Supporting Information (Org. Lett.)

Probing the Stereoselectivity of the Heck Arylation of Endocyclic Enecarbamates with Diazonium Salts. Concise Syntheses of (2*S*,5*R*)-Phenylproline Methyl Ester and Schramm's C-Azanucleoside.

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Heck arylation procedure. Synthesis of **8a** and **8b**:

(2*RS*,5*S*)-1-(*tert*-Butoxycarbonyl)-2-phenyl-5-carbomethoxy-3-pyrroline (8a,b**).**

To a solution of enecarbamate **7** (400 mg; 1.76 mmol) in 20 mL of dry acetonitrile was added, at once, a mixture of C₆H₅N₂BF₄ (500 mg, 2.60 mmol), Pd₂(dba)₃.dba (80 mg, 0.07 mmol) and NaOAc (650 mg, 7.92 mmol). The resulting dark mixture was stirred in a water bath at 30°C for 30 min, followed by the addition of 50 mL of EtOAc and 50 mL of saturated solution of NaHCO₃. The organic layer was separated and aqueous layer was extracted with EtOAc (30 mL). The combined organic layers were washed with water, saturated NaCl solution and then dried over anhydrous Na₂SO₄. After filtration, the solvent was evaporated in vacuum and the residue was flash chromatographed on silica gel (EtOAc/Hex = 4:1) to provide 500 mg (1.50 mmol; 70% yield) of an oil corresponding to the mixture of 3,4-desidroprolines **8a,b** which appears as a single spot on TLC. R_f = 0.29 (EtOAc/Hex = 1:4).

Heck arylation procedure. Synthesis of **12a** and **12b**:

To a solution of hydroxy enecarbamate **5** (507 mg; 2.86 mmol) in 30 mL of dry acetonitrile was added at once a mixture of *p*-(MeOCONH)-C₆H₄N₂BF₄ (758 mg; 2.86 mmol), Pd₂(dba)₃.dba (33 mg; 0.0286 mmol) and anhydrous NaOAc (704 mg; 8.58 mmol). The mixture became dark almost immediately displaying intense nitrogen bubbling. Magnetic stirring continued for 30 min when TLC indicated complete consumption of the starting enecarbamate **5**. The solvent was then evaporated *in vacuo* and the resulting residue dissolved in EtOAc (50 mL). This solution was then filtered through a short pad of silica gel and the filtrate concentrated in a rotatory evaporator. The residue was flash chromatographed (EtOAc/Hex = 1:2) to provide 478 mg of prolinol **12b** and 319 mg of prolinol **12a** (80% total yield).

Selected spectroscopic data

(5S)-1-(tert-Butoxycarbonyl)-5-hydroxymethyl-2-pyrroline (5).

TLC: R_f = 0.50 (EtOAc/Hex = 2:3) stained with I_2

Mp = 143-145 $^{\circ}$ C (white solid)

IR (film, NaCl) ν (cm^{-1}): 3440, 2978, 2935, 2873, 1697, 1624, 1400, 1369, 1138, 1045, 891.

^1H NMR (300 MHz, C_6D_6 , T = 55 $^{\circ}$ C, rotamers) δ (ppm): 6.38 (bs, 1H), 4.57 (m, 1H), 4.14 (m, 1H), 3.92 (bs, 1H), 3.68 (m, 1H), 3.51 (2dd, 1H, J = 6.6 and 11.1 Hz), 2.36 (m, 1H), 1.97 (apparent bs, 1H), 1.35 (s, 9H).

^{13}C NMR (75 MHz, C_6D_6 , rt) δ (ppm): 153.8, 129.5, 106.9, 80.8, 66.7, 60.2, 33.0, 28.3.

$[\alpha]_D^{20}$ = -143.8 (0.83, EtOAc).

HRMS (IE): Calcd. for $\text{C}_{10}\text{H}_{17}\text{NO}_3$, 199.12084; found 199.12354.

(2S,5S)-1-(tert-Butoxycarbonyl)-2-(p-methoxyphenyl)-5-hydroxymethyl-3-pyrroline (6a).

TLC: R_f = 0.30 (EtOAc/Hex = 1:1) phosphomolybdic acid

IR (film, NaCl) ν (cm^{-1}): 3408, 2976, 2931, 2837, 1693, 1670, 1610, 1512, 1456, 1394, 1367, 1248, 1174, 1132, 1036, 829.

^1H NMR (300 MHz, CDCl_3 , rotamers) δ (ppm): 7.25 (d, 1H, J = 8.6 Hz), 7.00 (d, 2H, J = 8.6 Hz), 5.88 (m, 2H), 5.51 (m, 1H), 5.13 (m, 1H), 4.06-3.85 (m, 3H), 3.96 (s, 1H), 1.33 (s, 9H).

^{13}C NMR (75 MHz, CDCl_3 , rotamers) δ (ppm): 158.8, 155.9, 133.9, 132.3, 127.5, 126.2, 125.2, 113.5, 80.5, 68.9, 68.4, 66.9, 28.3, 28.0.

$[\alpha]_D^{20}$ = -282 (0.40, CH_2Cl_2)

HRMS (IE): Calcd. for $\text{C}_{17}\text{H}_{23}\text{NO}_4$, 305.16271; found: 305.16209.

(2R,5S)-1-(tert-Butoxycarbonyl)-2-(p-methoxyphenyl)-5-hydroxymethyl-3-pyrroline (6b):

TLC: R_f = 0.40 (EtOAc/Hex = 1:1) phosphomolybdic acid

IR (film, NaCl) ν (cm^{-1}): 3411, 2974, 2931, 1695, 1670, 1612, 1512, 1394, 1248, 1173, 1111, 1036, 829.

^1H NMR (300 MHz, CDCl_3 , rotamers) δ (ppm): 7.27 (d, 2H, J = 8.6 Hz), 6.83 (d, 2H, J = 8.6 Hz), 5.68 (bs, 1H), 5.39 (bs, 1H), 4.80 and 4.78 (bs, 1H), 3.95-3.68 (m, 3H), 3.78 (s, 3H), 1.27 (s, 9H).

^{13}C NMR (75 MHz, CDCl_3 , rotamers) δ (ppm): 158.9, 133.2, 131.6, 128.3, 125.8, 125.2, 81.0, 68.9, 68.3, 68.1, 28.1.

$[\alpha]_D^{20}$ = +156 (0.08, CH_2Cl_2).

HRMS (IE): Calcd. for $\text{C}_{17}\text{H}_{23}\text{NO}_4$, 305.16271; found: 305.16035.

Methyl (2S,5S)-5-phenyl-pyrrolidine-2-carboxylate (10a).

TLC: R_f = 0.35 (EtOAc/Hex = 1:1) stained with I_2

IR (film, NaCl) ν (cm⁻¹): 3348, 3026, 2952, 2871, 1734, 1597, 1493, 1450, 1216, 1122, 1030, 761, 700.

¹H NMR (300 MHz, CDCl₃, rotamers) δ (ppm): 7.41-7.19 (m, 5H), 4.34 (t, 1H, J = 7 Hz), 4.02 (dd, 1H, J = 8.2 and 6 Hz), 3.74 (s, 3H), 2.47 (bs, 1H), 2.30 (m, 1H), 2.15 (m, 1H), 1.97 (m, 1H), 1.73 (m, 1H).

¹³C NMR (75 MHz, CDCl₃, rotamers) δ (ppm): 176.3, 144.3, 128.3, 126.9, 126.4, 61.7, 59.4, 34.6, 29.7.

$[\alpha]_D^{20}$ = -91 (0.43, CH₂Cl₂).

HRMS (IE): Calcd. for C₁₂H₁₅NO₂, 205.11028; found: 205.10819.

Methyl (2*S*,5*R*)-5-phenyl-pyrrolidine-2-carboxylate (10b).

TLC: R_f = 0.18 (EtOAc/Hex = 1:1) stained with I₂

IR (film, NaCl) ν (cm⁻¹): 3350, 3067, 3028, 2951, 2873, 1736, 1603, 1437, 1209, 1171, 1105, 758, 702.

¹H NMR (300 MHz, CDCl₃, rotamers) δ (ppm): 7.49-7.22 (m, 5H), 4.19 (dd, 1H, J = 9.2 and 5.6 Hz), 3.93 (dd, 1H, J = 8.4 and 4.8 Hz), 3.75 (s, 3H), 2.37 (bs, 1H), 2.15 (m, 3H), 1.68 (m, 1H).

¹³C NMR (75 MHz, CDCl₃, rotamers) δ (ppm): 175.5, 142.9, 128.4, 127.2, 126.4, 63.6, 60.0, 34.1, 30.53.

$[\alpha]_D^{20}$ = +11 (4.0, CH₂Cl₂).

HRMS (IE): Calcd. for C₁₂H₁₅NO₂, 205.11028; found: 205.10831.

(2*S*,5*S*)-1-(*tert*-Butoxycarbonyl)-2-(*p*-carbomethoxyamino-phenyl)-5-hydroxymethyl-3-pyrroline (12a).

TLC: R_f = 0.53 (EtOAc/Hex = 2:1); stained with I₂

Mp = 175.0-175.5⁰C (EtOAc, white solid)

IR (KBr) ν (cm⁻¹): 3255, 3194, 3124, 3066, 3001, 2978, 2954, 2939, 2900, 2854, 1736, 1655, 1604, 1543, 1412, 1311, 1223, 1146, 1065, 837, 771, 714.

¹H NMR (500 MHz, CD₃OD, rt, rotamers) δ (ppm): 7.40-7.24 (m, 4H), 5.99-5.90 (s + d, 1H, J = 6.1 Hz), 5.84-5.74 (s + d, 1H, J = 6.1 Hz), 5.46 and 5.40 (2s, 1H), 4.60 and 4.55 (2s, 1H), 3.97-3.88 (m + dd, 1H, J = 4.6 and 11.0 Hz), 3.77-3.68 and 3.60 (2m, 1H), 3.72 (s, 3H), 1.45 and 1.28 (2s, 9H).

¹³C NMR (75 MHz, CD₃OD, rt, rotamers) δ (ppm): 156.8, 156.4, 139.3, 137.4, 137.2, 132.2, 131.8, 128.8, 127.7, 119.3, 81.6, 70.3, 69.7, 68.6, 68.4, 65.7, 65.4, 52.5, 28.7.

$[\alpha]_D^{20}$ = -196.7 (2.26; CHCl₃).

MS (IE): 348 (1) [M⁺], 317 (39), 261 (35), 217 (100), 185 (42), 157 (21), 57 (59).

HRMS (IE): Calcd. for C₁₈H₂₄N₂O₅, 348.16852; found 348.16893.

(2*R*,5*S*)-1-(*tert*-Butoxycarbonyl)-2-(*p*-carbomethoxyamino-phenyl)-5-hydroxymethyl-3-pyrroline (12b).

TLC: R_f = 0.61 (EtOAc/Hex = 2:1); stained with I₂

Mp = 143-145⁰C (white solid)

IR (KBr) ν (cm^{-1}): 3379, 3251, 3194, 3120, 3066, 2981, 2951, 2927, 2900, 1728, 1666, 1608, 1547, 1404, 1230, 1173, 1134, 1068.

^1H NMR (500 MHz, CD_3OD , rt, rotamers) δ (ppm): 7.36 (2d, 2H, $J = 8.2$ Hz), 7.10 (d, 2H, $J = 8.5$ Hz), 5.86 and 5.85 (2 apparent t, 1H, $J = 1.8$ Hz), 5.75 and 5.74 (2 apparent t, 1H, $J = 1.8$ Hz), 4.79 and 4.70 (2m, 1H), 3.85 (dd, 1H, $J = 4.6$ and 11.0 Hz), 3.80 (dd, 1H, $J = 3.4$ and 11.3 Hz), 3.71 and 3.70 (2s, 3H), 1.40 and 1.11 (2s, 9H).

^{13}C NMR (75 MHz, CD_3OD , rt, rotamers) δ (ppm): 156.3, 155.7, 139.3, 139.0, 138.3, 137.3, 133.2, 133.0, 128.2, 127.9, 127.8, 127.2, 119.7, 119.5, 81.2, 81.1, 70.5, 70.3, 68.4, 68.0, 63.5, 63.1, 52.5, 28.8, 28.7, 28.5.

$[\alpha]_{\text{D}}^{20} = +131.9$ (2.31; CHCl_3).

MS (IE): 348 (1) $[\text{M}^+]$, 317 (26), 261 (27), 217 (100), 185 (32), 157 (12), 57 (46).

HRMS (IE): Calcd for $\text{C}_{18}\text{H}_{24}\text{N}_2\text{O}_5$, 348.16852; found 348.16791.

(1S)-N-(*tert*-Butoxycarbonyl)-1-(*p*-carbomethoxyamino-phenyl)-1,4-dideoxy-1,4-imino-D-ribitol (13).

TLC: $R_f = 0.60$ (EtOAc/MeOH 3%), reveals under UV light

Mp = 206.5-207.5 $^{\circ}\text{C}$ (DMSO, white solid; decomposes under melting)

IR (KBr) ν (cm^{-1}): 3541, 3398, 3302, 3078, 3001, 2978, 2954, 2920, 1739, 1655, 1604, 1547, 1404, 1315, 1242, 1149, 1068, 829, 768.

^1H MNR (500 MHz, DMSO-d_6 , rt, rotamers) δ (ppm): 9.54 (bs, 1H), 7.41-7.28 (m, 2H), 7.21-7.15 (d, 2H, $J = 7.6$ Hz), 5.05-4.85 (m, 3H), 4.36-4.20 (bs + large d, 1H, $J = 6.4$ Hz), 3.95 (bs, 1H), 3.88-3.74 (sl, 1H), 3.70-3.51 (s + m, 6H), 1.35 and 1.04 (2s, 9H).

^1H NMR (300 MHz, DMSO-d_6 , $T = 70^{\circ}\text{C}$, rotamers) δ (ppm): 9.28 (s, 1H), 7.35 (d, 2H, $J = 8.1$ Hz), 7.19 (d, 2H, $J = 8.8$ Hz), 4.74 (d, 1H, $J = 7.3$ Hz), 4.70 (t, 1H, $J = 5.1$ Hz), 4.66 (d, 1H, $J = 3.7$ Hz), 4.33 (d, 1H, $J = 7.3$ Hz), 3.98 (m, 1H), 3.90-3.83 (2dd, 1H, $J = 7.3$ and 12.4 Hz), 3.74-3.50 (s + m, 6H), 1.18 (s, 9H).

^{13}C NMR (75 MHz, CD_3OD , rt, rotamers) δ (ppm): 154.6, 153.9, 137.3, 126.5, 126.3, 117.9, 117.6, 78.2, 71.2, 66.3, 65.3, 60.7, 60.6, 51.4, 48.5, 28.0, 27.6.

$[\alpha]_{\text{D}}^{20} = -25.3$ (1.38; MeOH).

MS (IE): 382 (4) $[\text{M}^+]$, 306 (100), 246 (16), 217 (12), 91 (11), 73 (17), 57 (45).

HRMS (IE): Calcd for $\text{C}_{18}\text{H}_{26}\text{N}_2\text{O}_7$, 382.17400; found 382.17481.