR (150 MHz, CDCl\(_3\), mixture of diastereoisomers) \(\delta\): 206.73 (1C of minor isomer), 202.93 (1C of major isomer), 201.81 (1C of minor isomer), 199.97 (1C of major isomer), 167.86 (1C of minor isomer), 167.77 (1C of major isomer), 143.56 (1C of major isomer), 143.17 (1C of minor isomer), 135.19 (1C of minor isomer), 135.02 (1C of major isomer), 126.93 (1C of major isomer), 126.67 (1C of minor isomer), 125.07 (1C of minor isomer), 124.91 (1C of major isomer), 124.24 (1C of minor isomer), 124.16 (1C of major isomer), 119.69 (1C of both isomers), 116.29 (1C of major isomer), 116.25 (1C of minor isomer), 111.81 (1C of major isomer), 110.79 (1C of minor isomer), 80.03 (1C of major isomer), 75.97 (1C of minor isomer), 71.86 (1C of major isomer), 71.66 (1C of minor isomer), 62.55 (1C of minor isomer), 62.31 (1C of major isomer), 58.28 (1C of minor isomer), 58.23 (1C of major isomer), 49.30 (1C of minor isomer), 48.56 (1C of major isomer), 36.04 (1C of minor isomer), 35.88 (1C of major isomer), 33.07 (1C of minor isomer), 32.44 (1C of major isomer), 30.60 (1C of major isomer), 30.54 (1C of minor isomer), 30.15 (1C of both isomers), 27.17 (1C of minor isomer), 26.81 (1C
of major isomer), 23.83 (1C of both isomers). HRMS Calcd for C_{22}H_{26}N_{2}NaO_{5} (M+Na+): 421.1739; Found: 421.1761.

**General Experimental Procedures for Ring Expansion Reaction of 3:**

To a solution of 3 (0.1 mmol) in MeCN (1 mL) was added H_{2}O (2.0 eq.) and PIFA (1.0 eq.) at 0 °C and the resultant solution was stirred at the same temperature for 2 h (monitored by TLC). The reaction was diluted with dichloromethane (20 mL) and washed with brine (10 mL × 2). The organic phase was dried over anhydrous Na_{2}SO_{4}, filtered, concentrated, and purified by flash column chromatography with a mixed petroleum ether, dichloromethane, and EtOAc as eluent (v/v/v = 5:1:1 to 3:1:1) on silica gel to give the desired product.

\[ 11a \]

\[ ^{1}H\text{-NMR (300 MHz, CDCl}_{3}, \text{only major isomer is shown)} \delta: 8.53 \text{ (d, } J = 8.1 \text{ Hz, 1H),} \]
\[ 7.40–7.31 \text{ (m, 2H),} \]
\[ 7.30–7.22 \text{ (m, 1H),} \]
\[ 5.24 \text{ (br, 1H),} \]
\[ 3.87 \text{ (s, 3H),} \]
\[ 3.82 \text{ (s, 3H),} \]
\[ 3.18 \text{ (d, } J = 15.3 \text{ Hz, 1H),} \]
\[ 3.11–2.97 \text{ (m, 1H),} \]
\[ 2.92–2.77 \text{ (m, 2H),} \]
\[ 2.21–2.02 \text{ (m, 1H),} \]
\[ 1.95–1.83 \text{ (m, 1H),} \]
\[ 1.59 \text{ (s, 3H).} \]
\[ ^{13}C\text{-NMR (100 MHz, CDCl}_{3}, \text{only major isomer is shown)} \delta: 171.31, 169.22, 168.52, 142.45, 134.27, 126.56, 125.68, 124.82, 118.26, 116.76, 112.74, 88.58, 63.51, 54.23, 49.60, 35.39, 32.19, 30.33, 21.41. \]

HRMS Calcd for C_{19}H_{21}N_{2}O_{6} (M+H^{+}): 373.1399; Found: 373.1381.
$^{1}$H-NMR (300 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 8.50 (d, $J = 8.4$ Hz, 1H), 7.36–7.06 (m, 8H), 5.30 (d, $J = 12.0$ Hz, 1H), 5.21 (br, 1H), 5.17 (d, $J = 12.0$ Hz, 1H), 3.66 (s, 3H), 3.15 (d, $J = 15.2$ Hz, 1H), 3.21–2.95 (m, 2H), 2.91–2.71 (m, 2H), 2.16–1.99 (m, 1H), 1.93–1.80 (m, 1H), 1.54 (s, 3H).

$^{13}$C-NMR (150 MHz, CDCl$_3$) $\delta$: 171.28, 168.54 (2C), 142.42, 134.26, 133.95, 128.98, 128.92, 128.69, 126.48, 125.64, 124.75, 118.53, 116.66, 112.78, 88.87, 69.56, 63.55, 49.76, 35.45, 32.21, 30.36, 21.39. HRMS Calcd for C$_{25}$H$_{24}$N$_2$NaO$_6$ (M+Na$^+$): 471.1532; Found: 471.1529.

$^{1}$H-NMR (400 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 8.51 (d, $J = 8.4$ Hz, 1H), 7.40–7.30 (m, 2H), 7.30–7.24 (m, 1H), 5.46–5.17 (br, 1H), 3.86 (s, 3H), 3.81 (s, 3H), 3.10–2.75 (m, 4H), 2.20–2.03 (m, 2H), 1.98–1.80 (m, 2H), 1.05 (t, $J = 7.2$ Hz, 3H).

$^{13}$C-NMR (100 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 170.92, 169.25, 168.57, 143.51, 134.24, 126.59, 125.60, 124.76, 118.26, 116.71, 112.43, 88.56, 63.52, 54.23, 45.83, 35.30, 29.95, 25.86, 8.34. HRMS Calcd for C$_{20}$H$_{22}$N$_2$NaO$_6$ (M+Na$^+$): 409.1376; Found: 409.1381.
$^1$H-NMR (400 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 8.49 (d, $J = 8.4$ Hz, 1H), 7.38–7.13 (m, 6H), 7.07 (d, $J = 7.2$ Hz, 2H), 5.36–5.14 (m, 3H), 3.66 (s, 3H), 3.03 (d, $J = 15.6$ Hz, 1H), 2.97–2.74 (m, 3H), 2.18–1.98 (m, 2H), 1.93–1.78 (m, 2H), 1.00 (t, $J = 7.6$ Hz, 3H). $^{13}$C-NMR (100 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 170.92, 168.63, 168.46, 143.40, 134.18, 133.94, 128.87, 128.80, 128.60, 126.50, 125.53, 124.66, 118.53, 116.56, 112.51, 88.88, 69.44, 63.51, 45.94, 35.26, 29.99, 25.79, 8.35.

HRMS Calcd for C$_{26}$H$_{26}$N$_2$NaO$_6$ (M+Na$^+$): 485.1688; Found: 485.1657. C$_{26}$H$_{26}$KN$_2$O$_6$ (M+K$^+$): 501.1428; Found: 501.1398.

$^1$H-NMR (400 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 8.51 (d, $J = 8.0$ Hz, 1H), 7.40–7.30 (m, 2H), 7.30–7.19 (m, 1H), 5.31–5.17 (br, 1H), 3.85 (s, 3H), 3.82 (s, 3H), 3.06 (d, $J = 15.6$ Hz, 1H), 3.00–2.72 (m, 3H), 2.19–1.98 (m, 2H), 1.95–1.81 (m, 2H), 1.56–1.29 (m, 4H), 0.93 (t, $J = 6.8$ Hz, 3H). $^{13}$C-NMR (100 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 171.21, 169.31, 168.62, 143.65, 134.27, 126.61, 125.66, 124.83, 118.21, 116.78, 112.40, 88.57, 63.46, 54.28, 46.33, 35.24, 32.77, 30.74, 30.12, 26.01, 23.14, 13.96. HRMS Calcd for C$_{22}$H$_{26}$N$_2$NaO$_6$ (M+Na$^+$): 437.1689; Found: 437.1700.
$^1$H-NMR (400 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 8.49 (d, $J = 8.0$ Hz, 1H), 7.38–7.12 (m, 6H), 7.12–7.04 (d, $J = 7.2$ Hz, 2H), 5.42–5.33 (br, 1H), 5.22 (dd, $J_1 = 61.6$ Hz, $J_2 = 12.0$ Hz, 2H), 3.64 (s, 3H), 2.94 (dd, $J_1 = 57.6$ Hz, $J_2 = 15.6$ Hz, 2H), 2.80 (m, 3H), 2.15–1.92 (m, 2H), 1.92–1.71 (m, 2H), 1.50–1.16 (m, 4H), 0.86 (t, $J = 7.2$ Hz, 3H). $^{13}$C-NMR (100 MHz, CDCl$_3$, only major isomer is shown) $\delta$: 170.97, 168.64, 168.36, 143.38, 134.11, 128.82, 128.73, 128.57, 126.49, 125.46, 124.61, 118.58, 116.52, 112.33, 88.88, 69.32, 63.32, 46.42, 35.05, 32.62, 30.67, 30.00, 25.93, 22.96, 13.82. HRMS Calcd for C$_{28}$H$_{30}$N$_2$NaO$_6$ (M+Na$^+$): 513.2002; Found: 513.2001.
Copies of $^1$H- and $^{13}$C-NMR Spectra

Figure S1. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of Compound 9
Figure S2. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of Compound 10
Figure S3. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of Compound cis-3a
Figure S4. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of Compound *trans-3a*
Figure S5. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of cis-3b
Figure S6. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3b
**Figure S7.** $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of cis-3c
Figure S8. \(^1\)H- (upper) and \(^{13}\)C-NMR (lower) spectra of *trans*-3c
Figure S9. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3d
Figure S10. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3e
Figure S11. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3f
Figure S12. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-3g
Figure S13 $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of cis-/trans-$3g$
Figure S14. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3h
Figure S15. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3i
Figure S16. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3j
**Figure S17.** $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of mixture of cis-/trans-3k
Figure S18. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of compound 11a
Figure S19. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of compound 11b
Figure S20 $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of compound 11c
Figure S21. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of compound 11d
Figure S22. $^1$H- (upper) and $^{13}$C-NMR (lower) spectra of compound 11e