

# **(Z)-3-*p*-Tolylsulfinylacrylonitriles as Chiral Dipolarophiles: Reactions with Diazoalkanes.**

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## **Supporting Information**

### **Experimental Section**

**General Methods.** All reactions were performed in flame-dried glassware equipped with rubber septa under positive pressure of argon. Flash chromatography was carried out with silica gel 60 (230-400 mesh ASTM), and silica gel F254 plates were used for preparative TLC. NMR spectra were determined in  $\text{CDCl}_3$  solutions at 200 (or 300) and 50.3 (or 75) MHz for  $^1\text{H}$  and  $^{13}\text{C}$ -NMR, respectively. Compounds **1a-d** were synthesized and purified according to procedure described in ref 1. In order to verify the optical purity of **1a** to be used as the substrate in further reactions, it is necessary to check it by NMR using  $\text{Yb}(\text{hfc})_3$  as the LSR (substrate-LSR molar ratio 1:0.3).

**1,3-Dipolar Cycloadditions. General Procedure.** To a solution of (Z)-3-*p*-tolylsulfinylacrylonitrile (**1**) (1 mmol) in anhydrous  $\text{Et}_2\text{O}$  (substrates **1a-c**) or  $\text{MeOH}$  (substrate **1d**) (2 mL), cooled at the indicated temperature (see Table 1), was added a 0.95M solution of diazoalkane in  $\text{Et}_2\text{O}$  (10 equiv). The resulting mixture was stirred under the conditions shown in Table 1 and evaporated. The residue was purified as indicated in each case.

**(3S,4S)-3-*n*-Butyl-4-[(*R*)-*p*-tolylsulfinyl]-4,5-dihydro-3*H*-pirazole-3-carbonitrile (**4b**):** It was obtained by 1,3-dipolar cycloaddition reaction of (*R,Z*)-2-*n*-butyl-3-(*p*-tolylsulfinyl)propenenitrile (**1b**) with diazomethane as a white solid. It was crystallized from hexane: mp 97-98 °C;  $[\alpha]^{20}_{\text{D}} = +40.6^\circ$  (c 1,

CHCl<sub>3</sub>); <sup>1</sup>H-NMR δ 7.56 and 7.38 (AA'BB' system, 4H), 5.28 (dd, 1H, *J* = 4.9 and 19.2), 4.89 (dd, 1H, *J* = 8.7 and 19.2), 2.88 (dd, 1H, *J* = 4.9 and 8.7), 2.44 (s, 3H), 1.90 (m, 2H), 1.65 (m, 2H), 1.35 (m, 2H), 0.89 (t, 3H, *J* = 7.0); <sup>13</sup>C-NMR δ 143.0, 138.5, 130.4 (2C), 124.3 (2C), 114.4, 89.0, 75.5, 62.5, 37.5, 26.4, 22.2, 21.4, 13.6; IR (CH<sub>2</sub>Cl<sub>2</sub>) 2959, 2930, 2870, 2242, 1493, 1466, 1380, 1085, 1044 cm<sup>-1</sup>; MS (FAB) 290 (100) [M<sup>+</sup>+1], 262 (20), 150 (7), 140 (88), 125 (8), 92 (13); HRMS (FAB) C<sub>15</sub>H<sub>20</sub>N<sub>3</sub>OS requires 290.132709. Found 290.133495. Anal. Calcd for C<sub>15</sub>H<sub>19</sub>N<sub>3</sub>OS: C, 62.28; H, 6.57; N, 14.53; S, 11.07. Found: C, 62.08; H, 6.51; N, 14.35; S, 11.42.

**(3S,4S)-3-terc-Butyl-4-[(R)-*p*-tolylsulfinyl]-4,5-dihydro-3*H*-pirazole-3-carbonitrile (4c):** It was obtained by 1,3-dipolar cycloaddition reaction of (*R,Z*)-2-*t*-butyl-3-(*p*-tolylsulfinyl)propenenitrile (**1c**) with diazomethane as a white solid. It was crystallized from hexane: mp 80-82 °C; [α]<sup>20</sup><sub>D</sub> = +26.9° (c 1, CHCl<sub>3</sub>); <sup>1</sup>H-NMR δ 7.51 and 7.36 (AA'BB' system, 4H), 5.35 (dd, 1H, *J* = 4.8 and 19.9), 4.50 (dd, 1H, *J* = 9.1 and 19.9), 2.91 (dd, 1H, *J* = 4.8 and 9.1), 2.42 (s, 3H), 1.10 (s, 9H); <sup>13</sup>C-NMR δ 142.5, 138.0, 130.2 (2C), 123.6 (2C), 114.1, 97.9, 75.0, 58.7, 39.4, 24.8 (3C), 21.1; IR (CH<sub>2</sub>Cl<sub>2</sub>) 2972, 2239, 1492, 1472, 1086, 1051 cm<sup>-1</sup>; MS (FAB) 290 (100) [M<sup>+</sup>+1], 262 (15), 246 (6), 167 (4), 150 (7), 140 (33), 125 (6), 108 (5), 91 (11), 77 (7); HRMS (FAB) C<sub>15</sub>H<sub>20</sub>N<sub>3</sub>OS requires 290.132709. Found 290.132235. Anal. Calcd for C<sub>15</sub>H<sub>19</sub>N<sub>3</sub>OS: C, 62.28; H, 6.57; N, 14.53; S, 11.07. Found: C, 61.91; H, 6.72; N, 13.88; S, 11.32.

**(3S,4S)-3-Benzyl-4-[(R)-*p*-tolylsulfinyl]-4,5-dihydro-3*H*-pirazole-3-carbonitrile (4d):** It was obtained by 1,3-dipolar cycloaddition reaction of (*R,Z*)-2-benzyl-3-(*p*-tolylsulfinyl)propenenitrile (**1d**) with diazomethane as a yellow solid. It was crystallized from hexane: mp 91-92 °C; [α]<sup>20</sup><sub>D</sub> = +77.1° (c 1, CHCl<sub>3</sub>); <sup>1</sup>H-NMR δ 7.35 (m, 7H), 7.08 (m, 2H), 5.19 (dd, 1H, *J* = 5.1 and 19.4), 4.24 (dd, 1H, *J* = 8.6 and 19.4), 3.38 and 3.17 (AB system, 2H, *J* = 14.1), 2.94 (dd, 1H, *J* = 5.1 and 8.6), 2.42 (s, 3H); <sup>13</sup>C-NMR δ 142.7, 138.2, 131.5, 130.4 (2C), 130.2 (2C), 129.0 (2C), 128.4, 124.0 (2C), 114.7, 89.4, 75.4, 60.8, 42.6, 21.4; IR (CH<sub>2</sub>Cl<sub>2</sub>) 3033, 2972, 2925, 2360, 1494, 1085, 1048 cm<sup>-1</sup>; MS (FAB) 324 (100) [M<sup>+</sup>+1], 296 (26), 279 (5), 247 (6), 231 (12), 184 (11), 155 (11), 140 (63), 123 (24), 91 (85); HRMS (FAB) C<sub>18</sub>H<sub>18</sub>N<sub>3</sub>OS requires 324.117059. Found 324.117787. Anal. Calcd for C<sub>18</sub>H<sub>17</sub>N<sub>3</sub>OS: C, 66.87; H, 5.26; N, 13.00; S, 9.91. Found: C, 66.44; H, 5.42; N, 12.56; S, 10.12.

**(3S,4S,5S)-3-n-Butyl-5-methyl-4-[(R)-p-tolylsulfinyl]-4,5-dihydro-3H-pirazole-3-carbonitrile (5b):**

It was obtained by 1,3-dipolar cycloaddition reaction of (*R,Z*)-2-*n*-butyl-3-(*p*-tolylsulfinyl)propenenitrile (**1b**) with diazoethane as a white solid. It was crystallized from hexane: mp 101-102 °C;  $[\alpha]^{20}_D = -201.3^\circ$  (c 1, CHCl<sub>3</sub>); <sup>1</sup>H-NMR δ 7.63 and 7.39 (AA'BB' system, 4H), 5.28 (q, 1H, *J* = 7.0), 2.45 (s, 3H), 2.40 (d, *J* = 7.0), 1.75 (m, 2H), 1.60 (m, 2H), 1.40 (d, 3H, *J* = 7.0) 1.28 (m, 2H), 0.85 (t, 3H, *J* = 7.0); <sup>13</sup>C-NMR δ 143.1, 138.8, 130.4 (2C), 124.6 (2C), 114.1, 89.2, 86.4, 69.3, 38.5, 26.4, 22.1, 21.4, 19.3, 13.6; IR (KBr) 3036, 3020, 2973, 2247, 1492, 1468, 1082, 1039 cm<sup>-1</sup>; MS (FAB) 304 (62) [M<sup>+</sup>+1], 276 (11), 248 (100), 164 (9), 140 (33), 123 (25), 109 (15), 91 (11); HRMS (FAB) C<sub>16</sub>H<sub>22</sub>N<sub>3</sub>OS requires 304.148359. Found 304.148030. Anal. Calcd for C<sub>16</sub>H<sub>22</sub>N<sub>3</sub>OS: C, 63.34; H, 6.98; N, 13.85; S, 10.57. Found: C, 63.28; H, 6.66; N, 13.95; S, 11.04.

**(3S,4S,5S)-3-tert-Butyl-5-methyl-4-[(R)-p-tolylsulfinyl]-4,5-dihydro-3H-pirazole-3-carbonitrile (5c):**

It was obtained by 1,3-dipolar cycloaddition reaction of (*R,Z*)-2-*t*-butyl-3-(*p*-tolylsulfinyl)propenenitrile (**1c**) with diazoethane as a white solid. It was crystallized from hexane: mp 99-100 °C;  $[\alpha]^{20}_D = -106.3^\circ$  (c 1, CHCl<sub>3</sub>); <sup>1</sup>H-NMR δ 7.52 and 7.39 (AA'BB' system, 4H), 5.35 (q, 1H, *J* = 7.3), 2.45 (s, 3H), 2.42 (d, 1H, *J* = 7.3) 1.15 (s, 9H), 1.10 (d, 3H, *J* = 7.3); <sup>13</sup>C-NMR δ 142.7, 138.4, 130.4 (2C), 123.8 (2C), 113.9, 98.7, 83.4, 65.9, 38.6, 25.5 (3C), 21.4, 18.2; IR (KBr) 2985, 2971, 2240, 1492, 1469, 1089, 1061 cm<sup>-1</sup>; MS (FAB) 304 (100) [M<sup>+</sup>+1], 276 (11), 248 (7), 164 (5), 139 (14), 123 (14), 109 (5), 91 (4); HRMS (FAB) C<sub>16</sub>H<sub>22</sub>N<sub>3</sub>OS requires 304.148359. Found 304.148748.

**(3S,4S,5S)-3-Benzyl-5-methyl-4-[(R)-p-tolylsulfinyl]-4,5-dihydro-3H-pirazole-3-carbonitrile (5d):** It

was obtained as a syrup by 1,3-dipolar cycloaddition reaction of (*R,Z*)-2-benzyl-3-(*p*-tolylsulfinyl)-propenenitrile (**1d**) with diazoethane:  $[\alpha]^{20}_D = -55.6^\circ$  (c 1, CHCl<sub>3</sub>); <sup>1</sup>H-NMR δ 7.35 and 7.39 (AA'BB' system, 4H), 7.28 (m, 4H), 6.94 (m, 1H), 5.22 (q, 1H, *J* = 7.3), 3.47 and 2.98 (AB system, 2H, *J* = 14.2) 2.46 (d, 1H, *J* = 7.1), 2.45 (s, 3H), 0.88 (d, 3H, *J* = 7.3); <sup>13</sup>C-NMR δ 142.8, 138.1, 131.5, 130.5 (2C), 130.3 (2C), 128.8 (2C), 128.3, 124.2 (2C), 114.2, 89.3, 86.4, 66.4, 43.1, 21.3, 18.0; IR (CH<sub>2</sub>Cl<sub>2</sub>) 3062, 3033, 2981, 2935, 2240, 1494, 1454, 1086, 1046 cm<sup>-1</sup>.

**(3S,4S)-3-n-Butyl-4-[(R)-p-tolylsulfinyl]-2,3,4,5-tetrahydro-3H-pirazole-3-carbonitrile (6b):** 1

mmol of (3S,4S)-3-*n*-butyl-4-[(*R*)-*p*-tolylsulfinyl]-4,5-dihydro-3H-pirazole-3-carbonitrile (**4b**) was solved

in 2 mL of THF-H<sub>2</sub>O (9:1) and treated with an excess of Al(Hg). The mixture was stirred at rt for 20 min and then filtered and the solid salts washed with THF. The filtrate was dried (MgSO<sub>4</sub>) and concentrated to afford a white solid in 92% yield. It was crystallized from AcOEt-hexane: mp 116-117 °C; [α]<sup>20</sup><sub>D</sub>= +31.8° (c 1, CHCl<sub>3</sub>); <sup>1</sup>H- δ 7.55 and 7.36 (AA'BB' system, 4H), 3.82 (bs, 1H), 3.78 (m, 1H), 3.05 (m, 2H), 2.43 (s, 3H) 1.72-1.18 (m, 6H), 0.91 (7, 3H, *J* = 6.9); <sup>13</sup>C-NMR δ 142.1, 138.5, 130.1 (2C), 124.0 (2C), 118.6, 73.5, 67.1, 47.5, 37.1, 27.2, 22.1, 21.5, 21.2, 13.5. Anal. Calcd for C<sub>15</sub>H<sub>21</sub>N<sub>3</sub>OS: C, 61.83; H, 7.26; N, 14.42; S, 11.00. Found: C, 61.61; H, 6.81; N, 14.41; S, 11.49.