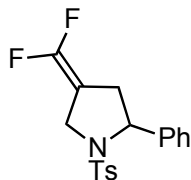


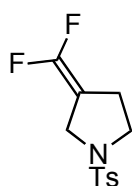
Nucleophilic 5-*endo-trig* Cyclizations of *N*-Homoallylic Sulfonamides: A Facile Method for the Construction of Pyrrolidine Rings

Junji Ichikawa,\* Guillaume Lapointe and Yu Iwai



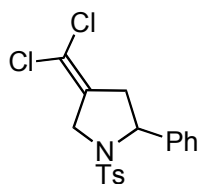
**4-Difluoromethylene-1-(4-methylbenzenesulfonyl)-2-phenylpyrrolidine (2a)**

Colorless crystals.  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  2.42 (3H, s), 2.54 (1H, br d,  $J = 15.0$  Hz), 2.66–2.73 (1H, m), 4.13 (1H, dm,  $J = 14.5$  Hz), 4.19 (1H, dm,  $J = 14.5$  Hz), 4.95 (1H, ddd,  $J = 8.2, 3.1, 1.5$  Hz), 7.22–7.31 (7H, m), 7.57 (2H, d,  $J = 8.3$  Hz).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  21.5, 33.9, 47.0 (d,  $J_{\text{CF}} = 4$  Hz), 63.2, 85.4 (dd,  $J_{\text{CF}} = 25, 22$  Hz), 126.2, 127.4, 127.7, 128.5, 129.6, 134.8, 140.8, 143.7, 149.8 (dd,  $J_{\text{CF}} = 283, 283$  Hz).  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3/\text{C}_6\text{F}_6$ )  $\delta$  72.0 (1F, dm,  $J_{\text{FF}} = 54.0$  Hz), 74.5 (1F, d,  $J_{\text{FF}} = 54.0$  Hz). IR (ZnSe) 3064, 3032, 2927, 2866, 1782, 1350, 1273, 1219, 1161, 1093, 1058  $\text{cm}^{-1}$ . Anal. Calcd for  $\text{C}_{18}\text{H}_{17}\text{NO}_2\text{F}_2\text{S}$ ; C, 61.88; H, 4.90; N, 4.01%. Found: C, 61.81; H, 4.95; N, 3.74%.



**3-Difluoromethylene-1-(4-methylbenzenesulfonyl)pyrrolidine (2b)**

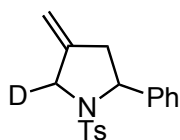
Colorless crystals.  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  2.45 (3H, s), 2.44–2.48 (2H, m), 3.30 (2H, ddd,  $J = 7.0, 7.0, 1.3$  Hz), 3.79–3.82 (2H, m), 7.36 (2H, d,  $J = 8.1$  Hz), 7.72 (2H, d,  $J = 8.1$  Hz).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  21.5, 24.6, 46.5 (d,  $J_{\text{CF}} = 4$  Hz), 48.0, 85.8 (dd,  $J_{\text{CF}} = 27, 22$  Hz), 127.8, 129.8, 132.3, 144.0, 149.9 (dd,  $J_{\text{CF}} = 285, 285$  Hz).  $^{19}\text{F}$  NMR (471 MHz,  $\text{CDCl}_3/\text{C}_6\text{F}_6$ )  $\delta$  71.6 (1F, dm,  $J_{\text{FF}} = 55.0$  Hz), 74.0 (1F, d,  $J_{\text{FF}} = 55.0$  Hz). IR (ZnSe) 2924, 2864, 1782, 1348, 1269, 1161, 1093, 1072, 1039, 812  $\text{cm}^{-1}$ . Anal. Calcd for  $\text{C}_{12}\text{H}_{13}\text{NO}_2\text{F}_2\text{S}$ ; C, 52.74; H, 4.79; N, 5.13%. Found: C, 52.83; H, 4.88; N, 4.87%.



**4-Dichloromethylene-1-(4-methylbenzenesulfonyl)-2-phenylpyrrolidine (2c)**

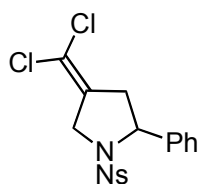
Colorless crystals.  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  2.42 (3H, s), 2.70 (1H, dm,  $J = 17.1$  Hz), 2.83 (1H, ddt,  $J = 17.1, 8.4, 1.5$  Hz), 4.17 (1H, d,  $J = 16.2$  Hz), 4.24 (1H, d,  $J = 16.2$  Hz), 4.96 (1H, dd,  $J$

= 8.4, 4.0 Hz), 7.22–7.31 (7H, m), 7.55 (2H, d,  $J = 8.2$  Hz).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  21.5, 40.5, 52.4, 63.5, 112.9, 126.4, 127.4, 127.9, 128.7, 129.7, 134.6, 135.0, 140.4, 143.8. IR (ZnSe) 3064, 3032, 1652, 1350, 1219, 1161, 1092, 912  $\text{cm}^{-1}$ . Anal. Calcd for  $\text{C}_{18}\text{H}_{17}\text{NO}_2\text{Cl}_2\text{S}$ ; C, 56.55; H, 4.48; N, 3.66%. Found: C, 56.27; H, 4.50; N, 3.49%.



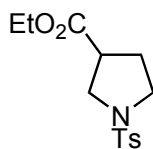
**1-(4-Methylbenzenesulfonyl)-3-methylene-5-phenyl(2- $^2\text{H}_1$ )pyrrolidine (3d)**

A white solid (1:1 diastereomer mixture).  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  2.32 (3H, s), 2.40 (1H, dm,  $J = 15.4$  Hz), 2.68 (1H, ddm,  $J = 15.4, 8.8$  Hz), 3.99 (0.5H, br s), 4.03 (0.5H, br s), 4.84 (1H, s), 4.87–4.84 (1H, m), 4.90 (1H, s), 7.13–7.20 (7H, m), 7.50 (2H, d,  $J = 8.3$  Hz).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  21.5, 41.4, 52.2 (t,  $J_{\text{CD}} = 23$  Hz), 63.1, 108.1, 126.3, 127.2, 127.3, 128.3, 129.4, 135.1, 141.8, 141.9, 143.2. IR (ZnSe) 3066, 2962, 2929, 1674, 1597, 1491, 1452, 1346, 1157, 1092  $\text{cm}^{-1}$ . Anal. Calcd for  $\text{C}_{18}\text{H}_{18}\text{DNO}_2\text{S}$ ; C, 68.76; H, 6.41; N, 4.45%. Found: C, 68.61; H, 6.24; N, 4.27%.



**4-Dichloromethylene-1-(2-nitrobenzenesulfonyl)-2-phenylpyrrolidine (2g)**

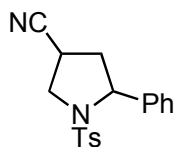
A white solid.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  2.80 (1H, dd,  $J = 17.1, 4.9$  Hz), 3.22 (1H, dd,  $J = 17.0, 8.4$  Hz), 4.46 (2H, s), 5.21 (1H, dd,  $J = 8.4, 4.9$  Hz), 7.14–7.26 (5H, m), 7.32 (1H, ddd,  $J = 8.2, 7.1, 2.0$  Hz), 7.44 (1H, d,  $J = 8.2$  Hz), 7.53–7.59 (2H, m).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  41.3, 52.6, 64.0, 113.4, 123.9, 126.7, 128.0, 128.6, 130.9, 131.2, 132.7, 133.3, 134.0, 139.5, 175.2. IR (ZnSe) 2921, 1658, 1539, 1350, 1161, 1124, 1076, 906  $\text{cm}^{-1}$ . HRMS (FAB): calcd for  $\text{C}_{17}\text{H}_{15}\text{Cl}_2\text{N}_2\text{O}_4\text{S}$  ( $[\text{M}+\text{H}]^+$ ) 413.0132, found 413.0134.



**Ethyl 1-(4-methylbenzenesulfonyl)pyrrolidine-3-carboxylate (5b)**

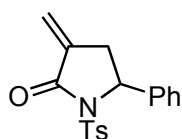
A white solid.  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ )  $\delta$  1.20 (3H, t,  $J = 7.3$  Hz), 2.01–2.07 (2H, m), 2.43 (3H, s), 2.94 (1H, dddd,  $J = 8.0, 7.3, 7.3, 7.3$  Hz), 3.30 (2H, dd,  $J = 7.3, 7.3$  Hz), 3.38 (1H, dd,  $J = 10.2, 7.3$  Hz), 3.55 (1H, dd,  $J = 10.2, 8.0$  Hz), 4.05 (2H, q,  $J = 7.3$  Hz), 7.33 (2H, d,  $J = 8.4$  Hz), 7.71 (2H, d,  $J = 8.4$  Hz).  $^{13}\text{C}$  NMR (126 MHz,  $\text{CDCl}_3$ )  $\delta$  14.0, 21.5, 28.3, 42.7, 47.3, 49.8, 61.0, 127.4, 129.5, 133.2, 143.4, 172.0. IR (ZnSe) 2981, 1728, 1342, 1182, 1155, 1092, 1036, 816  $\text{cm}^{-1}$ . HRMS (FAB):

calcd for  $C_{14}H_{20}NO_4S$  ( $[M+H]^+$ ) 298.1113, found 298.1108.



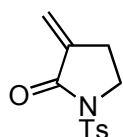
#### 4-Cyano-1-(4-methylbenzenesulfonyl)-2-phenylpyrrolidine (5c)

Colorless crystals (*anti:syn* = 37:63).  $^1H$  NMR (500 MHz,  $CDCl_3$ ) **anti isomer**  $\delta$  2.16–2.24 (2H, m), 2.46 (3H, s), 3.08 (1H, m), 3.60 (1H, dd,  $J$  = 10.4, 8.1 Hz), 3.97 (1H, dd,  $J$  = 10.4, 7.5 Hz), 4.93 (1H, dd,  $J$  = 6.1, 6.1 Hz), 7.25–7.35 (7H, m), 7.70 (2H, d,  $J$  = 8.2 Hz). **syn isomer**  $\delta$  2.16–2.24 (1H, m), 2.42 (3H, s), 2.67–2.79 (2H, m), 3.66 (1H, dd,  $J$  = 11.4, 8.8 Hz), 4.09 (1H, dd,  $J$  = 11.4, 7.3 Hz), 4.81 (1H, dd,  $J$  = 7.9, 7.9 Hz), 7.25–7.35 (7H, m), 7.56 (2H, d,  $J$  = 8.3 Hz).  $^{13}C$  NMR (126 MHz,  $CDCl_3$ ) **anti isomer**  $\delta$  21.6, 26.4, 39.5, 51.3, 62.3, 118.5, 125.9, 127.6, 127.9, 128.7, 130.0, 134.8, 140.5, 144.4. **syn isomer**  $\delta$  21.6, 27.3, 39.9, 51.7, 63.0, 118.3, 126.4, 127.4, 128.0, 128.7, 129.8, 134.8, 140.1, 144.1. IR (ZnSe) 3064, 3030, 2953, 2924, 2247, 1597, 1348, 1159, 1093, 1022  $cm^{-1}$ . HRMS (FAB): calcd for  $C_{18}H_{19}N_2O_2S$  ( $[M+H]^+$ ) 327.1167, found 327.1173.



#### 1-(4-Methylbenzenesulfonyl)-3-methylene-5-phenylpyrrolidin-2-one (6d)

A white solid.  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta$  2.35 (3H, s), 2.73 (1H, dddd,  $J$  = 16.9, 1.8, 1.8, 1.8 Hz), 3.30 (1H, dddd,  $J$  = 16.9, 9.2, 3.5, 3.5 Hz), 5.41 (1H, dd,  $J$  = 9.2, 1.8 Hz), 5.52 (1H, dd,  $J$  = 3.5, 1.8 Hz), 6.23 (1H, dd,  $J$  = 3.5, 1.8 Hz), 7.08–7.11 (4H, m), 7.22–7.31 (3H, m), 7.41 (2H, d,  $J$  = 8.2 Hz).  $^{13}C$  NMR (126 MHz,  $CDCl_3$ )  $\delta$  21.6, 34.8, 59.6, 121.2, 126.5, 128.3, 128.5, 128.8, 129.0, 135.2, 137.2, 140.6, 144.8, 165.7. IR (ZnSe) 2924, 2854, 1722, 1362, 1265, 1165, 1086  $cm^{-1}$ . HRMS (FAB): calcd for  $C_{18}H_{18}NO_3S$  ( $[M+H]^+$ ) 328.1008, found 328.1013.



#### 1-(4-Methylbenzenesulfonyl)-3-methylenepyrrolidin-2-one (6e)

A white solid.  $^1H$  NMR (400 MHz,  $CDCl_3$ )  $\delta$  2.44 (3H, s), 2.81 (2H, dddd,  $J$  = 7.2, 7.2, 2.6, 2.6 Hz), 3.89 (2H, dd,  $J$  = 7.2, 7.2 Hz), 5.46 (1H, t,  $J$  = 2.6 Hz), 6.10 (1H, t,  $J$  = 2.6 Hz), 7.33 (2H, d,  $J$  = 8.2 Hz), 7.96 (2H, d,  $J$  = 8.2 Hz).  $^{13}C$  NMR (126 MHz,  $CDCl_3$ )  $\delta$  21.8, 24.1, 43.8, 120.7, 128.2, 129.6, 134.8, 137.5, 145.2, 165.6. IR (ZnSe) 2924, 2852, 1724, 1354, 1271, 1165, 1111  $cm^{-1}$ . HRMS (FAB): calcd for  $C_{12}H_{14}NO_3S$  ( $[M+H]^+$ ) 252.0694, found 252.0706.