Supplemental Material

The Reaction of Cyclic Carbinol Amides with Triflic Anhydride as a Method to Prepare α -Trifluoro-methyl-Sulfonamido Furans

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Supporting Information Available: Characterization of all new compounds prepared in this study.

Supplementary Material

Melting points are uncorrected. Mass spectra were determined at an ionizing voltage of 70eV. Unless otherwise noted, all reactions were performed in flame dried glassware under an atmosphere of dry nitrogen. Solutions were evaporated under reduced pressure with a rotary evaporator and the residue was chromatographed on a silica gel column using an ethyl acetate-hexane mixture as the eluent unless specified otherwise.

General Procedure for the Preparation of Hydroxy Lactams. A solution of the corresponding amine (5.6 mmol) in water (0.5 mL) was added to α -angelica lactone (**5**) (0.5 g, 5.1 mmol) and the mixture was stirred at room temperature for 1 h. The solution was concentrated under reduced pressure, and the resulting residue was purified by flash chromatography on silica gel using 20% acetone in CHCl_3 as the eluent.

1-Allyl-5-hydroxy-5-methyl-pyrrolidin-2-one (6) was prepared in 81% yield from lactone **5** and allyl amine: IR (neat) 1673, 1454, 1409, and 1102 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.47 (s, 3H), 2.12-2.07 (m, 2H), 2.36-2.25 (m, 1H), 2.56-2.46 (m, 1H), 3.92-3.80 (m, 2H), 4.31 (s, 1H), 5.09 (dd, 1H, J = 10.0 and 1.6 Hz), 5.16 (dd, 1H, J = 17.2 and 1.6 Hz), and 5.80 (qt, 1H, J = 10.0 and 6.0 Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 27.0, 29.2, 35.0, 41.4, 90.5, 116.9, 134.6, and 174.9; HRMS Calcd. for $\text{C}_8\text{H}_{13}\text{NO}_2$: 155.0946. Found: 155.0950.

1-Benzyl-5-hydroxy-5-methyl-pyrrolidin-2-one (7) was prepared in 67% yield from lactone **5** and benzyl amine: IR (neat) 1666, 1249, 1413, 1356, 1200, and 1098 cm^{-1} ; ^1H -NMR (300 MHz, CDCl_3) δ 1.33 (s, 3H), 2.16-2.06 (m, 2H), 2.40-2.31 (m, 1H), 2.64-2.50 (m, 1H), 4.00 (brs, 1H), 4.31 (d, 1H, J = 15.3 Hz), 4.60 (d, 1H, J = 15.3 Hz), and 7.29-7.18 (m, 5H); ^{13}C -NMR (75 MHz, CDCl_3) δ 27.2, 29.3, 35.1, 42.5, 90.7, 127.4,

127.9, 128.7, 138.7, and 175.6; HRMS Calcd. for $C_{12}H_{15}NO_2$: 205.1103. Found: 205.1099.

5-Hydroxy-1,5-dimethyl-pyrrolidin-2-one was prepared in 92% yield from lactone **5** and a 30% aqueous solution of methylamine: ^1H -NMR (300 MHz, $CDCl_3$) δ 1.44 (s, 3H), 1.94-2.52 (m, 4H), 2.72 (s, 3H), and 4.60 (s, 1H). The spectral data for this compound is identical to that reported in the literature.¹

5-Hydroxy-5-methyl-1-phenethyl-pyrrolidin-2-one was prepared in 61% yield from lactone **5** and phenethyl amine: IR (neat) 1682, 1496, 1455, 1359, and 1142 cm^{-1} ; ^1H -NMR (400 MHz, $CDCl_3$) δ 1.38 (s, 3H), 2.12-2.00 (m, 2H), 2.27 (ddd, 1H, J = 14.6, 8.9, and 6.0 Hz), 2.50 (ddd, 1H, J = 16.8, 9.2, and 7.3), 2.81 (ddd, 1H, J = 13.3, 9.8, and 5.8 Hz), 2.94 (ddd, 1H, J = 13.3, 10.2, and 6.0 Hz), 3.50-3.31 (m, 2H), and 7.16-7.28 (m, 5H); ^{13}C -NMR (75 MHz, $CDCl_3$) δ 26.4, 29.3, 35.2, 35.3, 41.1, 90.2, 126.6, 128.6, 129.0, 139.4, and 175.0; HRMS Calcd. for $C_{13}H_{17}NO_2$: 219.1259. Found: 219.1258.

3-(2-Hydroxy-2-methyl-5-oxo-pyrrolidin-1-yl)-propionic Acid *tert*-Butyl Ester was prepared in 89% from lactone **5** and β -alanine *tert*-butyl ester:² IR (neat) 1726, 1671, 1417, and 1157 cm^{-1} ; ^1H -NMR (400 MHz, $CDCl_3$) δ 1.37 (s, 9H), 1.46 (s, 3H), 2.09-1.98 (m, 2H), 2.22 (ddd, 1H, J = 13.4, 7.9, and 5.4 Hz), 2.52-2.38 (m, 2H), 2.69 (dtd, 1H, J = 11.1, 7.6, and 1.9 Hz), 3.30 (dt, 1H, J = 14.3 and 7.3 Hz), 3.54 (dt, 1H, J = 14.3 and 7.3 Hz), and 4.66 (brs, 1H); ^{13}C -NMR (75 MHz, $CDCl_3$) δ 26.4, 28.1, 29.3, 34.7, 35.3, 81.6, 90.0, 173.0 and 170.5; HRMS Calcd. for $C_{12}H_{21}NO_4$ ($M-H^+$): 242.1392. Found: 242.1392.

1,1'-Diallyl-2,2'-dimethyl-1,2,3,4,1',2'-hexahydro-[2,3']bipyrrolyl-5,5'-dione (8). To a solution of hydroxy lactam **6** (0.05 g, 0.3 mmol) in benzene (2 mL) was added 0.006 g (0.03 mmol) of *p*-TsOH. The mixture was heated at reflux for 5 h, allowed to cool, and concentrated under reduced pressure. Purification by flash chromatography on silica gel using 25% acetone in $CHCl_3$ as the eluent gave 0.014 g

of **8** (33% yield) as a yellow oil which consisted of a mixture of diastereomers: IR (neat) 1684, 1675, 1431, 1401, and 1329 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.18 and 1.22 (d, 3H, $J = 7.0$ Hz), 1.60 (s, 3H), 1.97-1.84 (m, 1H), 2.44-2.29 (m, 3H), 3.67-3.44 (m, 2H), 4.17-3.87 (m, 2H), 4.42-4.34 (m, 1H), 5.18-5.03 (m, 4H), 5.84-5.67 (m, 2H), and 6.58 and 6.55 (t, 1H, $J = 2.0$ Hz); ^{13}C -NMR (100 MHz CDCl_3) δ 16.8, 24.6, 24.7, 29.6, 29.7, 32.3, 32.4, 42.7, 43.2, 55.2, 62.9, 63.1, 116.6, 117.9, 133.6, 134.5, 140.6, 142.37, 142.41, 168.3, 168.4, 175.4, and 175.5; HRMS Calcd. for $\text{C}_{16}\text{H}_{22}\text{N}_2\text{O}_2$: 274.1681. Found: 274.1670.

1-Benzyl-5-(3,3,3-trifluoro-2-oxo-propylidene)-pyrrolidin-2-one (9). To a solution of hydroxy lactam **7** (0.1 g, 0.5 mmol) in CH_2Cl_2 (5 mL) at -78°C was sequentially added pyridine (0.4 mL, 4.9 mmol) and trifluoroacetic anhydride (TFAA) (0.15 mL, 1.1 mmol). The mixture was allowed to warm to room temperature, stirred for 10 min, quenched with water (10 mL) and the organic layer was separated. The aqueous phase was extracted twice with CHCl_3 . The combined organic phase was dried over MgSO_4 , filtered, and concentrated under reduced pressure. The residue was purified by flash chromatography on silica gel (50% Et_2O in hexane) to give **9** as a white solid (0.11 g, 79%), mp $81\text{--}82^\circ\text{C}$; IR (KBr) 1754, 1692, 1569, 1417, and 1290 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 2.71-2.68 (m, 2H), 3.36-3.30 (m, 2H), 4.77 (s, 2H), 5.89 (s, 1H), 7.25-7.20 (m, 2H), and 7.36-7.29 (m, 3H); ^{13}C -NMR (100 MHz CDCl_3) δ 26.9, 27.5, 44.8, 92.3, 116.5 (q, $J = 289.8$ Hz), 127.6, 128.5, 129.2, 134.1, 168.1, 177.5, and 178.9 (q, $J = 33.3$ Hz); Anal. Calcd. for $\text{C}_{14}\text{H}_{12}\text{F}_3\text{NO}_2$: C, 59.34; H, 4.27; N, 4.95. Found: C, 59.55; H, 4.26; N, 4.97.

1-Benzyl-5-methylene-pyrrolidin-2-one (10). To a solution of hydroxy lactam **7** (0.1 g, 0.5 mmol) in CH_2Cl_2 (5 mL) was sequentially added pyridine (0.4 mL, 4.9 mmol) and acetic anhydride (Ac_2O) (0.1 mL, 1.1 mmol). The mixture was heated at reflux for 16 h, cooled, diluted with CHCl_3 , and washed with water. The organic layer was separated, dried over MgSO_4 , filtered, and concentrated under reduced pressure.

The NMR data of the crude reaction mixture indicated the quantitative formation of compound **10**; $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 2.52-2.65 (m, 2H), 2.67-2.80 (m, 2H), 4.12 (d, 1H, $J = 1.8$ Hz), 4.19 (d, 1H, $J = 1.8$ Hz), 4.68 (s, 2H), and 7.20-7.39 (m, 5H). The spectral data of this compound is identical to that reported in the literature³.

***N*-Benzyl-*C,C,C*-trifluoro-*N*-(5-methyl-furan-2-yl)-methanesulfonamide (11).** To a solution of hydroxy lactam **7** (5 mmol) in 5 mL of CH_2Cl_2 at -78°C was added pyridine (25 mmol) and then triflic anhydride (Tf_2O) (10 mmol). The reaction mixture was allowed to warm to 25°C over 30 min and was stirred for an additional 10 min. Water (10 mL) was added and the organic layer was separated. The aqueous layer was extracted with chloroform and the combined organic phase was washed with water and brine, dried over MgSO_4 , filtered, and concentrated under reduced pressure. The crude product was purified by flash chromatography on silica gel using 20% Et_2O in hexane as the eluent to give furan **11** in 60% yield as a colorless oil: IR (neat) 1619, 1497, 1404, 1209, 1141, and 1027 cm^{-1} ; $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 2.21 (s, 3H), 4.82 (s, 2H), 5.85 (dd, 1H, $J = 3.2$ and 1.0 Hz), 5.91 (d, 1H, $J = 3.2$ Hz), 7.27-7.20 (m, 2H), and 7.33-7.29 (m, 3H); $^{13}\text{C-NMR}$ (100 MHz, CDCl_3) δ 13.9, 56.5, 107.4, 110.2, 120.2 (q, $J = 321.1$ Hz), 128.8, 129.1, 134.3, 139.7, and 151.8; Found: 319.0500; Anal. Calcd. for $\text{C}_{13}\text{H}_{12}\text{F}_3\text{NO}_3\text{S}$: C, 48.90; H, 3.79; N, 4.39. Found: C, 49.12; H, 3.85; N, 4.42.

***N*-Methyl-*C,C,C*-trifluoro-*N*-(5-methyl-furan-2-yl)-methanesulfonamide (12).** This compound was prepared in 60% yield from 5-hydroxy-1,5-dimethyl-pyrrolidin-2-one using the above procedure: IR (neat) 1619, 1593, 1400, 1231, 1196, and 1128 cm^{-1} ; $^1\text{H-NMR}$ (400 MHz, CDCl_3) δ 2.26 (s, 3H), 3.40 (s, 3H), 5.97 (dd, 1H, $J = 3.2$ and 1.0 Hz), and 6.18 (d, 1H, $J = 3.2$ Hz); $^{13}\text{C-NMR}$ (100 MHz CDCl_3) δ 13.9, 40.1, 107.4, 107.6, 120.2 (q, $J = 322.4$ Hz), 142.0, and 151.5; HRMS Calcd. for $\text{C}_7\text{H}_8\text{F}_3\text{NO}_3\text{S}$: 243.0177. Found: 243.0179.

***N*-Allyl-*C,C,C*-trifluoro-*N*-(5-methyl-furan-2-yl)-methanesulfonamide (13)**

was prepared in 83% yield from hydroxy lactam **6** using the above procedure: IR (neat) 1616, 1559, 1400, 1228, 1199, 1133, and 1055 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 2.26 (s, 3H), 4.27 (d, 2H, $J = 6.7$ Hz), 5.23-5.19 (m, 1H), 5.26-5.24 (m, 1H), 5.83 (qt, 1H, $J = 10.2$ and 6.7 Hz), 5.97 (dd, 1H, $J = 3.2$ and 1.0 Hz), and 6.17 (d, 1H, $J = 3.2$ Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 13.9, 55.5, 107.4, 109.7, 120.1 (q, $J = 321.7$ Hz), 120.9, 131.2, 140.1, and 151.9; HRMS Calcd. for $\text{C}_9\text{H}_{10}\text{F}_3\text{NO}_3\text{S}$: 269.0333. Found: 269.0338.

***N*-Phenethyl-*C,C,C*-trifluoro-*N*-(5-methyl-furan-2-yl)-methanesulfonamide (14)**

was prepared in 79% yield from 5-hydroxy-5-methyl-1-phenethyl-pyrrolidin-2-one using the above procedure: IR (neat) 1617, 1406, 1229, 1190, 1141, and 1068 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 2.29 (s, 3H), 2.93 (dd, 2H, $J = 8.0$ and 8.0 Hz), 3.93 (dd, 2H, $J = 8.0$ and 8.0 Hz), 6.00 (dd, 1H, $J = 3.2$ and 1.2 Hz), 6.19 (d, 1H, $J = 3.2$ Hz), and 7.15-7.34 (m, 5H); ^{13}C -NMR (100 MHz, CDCl_3) δ 13.9, 35.5, 54.1, 107.5, 109.7, 120.1 (q, $J = 321.5$ Hz), 127.1, 128.8, 129.0, 137.0, 140.2, and 152.0; Anal. Calcd. for $\text{C}_{14}\text{H}_{14}\text{F}_3\text{NO}_3\text{S}$: C, 50.45; H, 4.23; N, 4.20. Found: C, 50.66; H, 4.34; N, 4.33.

3-[(5-Methyl-furan-2-yl)-trifluoromethanesulfonyl-amino]-propionic Acid *tert*-Butyl Ester (15)

was prepared in 72% yield from 3-(2-hydroxy-2-methyl-5-oxo-pyrrolidin-1-yl)-propionic acid *tert*-butyl ester using the above procedure: IR (neat) 1730, 1618, 1559, 1407, 1370, 1190, 1089, and 1060 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.41 (s, 9H), 2.24 (s, 3H), 2.53 (t, 2H, $J = 7.3$ Hz), 3.94 (t, 2H, $J = 7.3$ Hz), 5.96 (dd, 1H, $J = 3.2$ and 1.0 Hz), and 6.19 (d, 1H, $J = 3.2$ Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 13.9, 28.1, 35.0, 48.6, 81.7, 107.5, 110.1, 120.0 (q, $J = 321.7$ Hz), 139.6, 152.2, and 169.3; Anal. Calcd. for $\text{C}_{13}\text{H}_{18}\text{F}_3\text{NO}_5\text{S}$: C, 43.69; H, 5.08; N, 3.92. Found: C, 43.87; H, 5.07; N, 4.02.

4-Oxo-pentanoic Acid But-3-enylamide (16). To a solution of lactone **5** (0.5 g, 5.1 mmol) in 10 mL of THF at 0 $^\circ\text{C}$ was added 4-butenylamine⁴ (5.6 mmol) dropwise.

The reaction was allowed to warm to room temperature and was stirred for 2 h. The solvent was removed under reduced pressure and the residue was purified by flash chromatography on silica gel using Et₂O as the eluent. The keto amide **16** was obtained in 63% yield as a colorless oil; IR (neat) 1716, 1650, 1437, 1360, and 1164 cm⁻¹; ¹H-NMR (400 MHz, CDCl₃) δ 2.18 (s, 3H), 2.24 (qt, 2H, J = 6.7 and 1.3 Hz), 2.40 (t, 2H, J = 6.7 Hz), 2.79 (t, 2H, J = 6.7 Hz), 3.30 (q, 2H, J = 6.7 Hz), 5.12-5.05 (m, 2H), 5.80-5.69 (m, 1H), and 5.70 (brs, 1H); ¹³C-NMR (100 MHz, CDCl₃) δ 29.9, 30.0, 33.8, 38.6, 38.7, 117.2, 135.4, 172.0, and 208.0; HRMS Calcd. for C₉H₁₅NO₂: 169.1103. Found: 169.1108.

***N*-But-3-enyl-*C,C,C*-trifluoro-*N*-(5-methyl-furan-2-yl)-**

methanesulfonamide (17) was prepared in 75% yield from **16** using the above procedure: IR (neat) 1619, 1558, 1402, 1230, 1196, 1131, and 1071 cm⁻¹; ¹H-NMR (400 MHz, CDCl₃) δ 2.26 (s, 3H), 2.32 (q, 2H, J = 7.0 Hz), 3.74 (t, 2H, J = 7.0 Hz), 5.09-5.07 (m, 1H), 5.12-5.10 (m, 1H), 5.76-5.65 (m, 1H), 5.98 (dd, 1H, J = 2.8 and 0.8 Hz), and 6.19 (d, 1H, J = 2.8 Hz); ¹³C-NMR (100 MHz, CDCl₃) δ 13.9, 32.9, 52.1, 107.5, 109.9, 118.3, 120.1 (q, J = 321.7), 133.3, 139.9, and 152.0; Anal. Calcd. for C₁₀H₁₂F₃NO₃S: C, 42.40; H, 4.27; N, 4.94. Found: C, 42.41; H, 4.33; N, 4.89.

***N*-But-3-enyl-*N*-(5-methyl-furan-2-yl)-2,2,2-trifluoroacetamide (18).** To a cooled solution of compound **16** (0.1 g, 0.6 mmol) at -78°C in freshly distilled CH₂Cl₂ (5 mL) was sequentially added pyridine (0.5 mL, 6.0 mmol) and TFAA (0.18 mL, 1.3 mmol). The reaction mixture was allowed to warm to 25 °C over 30 min and was stirred for 10 min, water was added and the organic layer was separated. The aqueous layer was extracted with chloroform and the combined organic phase was washed with water and brine, dried over MgSO₄, filtered, and concentrated under reduced pressure. The crude product was purified by flash chromatography on silica gel using 20% Et₂O in hexane as the eluent to give furan **18** in 76% yield (0.11 g) as a colorless oil: IR (neat) 1722, 1622, 1415, 1212, 1158, and 1023 cm⁻¹; ¹H-NMR (400

MHz, CDCl_3) δ 2.25 (s, 3H), 2.38-2.29 (m, 2H), 3.72 (dd, 2H, $J = 7.6$ and 7.6 Hz), 5.12-5.02 (m, 2H), 5.79-5.66 (m, 1H), 5.96 (dd, 1H, $J = 3.2$ and 1.2 Hz), and 6.08 (d, 1H, $J = 3.2$ Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 13.8, 31.8, 49.3, 107.1, 108.1, 116.2 (q, $J = 286.8$ Hz), 117.7, 134.2, 142.0, 151.2, and 158.0 (q, $J = 35.1$); Anal. Calcd. for $\text{C}_{11}\text{H}_{12}\text{F}_3\text{NO}_2$: C, 53.44; H, 4.89; N, 5.67. Found: C, 53.16; H, 4.84; N, 5.62.

***N*-(4-Methoxy-benzyl)-2-(2-oxo-cyclohexyl)-acetamide (19).** To a solution of 2-(2-oxo-cyclohexyl)-acetic acid⁵ (1.0 g, 6.4 mmol) and 4-methoxybenzylamine (1.0 g, 7 mmol) in CH_2Cl_2 (15 mL) was added 1-[3-(dimethylamino)propyl]-3-ethylcarbodiimide hydrochloride (EDCI) (1.4 g, 7 mmol) in one portion followed by 4-(dimethylamino)-pyridine (DMAP) (0.05 g). The mixture was stirred at 25 °C for 2 h and then diluted with water (20 mL). The organic phase was separated and the aqueous phase was extracted with CHCl_3 . The combined organic phase was washed with 1N HCl and brine, dried over MgSO_4 , filtered, and concentrated under reduced pressure. The crude product was purified by flash chromatography on silica gel (10% acetone in CHCl_3) to give keto amide **19** in 86% yield (1.4 g) as a pale yellow solid; mp 114-116 °C; IR (KBr) 1708, 1693, 1637, 1512, 1248, 1175, and 1036 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.40 (dq, 1H, $J = 12.7$ and 3.8 Hz), 1.92-1.55 (m, 3H), 2.07 (dd, 1H, $J = 14.4$ and 14.4 Hz), 2.23-2.09 (m, 2H), 2.45-2.30 (m, 2H), 2.62 (dd, 1H, $J = 7.7$ and 4.8 Hz), 3.01-2.89 (m, 1H), 3.79 (s, 3H), 4.35 (qd, 2H, $J = 10.6$ and 5.3 Hz), 6.03 (brs, 1H), 6.90-6.82 (m, 2H), and 7.23-7.17 (m, 2H); ^{13}C -NMR (100 MHz, CDCl_3) δ 25.4, 28.2, 34.7, 36.9, 42.2, 43.2, 47.9, 55.4, 114.2, 129.2, 130.6, 159.1, 171.8, and 212.7; Anal. Calcd. for $\text{C}_{16}\text{H}_{21}\text{NO}_3$: C, 69.79; H, 7.69; N, 5.09. Found: C, 69.74; H, 7.67; N, 5.07.

***N*-(4-Methoxy-benzyl)-*N*-(4,5,6,7-tetrahydro-benzofuran-2-yl)-2,2,2-trifluoro acetamide (20).** To a solution of **19** (0.3 g, 1.17 mmol) in 12 mL of freshly distilled CH_2Cl_2 was sequentially added pyridine (1 mL, 12 mmol) and TFAA (0.4 mL, 2.6 mmol). The reaction was stirred at 25 °C for 6 h, and then quenched by the

addition of water. The organic layer was separated, the aqueous layer was extracted with chloroform and the combined organic phase was washed with water, brine, dried over MgSO_4 , filtered, and concentrated under reduced pressure. The crude product was purified by flash chromatography on silica gel using 20% Et_2O in hexane as the eluent to give furan **20** in 78% yield (0.32 g) as a colorless oil: IR (neat) 1716, 1513, 1251, 1209, and 1166 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.75-1.66 (m, 2H), 1.87-1.78 (m, 2H), 2.37-2.30 (m, 2H), 2.55-2.48 (m, 2H), 3.78 (s, 3H), 4.73 (s, 2H), 5.76 (s, 1H), 6.86-6.80 (m, 2H), and 7.22-7.15 (m, 2H); ^{13}C -NMR (100 MHz, CDCl_3) δ 21.9, 22.9, 23.0, 53.5, 55.4, 108.2, 114.0, 116.2 (q, $J = 288.4$ Hz), 118.1, 127.6, 130.5, 141.4, 149.7, 157.8 (q, $J = 35.1$ Hz), and 159.6; Anal. Calcd. for $\text{C}_{18}\text{H}_{18}\text{F}_3\text{NO}_3$: C, 61.19; H, 5.13; N, 3.96. Found: C, 61.35; H, 5.28; N, 4.04.

7a-Hydroxy-1-(4-methoxy-benzyl)-1,4,5,6,7,7a-hexahydro-indol-2-one

(21). To a solution of **20** (0.28 g, 0.8 mmol) in MeOH (5 mL) was added water (0.5 mL) and K_2CO_3 (0.55 g, 4 mmol). The mixture was heated at reflux for 2 h, allowed to cool to room temperature, diluted with water, and extracted with CHCl_3 . The combined organic phase was washed with brine, dried over MgSO_4 , filtered, and concentrated under reduced pressure. The crude product was purified by recrystallization from Et_2O -hexane to give lactam **21** in 19% yield (0.04 g) as colorless solid; mp 157-158 °C, IR (KBr) 1670, 1512, and 1245 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.06-0.91 (m, 1H), 1.30-1.12 (m, 1H), 1.73-1.50 (m, 2H), 2.00-1.87 (m, 1H), 2.12-2.01 (m, 1H), 2.41 (tdd, 1H, $J = 13.4, 5.5$, and 2.2 Hz), 2.65-2.55 (m, 1H), 3.76 (s, 3H), 3.79 (brs, 1H), 4.24 (d, 1H, $J = 15.1$ Hz), 4.64 (d, 1H, $J = 15.1$ Hz), 5.61 (d, 1H, $J = 1.9$ Hz), 6.83-6.76 (m, 2H), and 7.28-7.20 (m, 2H); ^{13}C -NMR (100 MHz, CDCl_3) δ 21.5, 26.6, 27.7, 38.5, 41.2, 55.4, 89.3, 113.9, 117.4, 129.6, 131.4, 158.9, 163.9, and 170.4; Anal. Calcd. for $\text{C}_{16}\text{H}_{19}\text{NO}_3$: C, 70.31; H, 7.01; N, 5.12. Found: C, 69.96; H, 7.31; N, 4.95.

5-Methyl-1-trifluoromethanesulfonyl-2,3-dihydro-1H-indole (27). A

solution of **17** (0.27 g, 1 mmol) in toluene (5 mL) was heated in a sealed tube at 130°C

for 4 h. The mixture was allowed to cool to room temperature and the solvent was removed under reduced pressure. The crude product was purified by flash chromatography on silica gel (10% Et₂O in hexane) to give **27** as a colorless oil in 96% yield (0.26 g): IR (neat) 1487, 1402, 1228, 1189, 1148, and 1059 cm⁻¹; ¹H-NMR (400 MHz, CDCl₃) δ 2.32 (s, 3H), 3.17 (t, 2H, J = 8.3 Hz), 4.20 (t, 2H, J = 8.3 Hz), 7.01 (dd, 1H, J = 8.3 and 1.0 Hz), 7.05 (d, 1H, J = 0.6 Hz), and 7.30 (d, 1H, J = 8.3 Hz); ¹³C-NMR (100 MHz, CDCl₃) δ 21.0, 28.2, 51.6, 114.4, 120.5 (q, J = 323.2 Hz), 126.3, 128.7, 131.5, 135.1, and 137.5; HRMS Calcd. for C₁₀H₁₀F₃NO₂S: 265.0384. Found: 265.0387; Anal. Calcd. for C₁₀H₁₀F₃NO₂S: C, 45.28; H, 3.80; N, 5.28. Found: C, 45.52; H, 3.90; N, 5.32.

5-Methyl-2,3-dihydro-1H-indole (28). To a solution of **27** (0.2 g, 0.75 mmol) in Et₂O (7.0 mL) was added LiAlH₄ (0.09 g, 2.3 mmol) in one portion. The reaction mixture was heated at reflux for 6 h, cooled to 25 °C, and quenched by the addition of Na₂SO₄·10H₂O until a white precipitate appeared. The mixture was filtered and the precipitate was washed with Et₂O. The combined filtrate was concentrated under reduced pressure and the residue was purified by flash chromatography on silica gel (50% Et₂O in hexane) to give indoline **28** as pale yellow oil in 90% yield (0.089 g): ¹H-NMR (400 MHz, CDCl₃) δ 2.23 (s, 3H), 3.01 (t, 2H, J = 8.3 Hz), 3.56 (t, 2H, J = 8.3 Hz), 4.34 (s, 1H), 6.65 (d, 1H, J = 7.8 Hz), 6.86 (d, 1H, J = 7.8 Hz), and 6.97 (s, 1H). The spectral data of this compound is identical to that reported in the literature⁶.

1-(5-Methyl-2,3-dihydro-indol-1-yl)-2,2,2-trifluoroethanone (30). A solution of **18** (0.12 g, 1 mmol) in toluene (2 mL) was heated in a sealed tube at 130 °C for 20 h. The mixture was allowed to cool to room temperature and the solvent was removed under reduced pressure. The crude product was purified by flash chromatography on silica gel (10% Et₂O in hexane) to give **30** as white solid in 91% yield (0.11 g); mp 85-86 °C; IR (KBr) 1686, 1487, 1442, 1252, 1203, 1141, and 1071 cm⁻¹; ¹H-NMR (400 MHz, CDCl₃) δ 2.34 (s, 2H), 3.21 (t, 2H, J = 8.3 Hz), 4.29-4.22 (m,

2H), 7.09-7.04 (m, 2H), and 8.07 (d, 1H, $J = 8.9$ Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 21.3, 28.5, 48.1, 116.0 (q, $J = 288.1$ Hz), 117.8, 125.7, 128.5, 131.9, 136.0, 139.5, and 154.0 (q, $J = 35.4$ Hz); Anal. Calcd. for $\text{C}_{11}\text{H}_{10}\text{F}_3\text{NO}$: C, 57.64; H, 4.40; N, 6.11.

Found: C, 57.61; H, 4.29; N, 5.99.

***N*-(3-Methyl-but-3-enyl)-*N*-(5-methyl-furan-2-yl)-*C,C,C*-trifluoro-methane-sulfonamide (31).**

4-Oxo-pentanoic acid (3-methyl-but-3-enyl)-amide was prepared from lactone **5** and 3-methyl-but-3-enylamine; IR (neat) 1715, 1653, 1545, 1360, and 1164 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.62 (s, 3H), 2.08 (s, 3H), 2.10 (t, 2H, $J = 7.0$ Hz), 2.31 (t, 2H, $J = 6.7$ Hz), 2.69 (t, 2H, $J = 6.7$ Hz), 3.24 (q, 2H, $J = 7.0$ Hz), 4.62 (s, 1H), 4.70 (s, 1H), and 5.98 (brs, 1H); ^{13}C -NMR (100 MHz, CDCl_3) δ 22.2, 30.0, 30.1, 37.4, 37.5, 38.8, 112.3, 142.8, 172.0, and 208.0; HRMS Calcd. for $\text{C}_{10}\text{H}_{17}\text{NO}_2$: 183.1259. Found: 183.1264.

Treatment of the above lactam with Tf_2O using the usual procedure provided furan **31** in 62% yield; IR (neat) 1619, 1559, 1401, 1232, 1196, 1144, 1090, and 1023 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 1.72 (s, 3H), 2.27 (d, 3H, $J = 1.0$ Hz), 2.28 (t, 2H, $J = 7.4$ Hz), 3.80 (dd, 2H, $J = 7.4$ and 7.4 Hz), 4.71 (s, 1H), 4.83 (s, 1H), 5.99 (dd, 1H, $J = 3.1$ and 1.0 Hz), and 6.21 (d, 1H, $J = 3.1$ Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 13.9, 22.4, 36.8, 51.1, 107.5, 109.9, 113.2, 120.2 (q, $J = 322.2$ Hz), 140.0, 141.0, and 151.9; Anal. Calcd. for $\text{C}_{11}\text{H}_{14}\text{F}_3\text{NO}_3\text{S}$: C, 44.44; H, 4.75; N, 4.71. Found: C, 44.16; H, 4.69; N, 4.76.

5,7-Dimethyl-2-trifluoromethanesulfonyl-10-oxa-2-aza-

tricyclo[5.2.1.0^{1,5}]dec-8-ene (32). A solution of **31** (0.13 g, 0.4 mmol) in toluene (4.0 mL) was heated in a sealed tube at 130°C for 36 h. The mixture was allowed to cool to room temperature and the solvent was removed under reduced pressure. The crude product was purified by flash chromatography on silica gel (20% Et_2O in hexane) to give **32** as a white solid in 46% yield (0.06 g), mp 100-102°C; IR (KBr) 1398, 1248, 1183, 1146, and 1107 cm^{-1} ; ^1H -NMR (400 MHz, CDCl_3) δ 0.96 (s, 3H),

1.31 (d, 1 H, J = 11.4 Hz); 1.54 (s, 3H), 1.83 (d, 1H, J = 11.4 Hz); 1.94 (ddd, 1H, J = 12.4, 7.0, and 1.2 Hz); 2.21 (q, 1H, J = 11.4 Hz); 4.00-3.86 (m, 2H), 6.24 (d, 1H, J = 5.7 Hz), and 6.48 (d, 1H, J = 5.7 Hz); ^{13}C -NMR (100 MHz, CDCl_3) δ 19.8, 21.7, 36.3, 47.8, 52.0, 52.6, 85.4, 105.7, 120.0 (q, J = 322.7 Hz); 132.3, and 139.0; Anal. Calcd. for $\text{C}_{11}\text{H}_{14}\text{F}_3\text{NO}_3\text{S}$: C, 44.44; H, 4.75; N, 4.71. Found: C, 44.32; H, 4.76; N, 4.67.

Experimental References

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Figure 1. ORTEP of 1-Benzyl-5-(3,3,3-trifluoro-2-oxo-propylidene)-pyrrolidin-2-one (**9**).