Supporting Information
for DOI: 10.1055/s-0030-1261161
© Georg Thieme Verlag KG Stuttgart · New York 2011
**SUPPORTING INFORMATION**

**Heck reaction on Morita-Baylis-Hillman adduct: diastereoselective synthesis of pyrrolizidinones and pyrrolizidines**

Kristerson R. de Luna Freire, Cláudio F. Tormena and Fernando Coelho*

Universidade Campinas – UNICAMP - Instituto de Química – 13083-970 – Caixa Postal 6154 – Campinas, SP – Brazil; E-mail: coelho@iqm.unicamp.br

---

### Experimental procedure

<table>
<thead>
<tr>
<th>Compound Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>*(2R,4R)-tert-*Butyl 2-formyl-4-hydroxy-1-carboxylate (7)</td>
<td>S4</td>
</tr>
<tr>
<td>*(2R,4R)-tert-*Butyl 4-hydroxy-2-((S)-1-hydroxy-2-(methoxycarbonyl)allyl)pyrrolidine-1-carboxylate (8)</td>
<td>S4-S5</td>
</tr>
<tr>
<td><em>(1S,6R,7aR)-1,6-dihydroxy-2-methylenetetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-one (11)</td>
<td>S5-S6</td>
</tr>
<tr>
<td>*(2S,4R)-tert-buty1 2-formyl-4-hydroxy-1-carboxylate (9)</td>
<td>S6</td>
</tr>
<tr>
<td>*(2S,4R)-tert-buty1 4-hydroxy-2-((R)-1-hydroxy-2-(methoxycarbonyl)allyl)pyrrolidine-1-carboxylate (10)</td>
<td>S6-S7</td>
</tr>
<tr>
<td><em>(1R,6R,7aS)-1,6-dihydroxy-2-methylenetetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-one (12)</td>
<td>S7</td>
</tr>
<tr>
<td><em>(1S,6R,7aR,E)-2-benzylidene-1,6-dihydroxytetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-one (14)</td>
<td>S7-S8</td>
</tr>
<tr>
<td><em>(1S,6R,7aR,Z)-1,6-dihydroxy-2-(4-hydroxybenzylidene)tetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-one (15)</td>
<td>S8</td>
</tr>
<tr>
<td><em>(1S,6R,7aR,Z)-1,6-dihydroxy-2-(4-nitrobenzylidene)tetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-ona (16)</td>
<td>S8-S9</td>
</tr>
<tr>
<td><em>(1S,2S,6R,7aR)-2-benzyl-1,6-dihydroxytetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-one (18)</td>
<td>S9</td>
</tr>
<tr>
<td><em>(1S,2S,6R,7aR)-1,6-dihydroxy-2-(4-hydroxybenzyl)tetrahydro-1</em>H*-pyrrolizin-3(2<em>H</em>)-one (20)</td>
<td>S9</td>
</tr>
<tr>
<td>1,6-dihydroxy-2-(4-hydroxybenzyl)tetrahydro-1<em>H</em>-pyrrolizin-3(2<em>H</em>)-one (15)</td>
<td>S8-S9</td>
</tr>
<tr>
<td>1,6-dihydroxy-2-(4-nitrobenzylidene)tetrahydro-1<em>H</em>-pyrrolizin-3(2<em>H</em>)-ona (16)</td>
<td>S8-S9</td>
</tr>
<tr>
<td>General experimental procedure for the amide carbonyl reduction of pyrrolizidinones 16, 17, 18 and 20</td>
<td>S9-S10</td>
</tr>
<tr>
<td><em>(1S,2R,6R,7aR)-2-benzylhexahydro-1</em>H*-pyrrolazine-1,6-diol (19)</td>
<td>S10</td>
</tr>
<tr>
<td><em>(1S,2R,6R,7aR)-2-(4-hydroxybenzyl)hexahydro-1</em>H*-pyrrolazine-1,6-diol (21)</td>
<td>S10</td>
</tr>
<tr>
<td><em>(1S,6R,7aR,Z)-2-benzylidenehexahydro-1</em>H*-pyrrolazine-1,6-diol (22)</td>
<td>S10</td>
</tr>
</tbody>
</table>
(1S,6R,7aR,E)-2-(4-hydroxybenzylidene)hexahydro-1H-pyrrolizine-1,6-diol (23)

Table of spectra

<table>
<thead>
<tr>
<th>Spectra</th>
<th>Pages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1H- and 13C NMR spectra of cis-4-hydroxy-(D)-prolinal 7.</td>
<td>S12-S13</td>
</tr>
<tr>
<td>1H- and 13C NMR spectra of MBH adduct 8.</td>
<td>S14-S15</td>
</tr>
<tr>
<td>HRMS (ESI) of MBH adduct 8.</td>
<td>S16</td>
</tr>
<tr>
<td>1H-, 13C NMR spectra of pyrrolizidinone 11.</td>
<td>S17-S18</td>
</tr>
<tr>
<td>HRMS (ESI) of pyrrolizidinone 11.</td>
<td>S19</td>
</tr>
<tr>
<td>1H and 13C NMR spectra of trans-hydroxy-prolinal 9.</td>
<td>S20-S21</td>
</tr>
<tr>
<td>1H and 13C NMR spectrum of MBH adduct 10.</td>
<td>S22-S23</td>
</tr>
<tr>
<td>HRMS (ESI) of MBH adduct 10.</td>
<td>S24</td>
</tr>
<tr>
<td>1H- and 13C NMR (500 MHz, (CD3)2CO) spectrum of pyrrolizidinone 12.</td>
<td>S25-S26</td>
</tr>
<tr>
<td>HRMS (ESI) of pyrrolizidinone 12.</td>
<td>S27</td>
</tr>
<tr>
<td>nOe spectrum of pyrrolizidinone 12, irradiation at 1.59 ppm, H-7B.</td>
<td>S28</td>
</tr>
<tr>
<td>nOe spectrum of pyrrolizidinone 12, irradiation at 3.73 ppm, H-5B.</td>
<td>S28</td>
</tr>
<tr>
<td>nOe spectrum of pyrrolizidinone 12, irradiation at 3.89 ppm, H-7a.</td>
<td>S29</td>
</tr>
<tr>
<td>nOe spectrum of pyrrolizidinone 12, irradiation at 4.53 ppm, H-1).</td>
<td>S29</td>
</tr>
<tr>
<td>nOe spectrum of pyrrolizidinone 12, irradiation at 4.59 ppm, H-6).</td>
<td>S30</td>
</tr>
<tr>
<td>1H- and 13C NMR spectra of benzylidene-pyrrolizidinone 14</td>
<td>S31-S32</td>
</tr>
<tr>
<td>2-D NOESY spectrum of benzylidene-pyrrolizidine 14.</td>
<td>S33</td>
</tr>
<tr>
<td>HRMS (ESI) of benzylidene-pyrrolizidinone 14.</td>
<td>S34</td>
</tr>
<tr>
<td>1H- and 13C NMR spectra of hydroxy-benzylidene-pyrrolizidinone 15.</td>
<td>S35-S36</td>
</tr>
<tr>
<td>2-D NOESY spectrum of hydroxy-benzylidene-pyrrolizidinone 15.</td>
<td>S37</td>
</tr>
<tr>
<td>HRMS (ESI) of hydroxy-benzylidene-pyrrolizidinone 15.</td>
<td>S38</td>
</tr>
<tr>
<td>1H- and 13C NMR spectra of p-nitro-benzylidene-pyrrolizidinone 16.</td>
<td>S39-S40</td>
</tr>
<tr>
<td>2D-NOESY spectrum of p-nitro-benzylidene-pyrrolizidinone 16.</td>
<td>S41</td>
</tr>
<tr>
<td>HRMS (ESI) of p-nitro-benzylidene-pyrrolizidinone 16.</td>
<td>S42</td>
</tr>
<tr>
<td>1H- and 13C NMR spectra of benzyl-pyrrolizidinone 18.</td>
<td>S43-S44</td>
</tr>
</tbody>
</table>
HRMS (ESI) of benzyl-pyrrolizidinone \textbf{18}.

\(^1\)H- and \(^{13}\)C NMR spectra of hydroxy-benzyl-pyrrolizidinone \textbf{20}.

HRMS (ESI) of hydroxy-benzyl-pyrrolizidinone \textbf{20}.

\(^1\)H- and \(^{13}\)C NMR spectra of benzyldiene-pyrrolizidine \textbf{22}.

2D-NOESY spectrum of benzyldiene-pyrrolizidine \textbf{22}.

HRMS (ESI) of benzyldiene-pyrrolizidine \textbf{22}.

\(^1\)H- and \(^{13}\)C NMR spectra of hydroxy-benzyldiene-pyrrolizidine \textbf{23}.

2D-NOESY spectrum of benzyldiene-pyrrolizidine \textbf{23}.

HRMS (ESI) of hydroxy-benzyldiene-pyrrolizidine \textbf{23}.

\(^1\)H- and \(^{13}\)C NMR spectra of benzyl-pyrrolizidine \textbf{19}.

HRMS (ESI) of benzyl-pyrrolizidine \textbf{19}.

\(^1\)H- and \(^{13}\)C NMR spectra of hydroxy-benzyl-pyrrolizidine \textbf{21}.

HRMS (ESI) of hydroxy-benzyl-pyrrolizidine \textbf{21}.

\begin{table}[h]
\centering
\begin{tabular}{|l|l|}
\hline
\textbf{ATTACHMENT 1} & \\
\hline
\textbf{Experimental procedure and spectra} & \textbf{Page} \\
\hline
(2\textit{R},4\textit{R})-2-(ethoxycarbonyl)-4-hydroxypyrrolidinium chloride (\textbf{I}) & S63 \\
(2\textit{S},4\textit{R})-2-(ethoxycarbonyl)-4-hydroxypyrrolidinium chloride (\textbf{II}) & S63 \\
(2\textit{S},4\textit{R})-1-\textit{tert}-butyl 2-ethyl 4-hydroxypyrrolidine-1,2-dicarboxylate (\textbf{III}) & S63-S64 \\
\(^1\)H- and \(^{13}\)C NMR spectra of ester \textbf{I} & S65-S66 \\
HRMS (ESI) of ester \textbf{I} & S67 \\
\(^1\)H- and \(^{13}\)C NMR (300 MHz, CD\textsubscript{3}OD) spectrum of ester \textbf{II} & S68-S69 \\
HRMS (ESI) of ester \textbf{II} & S70 \\
\(^1\)H- and \(^{13}\)C NMR spectrum of ester \textbf{III} & S71-S72 \\
HRMS (ESI) of ester \textbf{III} & S73 \\
\hline
\end{tabular}
\end{table}
Experimental procedures

\((2R,4R)\)-tert-Butyl 2-formyl-4-hydroxypyrrolidine-1-carboxylate (7): A stirred solution of \((2R,4R)\)-1-tert-butyl 2-ethyl 4-methoxypyrrolidine-1,2-dicarboxylate (0.25 g, 0.96 mmol, see attachment I for experimental details) in anhydrous dichloromethane (5 mL), at -84 °C and under argon atmosphere, was slowly added (during 5 minutes) a toluene solution of DIBAL-H (1.0 mol/L solution, 1.9 ml, 2.89 mmol). The mixture was stirred for 20 min. At the same temperature and the evolution was followed by TLC. The cooling bath was removed and a saturated solution of sodium acetate (5 mL) was added. The reaction medium was poured into a stirred mixture of ethyl ether (50 mL) and saturated ammonium chloride (10 mL). After 2h, the gel formed was filtered over a pad of Celite® and the aqueous filtrate was extracted again with ethyl ether. The organic phases were combined, dried over anhydrous \(\text{Na}_2\text{SO}_4\) and evaporated. The residue was quickly filtered over a tiny amount of silica gel (Hexane : AcOEt 40:60 to 20:80), to provide aldehyde 7, as colorless oil (0.190 g) in 92 \% yield. Hydroxy-aldehyde 7 should be stored at -20 °C or used immediately after be prepared. \([\alpha]_D^{20} +45 \text{ (c 1.5; MeOH)}\); IR (Film, \(\nu_{\text{max}}\)): 3377, 2974, 2931, 2838, 1728, 1646, 1428, 1370, 1279 \text{ cm}^{-1}; \(^1\text{H NMR (250 MHz, DMSO-d}_6\text{, 90 °C)} \delta 1.42 (9H, s), 1.89 (1H, m), 2.23 (1H, m), 3.31 (1H, dd); 3.42 (1H, dd), 4.04 (1H, m), 4.27 (1H, m), 9.47 (1H, s); \(^{13}\text{C NMR (62.5 MHz, DMSO-d}_6\text{, 90 °C)} \delta 28.5, 38.1, 55.2, 64.1, 68.7, 79.7, 154.7, 202.8; \text{ HRMS (ESI-TOF)} \text{ Calcd. for C}_{10}\text{H}_{18}\text{NO}_4 \text{ [M + H]}^+ 216.1236. Found 216.1245. GC conditions: HP chiral, flow 1.5 mL/min; 100 °C; 10 °C/min up to 230 °C; pos run: 230 °C/15 min); \(T_R = 15.57 \text{ min (2); dr = 1:12.}\)

\((2R,4R)\)-tert-Butyl 4-hydroxy-2-((S)-1-hydroxy-2-(methoxycarbonyl)allyl)pyrrolidine-1-carboxylate (8): A mixture of hydroxy-aldehyde 7 (0.23 g, 1.069 mmol), DABCO (0.12 g, 1.069 mmol) and ethyl acrylate (2 mL) was sonicated for
96 h (followed by GC). Then, the excess of methyl acrylate was removed under reduced pressure (CAUTION: this operation should be performed under an efficient fume hood). The residue was diluted with dichloromethane (20 mL). The organic phase was washed with brine (3 x 30 mL), dried over anhydrous Na$_2$SO$_4$ and evaporated. The crude residue was purified by flash silica gel column chromatography (Hexane : CH$_2$Cl$_2$ : AcOEt – 3.0:5.0:3.0) to provide adduct 8 (0.258 g), as a colorless oil, in 80 % yield. $[\alpha]_D^{20}$ -2 (c 1.5; MeOH); IR (Film, $\nu_{\text{max}}$): 3387, 2970, 2958, 2933, 2355, 2332, 1715, 1666, 1413, 1368, 1155, 1090; $^1$H NMR (250 MHz, DMSO-d$_6$, 90 °C) $\delta$ 1.43 (s, 9H), 1.74 (dt, $J = 13.9, 4.3$ Hz, 1H), 1.92 (m, 1H), 3.10 (dd, $J = 11.2, 3.9$ Hz, 1H), 3.57 (dd, $J = 11.2, 5.9$ Hz, 1H), 3.71 (s, 3H), 4.05 (m, 2H), 4.94 (m, 1H), 5.87 (t, $J = 1.6$ Hz, 1H), 6.17 (d, $J = 1.3$ Hz, 1H); $^{13}$C NMR (62.5 MHz, DMSO-d$_6$, 90 °C) $\delta$ 27.8, 32.9, 50.8, 54.8, 58.6, 67.4, 68.0, 78.0, 124.0, 142.2, 153.2, 165.6; HRMS (ESI-TOF) Calcd. for C$_{14}$H$_{24}$NO$_6$ [M + H]$^+$ 302.1604. Found 302.1681; GC conditions: HP chiral, flow 1.5 mL/min; 100 °C; 10 °C/min up to 230 °C; pos run: 230 °C/15 min; $T_R = 22.97$ min.

(1S,6R,7aR)-1,6-dihydroxy-2-methylenetetrahydro-1H-pyrrolizin-3(2H)-one (11): To a stirred solution of Morita-Baylis-Hillman adduct 8 (0.20 g, 0.66 mmol) in toluene (3 mL), at 0 °C, was added concentrated HCl (0.1 mL, 3.31 mmol). The resulting mixture was further stirred for 5-7 min. Then, a 35% solution of NaOH was added (0.46 mL, 4 mmol) and the reaction was further stirred for 30 min, at room temperature. The medium was neutralized to pH 7 (10% HCl solution) and the solvents were removed under reduced pressure. The crude residue was purified by flash silica gel column chromatography (CH$_2$Cl$_2$ : MeOH - 95:05) to give pyrrolizidine 11 (0.06 g) as a white solid, in 57 % yield. $[\alpha]_D^{20}$ -5 (c 2; EtOH); M.p. 93-94° C; IR (KBr): $\nu$ 3396, 3205, 2985, 2946, 2883, 1654, 1442 cm$^{-1}$. $^1$H NMR (500 MHz, (CD$_3$)$_2$CO) $\delta$ 1.67 (m, $J = 13.4, 6.4, 4.4$ Hz, 1H, H-7A), 2.35 (ddd, $J = 13.4, 7.3, 5.6$ Hz, 1H, H-7B), 3.17 (dd, $J = 12.2, 5.2$ Hz, 1H,
(2S,4R)-tert-butyl 2-formyl-4-hydroxypyrrolidine-1-carboxylate (9): A stirred solution of (2S,4R)-1-tert-butyl 2-ethyl 4-methoxypyrrolidine-1,2-dicarboxylate (0.25 g, 0.96 mmol, compound III, for details, see attachment I at the end of this supporting informations) in anhydrous dichloromethane (5 mL), at -84 ºC and under argon atmosphere, was slowly added (during 5 minutes) a toluene solution of DIBAL-H (1.0 mol/L solution, 1.9 ml, 2.89 mmol). The mixture was stirred for 20 min. At the same temperature. The reaction evolution was followed by TLC. The cooling bath was removed and a saturated solution of sodium acetate (5 mL) was added. The reaction medium was poured into a stirred mixture of ethyl ether (50 mL) and saturated ammonium chloride (10 mL). After 2h, the gel formed was filtered over a pad of Celite® and the aqueous filtrate was extracted again with ethyl ether. The organic phases were combined, dried over anhydrous Na$_2$SO$_4$ and evaporated. The residue was quickly filtered over a tiny amount of silica gel (Hexane : AcOEt 40:60 to 20:80), to provide aldehyde 9, as colorless oil (0.188 g) in 91 % yield. Hydroxy-aldehyde 9 should be stored at -20 ºC or used immediately after be prepared. [α]$_D^{20}$ -54.5 (c 1.5; MeOH); IR (Film, ν$_{max}$): 3395, 2978, 2933, 1736, 1669, 1409, 1365, 1160, 1123 cm$^{-1}$; $^1$H NMR (300 MHz, DMSO-d$_6$, 90 ºC) δ 1.42 (s, 9H), 1.96 (m, 2H), 3.43 (m, 2H), 4.14 (m, 1H), 4.25 (m, 1H), 9.43 (s, 1H); $^{13}$C NMR (75 MHz, DMSO-d$_6$, 90 ºC) δ 28.5, 35.8, 55.5, 64.0, 68.7, 79.9, 154.2, 200.7; HRMS (ESI-TOF) Calcd. for C$_{10}$H$_{18}$NO$_4$ [M + H]$^+$ 216.1236. Found 216.1365. GC conditions: HP chiral, flow 1.5 mL/min; 100 ºC; 10 ºC/min up to 230 ºC; pos run: 230 ºC/15 min); T$_R$ = 15.39 min.

(2S,4R)-tert-butyl 4-hydroxy-2-((R)-1-hydroxy-2-(methoxycarbonyl)allyl)pyrrolidine-1-carboxylate (10): A mixture of hydroxy-aldehyde 9 (0.23 g, 1.069 mmol), DABCO (0.12 g, 1.069 mmol) and ethyl acrylate (2 mL) was sonicated for 96 h (followed by GC). Then, the excess of methyl acrylate was removed under reduced pressure (CAUTION: this operation should be performed under an efficient fume hood). The residue was diluted with dichloromethane (20 mL). The organic phase was washed with brine (3 x 30 mL), dried over anhydrous Na$_2$SO$_4$ and evaporated. The crude residue was purified by flash silica gel column chromatography (Hexane : CH$_2$Cl$_2$ : AcOEt – 3.0:5.0:3.0) to provide adducts 8 (0.206 g, see above for full spectral characterization) and 10 (0.052 g, spectral data below), as a colorless oil, in 70 % yield. [α]$_D^{20}$ -11 (c 1.5; MeOH); IR (Film, ν$_{max}$): 3402, 2879, 2952, 1720, 1670, 1417, 1368, 1273, 1163, 1092 cm$^{-1}$; $^1$H NMR (250 MHz, DMSO-d$_6$, 90 ºC) δ 1.45 (s, 9H), 1.52 (m, 1H), 1.98 (dt, J = 12.0, 5.9 Hz, 1H), 3.30 (m, 2H), 3.71 (s, 3H), 4.07 (m, 1H), 4.23 (s, 1H), 4.90 (s, 2H), 5.86 (s, 1H), 6.12 (s, 1H); $^{13}$C NMR (62.5 MHz, DMSO-d$_6$, 90 ºC) δ 27.8, 33.2, 50.8, 55.0, 58.4, 67.8, 68.1, 77.7, 123.6, 142.0, 153.5, 165.7; HRMS (ESI-TOF) Calcd. for C$_{14}$H$_{24}$NO$_6$ [M + H]$^+$ 302.1604. Found 302.1634. GC conditions: HP chiral, flow 1.5 mL/min; 100 ºC; 10 ºC/min up to 230 ºC; pos run: 230 ºC/15 min); T$_R$ = 22.09 min.
To a stirred solution of Morita-Baylis-Hillman adduct 10 (0.05 g, 0.165 mmol) in toluene (1 mL), at 0 °C, was added concentrated HCl (300 µL, 1.1 mmol). The resulting mixture was further stirred for 5-7 min. Then, a 35% solution of NaOH was added (0.16 mL, 1 mmol) and the reaction was further stirred for 30 min, at room temperature. The medium was neutralized to pH 7 (10% HCl solution) and the solvents were removed under reduced pressure. The crude residue was purified by flash silica gel column chromatography (CH₂Cl₂:MeOH - 95:05) to give pyrrolizidinone 12 (0.012 g) as a white solid, in 55 % yield. [α]D²⁰ -12 (c 2; DMSO); IR (Film, νmax): ν 3377, 3206, 2985, 2946, 2828, 1657, 1440 cm⁻¹; ¹H NMR (500 MHz, (CD₃)₂CO) δ 1.59 (ddd, J = 13.0, 10.8, 5.1 Hz, H-7B), 2.16 (dd, J = 13.0, 5.6 Hz, H-7A), 3.03 (d, J = 13.1 Hz, H-5A), 3.73 (dd, J = 13.0, 5.2 Hz, H-5B), 3.89 (dt, J = 10.5, 5.2 Hz, H-7a), 4.53 (dt, J = 5.1, 2.7 Hz, H-1), 4.59 (t, J = 5.1 Hz, H-6), 5.49 (d, J = 2.5 Hz, 1H, CH₂), 5.83 (d, J = 2.9 Hz, 1H, CH₂); ¹³C NMR (62.5 MHz, (CD₃)₂CO) δ 39.3, 51.6, 66.6, 72.8, 74.2, 116.9, 148.5, 167.9; HRMS (ESI-TOF) Calcd. for C₈H₁₂NO₃ [M + H]+ 170.0817. Found 170.0862.

To a solution of pyrrolizidinone 11 (0.13 g, 0.77 mmol) in DMF (3 mL) was added iodobenzene (0.184 g, 0.92 mmol, 0.1 mL) de iodobenzeno, triethylamine (0.218 g, 2.16 mmol, 0.3 mL) and Nájera palladacycle 13 (0.5 mol%, 0.004 mmol, 0.003 g). The resulting dark brown solution was stirred for 5h, at 110-120 °C. Then the solvent was removed under reduced pressure and the residue was purified by flash silica gel column chromatography (CH₂Cl₂:MeOH – solvent gradient: 0:100 to 97:05), to provide benzylidene-pyrrolizidinone 14 (0.14 g), as a colorless oil, in 76 %. [α]D²⁰ + 40 (c 1, MeOH); IR (Film, νmax): 3427, 3195, 2940, 2855, 1668, 1634, 1493, 1424,
1268, 1156, 1067 cm\(^{-1}\); \(^1\)H NMR (400 MHz, CD\(_3\)CN) \(\delta\) 1.30 (m, \(J = 13.8, 9.1, 5.4\) Hz, 1H, H-7A), 2.38 (m, \(J = 13.8, 6.8\) Hz, 1H, H-7B), 3.27 (dd, \(J = 12.3, 6.1\) Hz, 1H, H-5B), 3.56 (dd, \(J = 12.3, 3.3\) Hz, 1H, H-5A), 3.69 (ddd, \(J = 9.1, 7.4, 1.8\) Hz, 1H, H-7a), 4.47 (qd, \(J = 6.1, 3.3\) Hz, 1H, H-6), 4.91 (dd, \(J = 1.8\) Hz, 1H, H-1), 7.35 (d, \(J = 2.1\) Hz, 1H, CH), 7.41 (m, 3H, Ph), 7.79 (m, 3H, Ph); \(^{13}\)C NMR (62.5 MHz, (CD\(_3\)\(_2\)CO) \(\delta\) 38.1, 52.1, 68.2, 70.1, 72.0, 129.2, 130.3, 131.3, 134.1, 134.2, 137.1, 172.1; HRMS (ESI-TOF) Calcd. for C\(_{14}\)H\(_{16}\)NO\(_3\) \([M + H]^+\) 246.1130. Found 246.1168.

**1S,6R,7aR,Z)-1,6-dihydroxy-2-(4-hydroxybenzylidene)tetrahydro-1H-pyrrolizin-3(2H)-one (15):** To a solution of pyrrolizidinone 11 (0.25 g, 1.48 mmol) in DMF (3 mL) was added 4-iodophenol (0.49 g, 2.22 mmol), triethylamine (0.746 g, 7.39 mmol, 1.0 mL), Cy\(_2\)NMe (0.216 g, 1.1 mmol, 0.24 mL) and Najera palladacycle (0.5 mol%, 0.007 mmol, 0.006 g). The resulting brown solution was stirred for 8 h, at 110-120 °C. After, the solvent was removed under reduced pressure and the residue was purified by flash silica gel column chromatography (CH\(_2\)Cl\(_2\):MeOH – solvent gradient 0:100 to 97:3) to give hydroxybenzylidene-pyrrolizidinone 15 (0.20 g), as a colorless oil, in 51 % yield. [\(\alpha\)]\(_D\)\(^{20}\) + 32 (c 1, MeOH); IR (Film, \(\nu\) max): 3333, 2941, 1668, 1633, 1603, 1371, 1274, 1175, 1066 cm\(^{-1}\); \(^1\)H NMR (250 MHz, D\(_2\)O) \(\delta\) 1.36 (m, \(J = 13.3, 9.3, 5.7\) Hz, 1H, H-7A), 2.50 (dt, \(J = 13.3, 6.8\) Hz, 1H, H-7B), 3.39 (dd, \(J = 12.6, 6.3\) Hz, 1H, H-5B), 3.55 (dd, \(J = 12.6, 3.4\) Hz, 1H, H-5A), 3.78 (t, \(J = 8.3\) Hz, 1H, H-7a), 4.60 (m, 1H, H-6), 5.07 (t, \(J = 1.8\) Hz, 1H, H-1), 6.89 (d, \(J = 8.7\) Hz, 2H, Ar), 7.28 (d, \(J = 1.8\) Hz, 1H, CH), 7.59 (d, \(J = 8.7\) Hz, 2H, Ar); \(^{13}\)C NMR (62.5 MHz, (CD\(_3\)\(_2\)CO) 39.9, 53.5, 68.8, 70.7, 73.0, 116.4, 127.4, 132.5, 133.8, 136.3, 159.6, 172.4; HRMS (ESI-TOF) Calcd. for C\(_{14}\)H\(_{16}\)NO\(_3\) \([M + H]^+\) 262.1079. Found 262.1122.

**1S,6R,7aR,Z)-1,6-dihydroxy-2-(4-nitrobenzylidene)tetrahydro-1H-pyrrolizin-3(2H)-ona (16):** To a solution of pyrrolizidinone 11 (0.30 mmol, 0.05 g) in DMF (3 mL) were added 4-nitro-iodobenzene (1.5 equiv., 0.44 mmol, 0.11 g), triethylamine (5.0 equiv., 1.48 mmol, 0.2 mL), N-Methyl-dicyclohexylamine (Cy\(_2\)NMe, 0.75 equiv., 0.22 mmol, 0.04 mL), Najera’s palladacycle I (\(13\), 0.5 mol%, 0.002 mmol, 0.001 g). The resulting solution was stirred at 110-120 °C for 8 hs. After that, the solvent was removed under reduced pressure and the residue was purified by flash silica gel column chromatography (230-400 mesh; CH\(_2\)Cl\(_2\):MeOH - 0:100 to 95:5) to afford 0.07 of benzylidene-pyrrolizidinone 16, as a colorless oil, in 83% yield. [\(\alpha\)]\(_D\)\(^{20}\) + 28° (c 2, MeOH); IR (Film, \(\nu\) max): 3308, 2974, 2924, 2864, 1699, 1671, 1644, 1596, 1523, 1513, 1435, 1381, 1346, 1314, 1264, 1244, 1220, 1202, 1133, 1104, 1075, 1055 cm\(^{-1}\); \(^1\)H NMR (400 MHz, CD\(_3\)OD) \(\delta\) 1.49 (ddd, \(J = 13.2, 8.3, 5.1\) Hz, 1H, H-7A); 2.49 (ddd, \(J = 13.3, 7.4, 6.2\) Hz, 1H, H-7B); 3.38 (dd, \(J = 12.4, 5.8\) Hz, 1H, H-5B); 3.68 (dd, \(J = 12.4, 3.0\) Hz, 1H, H-5A); 3.80 (td, \(J = 8.1, 2.4\) Hz, 1H, H-7a); 4.56 (qd, \(J = 5.8, 3.3\) Hz 1H, H-6); 5.01 (t, \(J = 2.4\) Hz, 1H, H-1); 7.45 (d, \(J = 2.3\) Hz, 1H, CH); 8.01 (d, \(J = 8.8\) Hz, 2H, Ar); 8.26 (d, \(J = 8.9\) Hz, 2H, Ar); \(^{13}\)C NMRN (62.5 MHz, CD\(_3\)CN) 39.2, 53.3, 68.4, 71.5, 72.5, 124.3;
**General experimental procedure for the amide carbonyl reduction of pyrrolizidinones 14, 15, 18, 20:**

For example, to a solution of pyrrolizidinone 18 (0.063 g, 0.25 mmol) in anhydrous THF (5 mL) was added a freshly prepared solution of AlH₃ in THF (1 mol/L, 10 equiv., 2.5 mmol, 2.3 mL). The AlH₃ solution was prepared as follow: A solution of LiAlH₄ (2.4 mol/L, 2.5 mL, THF) was added, at 0°C, to a solution of AlCl₃ (2 mmol, 0.27 g) in anhydrous THF (5 mL). The resulting solution was stirred for 40 min. After addition, the reaction medium was stirred for 30-60 min, at room temperature. Then, the medium was quenched with a saturated solution of Na₂SO₄ and filtered over a pad of Celite® and the solvents were removed under reduced pressure. The residue was purified by neutral alumina column.
chromatography (eluting system CH₂Cl₂:MeOH 9:0:1:0) for compounds 18 and 20, and eluting system CH₂Cl₂:MeOH:NH₂OH (30 %) 7:8:2:0:0:2) for compounds 16 and 17, to provide the corresponding pyrrolizidines 19 in 80% yield, 21 in 53% yield, 22 in 50% yield and 23 in 21% yield.

**(1S,2R,6R,7aR)-2-benzylhexahydro-1H-pyrrolizine-1,6-diol** (19): a colorless oil; [α]D20 = 197 (c 1, MeOH); IR (Film, νmax): 3325, 2926, 2899, 1447, 1383, 1296, 1114, 1073 cm⁻¹; ¹H NMR (400 MHz, D₂O) δ 1.82 (dt, J = 13.6, 4.3 Hz, 1H, H-7a), 2.16 (dd, J = 13.6, 8.3, 5.4 Hz, 1H, H-7B), 2.31 (m, 1H, H-2), 2.59 (m, J = 14.0, 9.8 Hz (CH₂), J = 11.8, 4.0 Hz (H-5B), J = 11.0 Hz (H-3) 3H), 2.92 (dd, J = 11.8, 4.5 Hz, 1H, H-5A), 3.03 (m, J = 14.0, 4.1 Hz (CH₂), J = 11.0 Hz (H-3), 2H), 3.24 (td, J₁2 = 7.7, 4.8 Hz, 1H, H-7a), 3.88 (dd, J₁₂ = 9.5, J₁₇a = 7.7 Hz, 1H, H-1), 4.39 (quin, J = 4.5 Hz, 1H, H-6), 7.26 (t, J = 6.9 Hz, 3H, Ph), 7.35 (t, J = 7.4 Hz, 2H, Ph); ¹³C(100 MHz, D₂O) δ 35.7, 37.1, 48.6, 58.0, 60.3, 68.6, 73.1, 80.8, 126.3, 128.6, 128.9, 140.2; HRMS (ESI-TOF) calcd for C₁₄H₂₀NO₂ [M + H]⁺ 234.1494, found 234.1491.

**(1S,2R,6R,7aR)-2-(4-hydroxybenzyl)hexahydro-1H-pyrrolizine-1,6-diol** (21): a colorless oil; [α]D20 = 62 (c 1, MeOH); IR (Film, νmax): 3333, 2927, 2594, 1613, 1596, 1514, 1444, 1365, 1247, 1117, 1088 cm⁻¹; ¹H NMR (400 MHz, D₂O) δ 1.99 (d, J = 13.2, 4.0 Hz, 1H, H-7A) 2.22 (dd, J = 13.9, 8.9, 5.0 Hz, 1H, H-7B), 2.33 (m, 1H, H-2), 2.53 (dd, J = 13.9, 8.8 Hz, 1H, CH₂), 2.84 (dd, J = 12.1, 11.0 Hz, 1H, H-3), 2.91 (m, J = 13.9, 4.0 Hz (CH₂), J = 12.4, 3.8 Hz (H-5A), 2H), 3.16 (dd, J = 12.4, 4.1 Hz, 1H, H-5B), 3.38 (dd, J = 10.6, 6.9 Hz, 1H, H-3), 3.60 (td, J = 8.5, 3.4 Hz, 1H, H-7a), 3.98 (dd, J₁₂ = 9.6, J₁₇a = 8.0 Hz, 1H, H-1), 4.49 (m, 1H, H-6), 6.78 (m, J = 8.5 Hz, 2H, Ar), 7.06 (d, J = 8.5 Hz, 2H, Ar); ¹³C(100 MHz, D₂O) δ 33.8, 36.5, 47.8, 58.3, 60.3, 69.9, 72.4, 79.4, 115.8, 130.1, 130.3, 155.2; HRMS (ESI-TOF) Calcd. for C₁₄H₂₀NO₃ [M + H]⁺ 250.1443. Found 250.1461.

**(1S,6R,7aR,Z)-2-benzylidenehexahydro-1H-pyrrolizine-1,6-diol** (22): a colorless oil; [α]D20 = -73 (c 1, MeOH); IR (Film, νmax): 3406, 2925, 2855, 1646, 1495, 1448 1108, 1019 cm⁻¹; ¹H NMR (400 MHz, (CD₃)₂CO) δ 1.58 (m, J = 13.9, 8.4, 6.0 Hz, 1H, H-7A), 2.55 (m, J = 13.9, 8.4, 6.5 Hz, 1H, H-7B), 3.02 (dd, J = 11.9, 5.2 Hz, 1H, H-5B), 3.71 (dd, J = 11.9, 5.8 Hz, 1H, H-5A), 4.03 (d, J = 15.3 Hz, 1H, H-3), 4.22 (t, J₇a7a = 7.7B, 8.4 Hz, 1H, H-7a), 4.50 (quin, J = 5.8 Hz, 1H, H-6), 4.57 (d, J = 15.3 Hz, 1H, H-3), 4.70 (s, 1H, H-1), 6.79 (s, 1H, CH), 7.29 (t, J = 7.3 Hz, 1H, Ph), 7.37 (t, J = 7.5 Hz, 2H, Ph), 7.60 (d, J = 7.4 Hz, 2H, Ph); ¹³C NMR (62.5 MHz, (CD₃)₂CO) δ 39.2, 60.0, 61.6, 71.6, 74.1, 75.8, 127.0, 127.7, 129.0, 129.6, 137.8, 142.8; HRMS (ESI-TOF) Calcd. for C₁₄H₁₈NO₂ [M + H]⁺ 232.1338. Found 232.1380.

**(1S,6R,7aR,E)-2-(4-hydroxybenzylidene)hexahydro-1H-pyrrolizine-1,6-diol** (23): a colorless oil; [α]D20 = -48 (c 0.7, MeOH); IR (Film, νmax): 3431, 2923, 2852, 1628, 1603, 1509, 1416, 1384, 1364, 1268, 1242 cm⁻¹; ¹H NMR (400 MHz, D₂O)
$\delta$ 1.77 (m, $J = 13.6, 11.5, 5.6$ Hz, 1H, H-7A), 2.46 (m, $J = 13.9, 7.3$ Hz, 1H, H-7B), 2.74 (dd, $J = 11.5, 5.1$ Hz, 1H, H-5B), 3.30 (dd, $J = 11.5, 5.6$ Hz, 1H, H-5A), 3.43 (m, $J = 11.5, 7.0, 4.3$ Hz, 1H, H-7a), 3.85 (d, $J = 16.0, 1.5$ Hz, 1H, H-3), 4.17 (d, $J = 16.0$ Hz, 1H, H-3), 4.47 (m, $J = 5.6$ Hz 1H, H-6), 4.70 (d, $J = 4.3$ Hz, 1H, H-1), 6.67 (s, 1H, CH), 6.83 (d, $J = 8.5$ Hz, 2H, Ar), 7.18 (d, $J = 8.5$ Hz, 2H, Ar); $^{13}$C NMR (125 MHz, D$_2$O) $\delta$ 36.9, 55.3, 61.0, 69.5, 71.6, 79.5, 116.9, 126.1, 126.8, 130.6, 137.0, 159.5; HRMS (ESI-TOF) Calcd. for C$_{14}$H$_{18}$NO$_3$ [M + H]$^+$ 248.1287. Found 248.1289.

References:
$^{1}$H NMR (250 MHz, DMSO-d$_6$, 90 ºC) spectrum of cis-4-hydroxy-$(D)$-prolinal 7.
$^{13}$C NMR (62.5 MHz, DMSO-$d_6$, 90 °C) spectrum of cis-4-hydroxy-(D)-prolinaldehyde 7.
$^1$H NMR (250 MHz, DMSO-$d_6$, 90 °C) spectrum of MBH adduct 8.
$^{13}$C NMR (62.5 MHz, DMSO-d$_6$, 90 °C) spectrum of MBH adduct 8.
HRMS (ESI) of MBH adduct 8.
$^1$H NMR (500 MHz, (CD$_3$)$_2$CO) spectrum of pyrrolizidinone 11.
$^{13}$C NMR (62.5 MHz, (CD$_3$)$_2$CO) spectrum of pyrrolizidinone 11.
HRMS (ESI) of pyrrolizidinone 11.
$^{1}$H NMR (300 MHz, DMSO-$d_6$, 90 ºC) spectrum of trans-hydroxy-prolinal 9.
$^{13}$C NMR (75 MHz, DMSO-d$_6$, 90 ºC) spectrum of *trans*-hydroxy-prolinal 9.
$^1$H NMR (250 MHz, DMSO-$d_6$, 90 ºC) spectrum of MBH adduct 10.
$^{13}$C NMR (62.5 MHz, DMSO-$d_6$, 90 ºC) spectrum of MBH adduct 10.
HRMS (ESI) of MBH adduct 10.
$^1$H NMR (500 MHz, (CD$_3$)$_2$CO) spectrum of pyrrolizidinone 12.
$^{13}$C NMR (62.5 MHz, (CD$_3$)$_2$CO) spectrum of pyrrolizidinone 12.
HRMS (ESI) of pyrrolizidinone 12.
nOe [500 MHz, (CD$_3$)$_2$CO] spectrum of pyrrolizidinone 12, irradiation at 1.59 ppm, H-7B.

nOe [500 MHz, (CD$_3$)$_2$CO] spectrum of pyrrolizidinone 12, irradiation at 3.73 ppm, H-5B.
nOe [500 MHz, (CD$_3$)$_2$CO] spectrum of pyrrolizidinone 12, irradiation at 3.89 ppm, H-7a.

nOe [(500 MHz, (CD$_3$)$_2$CO] spectrum of pyrrolizidinone 12, irradiation at 4.53 ppm, H-1)
nOe [500 MHz, (CD$_3$)$_2$CO] spectrum of pyrrolizidinone 12, irradiation at 4.59 ppm, H-6)
$^1$H NMR (400 MHz, CD$_3$CN) spectrum of benzylidene-pyrrolizidinone 14.
$^{13}$C NMR [62.5 MHz, (CD$_3$)$_2$CO] spectrum of benzylidene-pyrrolizidinone 14.
2-D NOESY (400 MHz, CD$_3$CN) spectrum of benzylidene-pyrrolizidine 14.
HRMS (ESI) of benzylidene-pyrrolizidinone 14.
$^1$H NMR (250 MHz, $D_2$O) spectrum of hydroxy-benzylidene-pyrrolizidinone 15.
$^{13}$C NMR [62.5 MHz, (CD$_3$)$_2$CO] spectrum of hydroxy-benzylidene-pyrrolizidinone 15.
2-D NOESY (400 MHz, D$_2$O) spectrum of hydroxy-benzylidene-pyrrolizidinone 15.
HRMS (ESI) of hydroxy-benzylidene-pyrrolizidinone 15.
$^1$H NMR (400 MHz, CD$_3$OD) spectrum of $p$-nitro-benzylidene-pyrrolizidinone 16.
$^{13}$C NMR (62.5 MHz, CD$_3$CN) spectrum of $p$-nitro-benzylidene-pyrrolizidinone 16.
2D-NOESY (400 MHz, CD$_3$OD) spectrum of p-nitro-benzylidene-pyrrolizidinone 16.
HRMS (ESI) of $p$-nitro-benzylidene-pyrrolizidinone 16.
$^1$H NMR (500 MHz, CD$_3$OD) spectrum of benzyl-pyrrolizidinone 18.
$^{13}$C NMR [62.5 MHz, (CD$_3$)$_2$CO)] spectrum of benzyl-pyrrolizidinone 18.
HRMS (ESI) of benzyl-pyrrolizidinone 18.
$^1$H NMR [400 MHz, (CD$_3$)$_2$CO] spectrum of hydroxy-benzyl-pyrrolizidinone 20.
$\text{C NMR [62.5 MHz, (CD}_3\text{CO)] spectrum of hydroxy-benzyl-pyrrolizidinone 20.}$
HRMS (ESI) of hydroxy-benzyl-pyrrolizidinone 20.
$^1$H NMR [400 MHz, (CD$_3$)$_2$CO] spectrum of benzylidene-pyrrolizidine 22.
$^{13}$C NMR [(62.5 MHz, (CD$_3$)$_2$CO)] spectrum of benzylidene-pyrrolizidine 22.
2D-NOESY [400 MHz, (CD$_3$)$_2$CO)] spectrum of benzylidene-pyrrolizidine 22.
HRMS (ESI) of benzylidene-pyrrolizidine 22.
$^1$H NMR (400 MHz, D$_2$O) spectrum of hydroxy-benzylidene-pyrrolizidine 23.
$^{13}$C NMR (125 MHz, D$_2$O) spectrum of hydroxy-benzylidene-pyrrolizidine 23.
2D-NOESY (400 MHz, D$_2$O) spectrum of hydroxy-benzylidene-pyrrolizidine 23.
HRMS (ESI) of hydroxy-benzylidene-pyrrolizidine 23.
$^1$H NMR (400 MHz, D$_2$O) spectrum of benzyl-pyrrolizidine 19.
$^{13}$C NMR (100 MHz, D$_2$O) spectrum of benzyl-pyrrolizidine 19.
HMRS (ESI) of benzyl-pyrrolizidine 19.
'H NMR (400 MHz, D2O) spectrum of hydroxy-benzyl-pyrrolizidine 21.
$^{13}$C NMR (100 MHz, D$_2$O) spectrum of hydroxy-benzyl-pyrrolizidine 21.
HRMS (ESI) of hydroxy-benzyl-pyrrolizidine 21.
NOTE: In this part of our supporting information we have included the experimental procedure for the preparation the intermediates used for the synthesis of our asymmetric aldehydes. They appear here because these compounds are not cited in the manuscript. In order to differentiate these compounds from those described in our manuscript they were numbered using roman numbers.

(2R,4R)-2-(ethoxycarbonyl)-4-hydroxypyrrolidinium chloride (I):
To a solution of commercial cis-4-hydroxy-D-proline or trans-4-hydroxy-L-proline (0.50 g, 3.81 mmol) in ethanol (10 mL), at 0 ºC, was slowly dropped thionyl chloride (0.31 mL, 0.513 g, 4.31 mmol). After that, the cooling bath was removed and the resulting solution was refluxed for 12h and cooled to room temperature. The resulting crystals was filtered, washed with ethyl ether and dried under reduced pressure. The filtrate was diluted with ethyl ether to obtain crystals that were filtered, washed with ethyl ether and dried. The crystals were combined to afford 0.73 g of the corresponding ester in 98 % yield. [α]D^20 +18 (c 2; H2O); Lit. 1 [α]D^20 +20.37 (c 2; H2O); M. p. 143° C; IR (KBr, νmax): ν 3303, 2975, 2940, 1727, 1581, 1380, 1247, 1094 cm\(^{-1}\).
1H NMR (250 MHz, D2O) δ 1.29 (3H, t), 2.48 (2H, m), 3.46 (2H, m), 4.31 (2H, q), 4.64 (1H, m); 13C NMR (62.5 MHz, D2O) δ 12.8, 36.6, 53.1, 58.2, 63.6, 68.6, 170.0. HRMS (ESI-TOF) Calcd. for C7H14NO3 [M + H]^+ 160.0974. Found 160.0927.

(2S,4R)-2-(ethoxycarbonyl)-4-hydroxypyrrolidinium chloride (II):
[α]D^20 -29.2º (c 3; H2O); Lit. 2 [α]D^20 -28º (c 3; H2O); M. p. 144° C; IR (KBr, νmax): ν 3309, 2949, 2864, 2700, 2598, 1732, 1274, 1237 cm\(^{-1}\); 1H NMR (300 MHz, CD3OD) δ 1.33 (t, 3H), 2.19 (ddd, 1H), 2.43 (m, 1H), 3.31 (m, 1H), 3.45 (dd, 1H), 4.32 (q, 2H), 4.58 (m, 2H); 13C NMR (75 MHz, CD3OD) δ 14.3, 38.6, 55.0, 59.5, 64.0, 70.6, 170.2; HRMS (ESI-TOF) Calcd. for C7H14NO3 [M + H]^+ 160.0974. Found 160.1016.

(2S,4R)-1-tert-butyl 2-ethyl 4-hydroxypyrrolidine-1,2-dicarboxylate (III):
To a solution of the ester II (0.3 g, 1.53 mmol) in methanol (15 mL) was added di-terc-butyldicarbonate (Boc2O, 0.4 g, 1.84 mmol) and NaHCO3 (0.386 g, 4.60 mmol). The resulting suspension was immersed in a ultrasound bath for 4 h. The development of the reaction was followed by the CO2 releasing. After that, the solvent was removed and the residue was dissolved in cooled distilled water (10 mL) and the solution was acidified with a saturated solution of KHSO4 until pH 2 and extracted with ethyl acetate. The organic phase was separated, dried over anhydrous Na2SO4 and removed under reduced pressure to give 0.42 g of III, as a colorless oil, in 91 % yield [α]D^20 -69.1 (c 2; EtOH); Lit. 3 [α]D^20 -67.8 (c 2; EtOH); IR (film, νmax): 3436, 2976, 2933, 1744, 1703, 1679, 1401, 1192, 1155 cm\(^{-1}\); 1H NMR (300 MHz, DMSO-d6, 90 ºC) δ 1.21 (t, 3H), 1.38 (s, 9H), 2.06 (m, 2H), 3.33 (m, 2H), 4.12 (q, 2H), 4.26 (m, 2H); 13C NMR (75 MHz, DMSO-d6, 90 ºC) δ 13.5, 27.6, 38.2, 54.1, 57.4, 59.8, 67.7, 78.5,
152.9, 172.0; HRMS (ESI-TOF) Calcd. for C_{12}H_{22}NO_{5} [M + H]^+ 260.1498. Found 260.1473.

References:

$^1$H NMR (250 MHz, D$_2$O) spectrum of ester I.
$^{13}$C NMR (62.5 MHz, D$_2$O) spectrum of ester I.
HRMS (ESI) of ester I.
\(^1\)H NMR (300 MHz, CD\(_3\)OD) spectrum of ester II.
$^{13}$C NMR (75 MHz, CD$_3$OD) spectrum of ester II.
HRMS (ESI) of ester II.
$^1$H NMR (300 MHz, DMSO-$d_6$, 90 °C) spectrum of ester III.
$^{13}C$ NMR (75 MHz, DMSO-$d_6$, 90 °C) spectrum of ester III.
HRMS (ESI) of ester III.