Phosphine-Free Palladium Acetate-Catalyzed Suzuki Reaction in Water

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Supporting Information

Content

General procedure for Suzuki reaction.....	S2
Characterization data of the product of the Suzuki reaction.....	S3
References.....	S24

General Starting materials and solvents were purchased from common commercial sources and were used without additional purification. The gas chromatography analysis was performed on a GC instrument. ¹ H NMR spectra were recorded at 500 MHz, using TMS as internal standard. Mass spectroscopy data of the product of Suzuki reaction was collected on a MS-EI instrument.

General procedure for Suzuki reaction: A mixture of Na₂CO₃ (0.212 g, 2 mmol), Pd(OAc)₂ (2 mg, 1 mol%), PEG 2000 (3.5 g), and water (3 g) was heated to 50 °C with stirring. Afterward, aryl halides (1 mmol) and arylboronic acid (1.5 mmol) was added in the solution and the reaction carried out at 50 °C for the indicated time. After the reaction, the reaction solution was cooled to room temperature and the resulted suspend was extracted four times with diethyl ether (4×15 ml). The residue of the extraction was subjected to a second run of the Suzuki reaction by charging with the same substrates (bromotoluene, phenylboronic acid, water and Na₂CO₃) without further addition of Pd(OAc)₂ or PEG. The combined ether phase was analyzed by GC/MS and then concentrated. The further purification of the product was achieved by flash chromatography on a silica gel column.

Characterization data of the product of the Suzuki reaction

(1)

4-Methoxy-biphenyl [613-37-6, ref 1, T2-1]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.54 (q, 4 H, $J = 6.7$ Hz), 7.42 (t, 2 H, $J = 7.7$ Hz), 7.28 (t, 1 H, $J = 14.8$ Hz), 6.98 (d, 2 H, $J = 4.3$ Hz), 3.86 (s, 3 H). MS (EI): m/z (%): 184 (100) [M^+], 169 (44), 141 (38), 115 (26), 63 (4).

(2)

Biphenyl-3-ol [580-51-8, ref 2, T2-2]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.56 (d, 2 H, $J = 7.7$ Hz), 7.43 (t, 2 H, $J = 7.6$ Hz), δ 7.34 (m, 2 H), 7.17 (d, 1 H, $J = 7.7$ Hz), 7.06 (s, 1 H), 6.82 (m, 1 H), 4.82 (s, 1 H). MS (EI): m/z (%): 170 (100) [M^+], 141 (20), 115 (14).

(3)

Biphenyl-2-ylamine [90-41-5, ref 3, T2-3]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.44 (m, 4 H), 7.34 (m, 1 H), 7.15 (m, 2 H), 6.83 (m, 1 H), 6.76 (d, 1 H, $J = 7.8$ Hz), 3.73 (s, 2 H). MS (EI): m/z (%): 169 (99) [M^+], 168 (100), 167 (47), 139 (9), 115(14), 84 (20), 63 (14), 51 (17), 39 (20).

(4)

Biphenyl-4-ylamine [92-67-1, ref 4, T2-4]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.53 (d, 2 H, $J = 8.0\text{ Hz}$), 7.39 (m, 4 H), 7.15 (m, 2 H), 7.26 (t, 1 H, $J = 7.8\text{ Hz}$), 6.76 (d, 1 H, $J = 8.0\text{ Hz}$), 6.75 (t, 2 H, $J = 8.5\text{ Hz}$), 3.70 (s, 2 H). MS (EI): m/z (%): 169 (100) [M^+], 168 (20), 167 (11), 141 (7), 115 (7), 83 (6).

(5)

2-Methyl-biphenyl [643-58-3, ref 4, T2-5]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.42 (t, 2 H, $J = 7.5$ Hz), 7.34 (m, 3 H), 7.26 (m, 4 H), 2.28 (s, 3 H). MS (EI): m/z (%): 168 (100) [M^+], 167(100), 165 (60), 153 (59), 152(46), 141 (8), 139 (8), 115(14), 83(14), 63(6), 51(4).

(6)

4-Methyl-biphenyl [644-08-6, ref 1,T2-6]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.58 (d, 2 H, $J = 7.5$ Hz), 7.49 (d, 2 H, $J = 8.0$ Hz), 7.43 (t, 2 H, $J = 7.5$ Hz), 7.32 (t, 1 H, $J = 7.3$ Hz), 7.25 (d, 2 H, $J = 7.5$ Hz). MS (EI): m/z (%): 168 (100) [M^+], 167(68), 165 (22), 152 (20), 115 (6).

(7)

Biphenyl [92-52-4, ref 9, T2-7]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.60 (d, 4 H, $J = 7.5$ Hz), 7.44 (t, 4 H, $J = 7.2$ Hz), 7.35 (t, 2 H, $J = 7.2$ Hz). MS (EI): m/z (%): 154 (100) [M^+], 153 (35), 152 (20), 115 (3), 76(13), 51 (4).

(8)

1-Biphenyl-4-yl-ethanone [92-91-1, ref 4, T2-8]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 8.03 (d, 2 H, $J = 8.4$ Hz), 7.69 (d, 2 H, $J = 4.0$ Hz), 7.63 (t, 2 H, $J = 4.5$ Hz), 7.48 (t, 2 H, $J = 7.5$ Hz), 7.40 (t, 1 H, $J = 7.0$ Hz), 2.64 (s, 3 H). MS (EI): m/z (%): 196 (51) [M^+], 181 (100), 153(33), 152 (51), 76(13), 43 (4).

(9)

Biphenyl-4-carbonitrile [2920-38-9, ref 1, T2-9]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.73 (d, 2 H, $J=8.5$ Hz), 7.68 (d, 2 H, $J=8.5$ Hz), 7.59 (t, 2 H, $J=4.5$ Hz), 7.48 (t, 2 H, $J=7.5$ Hz), 7.42 (m, 1 H). MS (EI): m/z (%): 179 (100) [M^+], 151 (16), 89 (10), 76 (14).

(10)

4-Nitro-biphenyl [92-93-3, ref 1, T2-10]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 8.32 (d, 2 H, $J = 9.0$ Hz), 7.75 (d, 2 H, $J = 9.0$ Hz), 7.64 (d, 2 H, $J = 7.0$ Hz), 7.51 (t, 2 H, $J = 7.5$ Hz), 7.46 (t, 1 H, $J = 7.2$ Hz). MS (EI): m/z (%): 199 (100) [M^+], 169(37), 152 (100), 141 (24), 115 (13), 76 (13), 63 (7), 51(6).

(11)

4-Trifluoromethyl-biphenyl [398-36-7, ref 9, T3-2]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.69 (s, 4 H), 7.60 (d, 2 H, $J = 8.0$ Hz), 7.48 (t, 2 H, $J = 7.5$ Hz), 7.41 (t, 1 H, $J = 7.3$ Hz), MS (EI): m/z (%): 222(100) [M^+], 201 (13), 152 (26), 86(4).

(12)

4-Methoxy-4'-methyl-biphenyl [53040-92-9, ref 9, T3-3]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.51 (d, 2 H, $J = 8.0$ Hz), 7.45 (d, 2 H, $J = 8.0$ Hz), 7.22 (d, 2 H, $J = 8.0$ Hz), 6.97 (d, 2 H, $J = 8.5$ Hz), 3.85 (s, 3 H), 2.38 (s, 3 H). MS (EI): m/z (%): 198 (100) [M^+], 183 (54), 155 (27), 128 (8), 115 (5).

(13)

4'-Methyl-4-trifluoromethyl-biphenyl [97067-18-0, ref 5, T3-4]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.67 (s, 4 H), 7.50 (d, 2 H, $J = 8.1$ Hz), 7.28 (d, 2 H, $J = 8.0$ Hz), 2.40 (s, 3 H). MS (EI): m/z (%): 236 (100) [M^+], 235 (25), 167 (38), 165 (35), 152 (8), 91 (7).

(14)

4'-Methoxy-2-methyl-biphenyl [92495-54-0, ref 1, T3-5]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.23 (m, 6 H), 3.84 (s, 3 H), 2.27 (s, 3 H). MS (EI): m/z (%): 198 (100) [M^+], 183 (22), 167 (19), 165 (21), 155 (21), 153 (21), 128 (12), 115 (9).

(15)

2-Methyl-4'-trifluoromethyl-biphenyl [167021-49-0, ref 10, T3-6]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.70 (d, 2 H, $J = 8.0$ Hz), 7.46 (d, 2 H, $J = 8.5$ Hz), 7.30 (m, 3 H), 7.24 (d, 1 H, $J = 7.5$ Hz) 2.29 (s, 3 H). MS (EI): m/z (%): 236 (86) [M^+], 217 (11), 167 (100), 166 (32), 165 (61), 152 (21) 82 (10).

(16)

4, 4'-Dimethoxy-biphenyl [2132-80-1, ref 8, T3-7]

¹H NMR (500 MHz, CDCl₃, TMS): δ7.52 (d, 4 H, *J* = 9.0 Hz), 7.00 (d, 4 H, *J* = 8.5 Hz), 3.89(s, 6 H).

MS (EI): *m/z* (%): 214 (100) [M⁺], 199 (81), 171 (24), 156 (8), 128 (13), 102 (16), 39 (10).

(17)

4'-Methoxy-4-trifluoromethyl-biphenyl [10355-12-1, ref 7, T3-8]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 7.65 (q, 4 H, $J = 6.6$ Hz), 7.54 (d, 2 H, $J = 8.7$ Hz), 7.00 (d, 2 H, $J = 8.6$ Hz), 3.86 (s, 3 H). MS (EI): m/z (%): 252 (100) $[\text{M}^+]$, 237 (26), 209 (42), 183 (8), 139(6).

(18)

1-(4'-Methoxy-biphenyl-4-yl)-ethanone [3021-18-6, ref 6, T3-9]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 8.00 (d, 2 H, $J = 8.5$ Hz), 7.65 (d, 2 H, $J = 8.5$ Hz), 7.58 (d, 2 H, $J = 9.0$ Hz), 7.00 (d, 2 H, $J = 8.5$ Hz), 3.87 (s, 3 H), 2.61 (s, 3 H). MS (EI): m/z (%): 226 (68) [M^+], 211 (100), 183 (10), 152 (10), 139 (21), 105 (6), 43 (3).

(19)

1-(4'-Trifluoromethyl-biphenyl-4-yl)-ethanone [142557-76-4, ref 11, T3-10]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 8.06 (d, 2 H, $J = 8.4$ Hz), 7.72 (s, 4 H), 7.69 (d, 2 H, $J = 8.4$ Hz), 2.65 (s, 3 H). MS (EI): m/z (%): 264 (36) [M^+], 249 (100), 221 (8), 201 (26), 152 (24), 43(4).

(20)

4'-Methoxy-4-nitro-biphenyl [2143-90-0, ref 12, T3-11]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 8.28 (d, 2 H, $J = 9.0$ Hz), 7.71 (d, 1 H, $J = 16.1$ Hz), 7.69 (d, 2 H, $J = 8.5$ Hz), 7.59 (d, 2 H, $J = 8.5$ Hz), 7.02 (d, 2 H, $J = 9.0$ Hz), 3.88 (s, 3 H). MS (EI): m/z (%): 229 (100) [M^+], 199 (17), 183 (12), 152(13), 139 (35), 128 (6), 63 (4).

(21)

4-Nitro-4'-trifluoromethyl-biphenyl [80245-34-7, ref 13, T3-12]

^1H NMR (500 MHz, CDCl_3 , TMS): δ 8.34 (q, 2 H, $J = 2.9$ Hz), 7.76 (m, 6 H). MS (EI): m/z (%): 267 (100) [M^+], 248 (10), 237 (40), 209 (33), 201(50), 170 (7), 152(51), 75(4).

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