Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

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Table of Contents

1. Chemicals .................................................................................................................................... 3
2. Methods....................................................................................................................................... 4
3. Spectra ......................................................................................................................................... 5

Figure S1. $^1$H-NMR: 4-tert-butyopyridine-N-oxide. ........................................................................ 6
Figure S2. $^{13}$C-NMR: 4-tert-butyopyridine-N-oxide. ................................................................. 7
Figure S3. $^1$H-NMR: 4-(tert-butyl)-2-chloropyridine (2) [81167-60-4]. ................................. 8
Figure S4. $^{13}$C-NMR: 4-(tert-butyl)-2-chloropyridine (2) [81167-60-4]. ............................. 9
Figure S5. $^1$H-NMR: 4,4’-Di-tert-butyl-2,2’-bipyridine [72914-19-3] (3a). .......................... 10
Figure S6. $^{13}$C-NMR: 4,4’-Di-tert-butyl-2,2’-bipyridine [72914-19-3] (3a). ............................ 11
Figure S7. $^1$H-NMR: 5,5’-Bis(trifluoromethyl)-2,2’-bipyridine [142946-80-3] (3b). ............. 12
Figure S8. $^{13}$C-NMR: 5,5’-Bis(trifluoromethyl)-2,2’-bipyridine [142946-80-3] (3b). ............ 13
Figure S10. $^1$H-NMR: 2,2’-Bipyridine [366-18-7] (3c). ............................................................. 15
Figure S11. $^{13}$C-NMR: 2,2’-Bipyridine [366-18-7] (3c). ............................................................. 16
Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

1. Chemicals

NiBr$_2$•3H$_2$O, NiCl$_2$(glyme), Manganese (-325 mesh), 2-chloropyridine, 2-chloro-5-(trifluoromethyl)pyridine, 3-bromopyridine, and 4-tert-butylpyridine were purchased from Aldrich and used as received.

DMF was dried and purified by passage though a column of sieves and activated alumina in a Vacuum Atmospheres solvent delivery system.

4-tert-butylpyridine-$N$-oxide was prepared according to the literature procedure with added details below.$^1$ Prior to use, 4-tert-butylpyridine was distilled from KOH pellets by bulb-to-bulb short path distillation (26 °C, 85 mtorr). In a 1 L round bottom flask, 4-tert-butyl pyridine (18.0 mL, 16.6 g, 123 mmol) was added to glacial acetic acid (135 mL). Next, hydrogen peroxide (30% in water, 100 mL) was added and the reaction mixture was refluxed under air for 4 h. Additional hydrogen peroxide (30% in water, 100 mL) was added and the reflux was continued overnight (12 h). Approximately 200 mL of the solvent was removed on a rotary evaporator (45 °C, 74 torr), and the remaining solution was neutralized with a saturated sodium carbonate solution to give a cloudy white mixture. Enough water was added to the mixture to dissolve the precipitated material before extracting the organics with methylene chloride (4 x 75 mL) and the combined organics were dried over MgSO$_4$, filtered, and concentrated by rotary evaporation (28 °C, 74 torr) to yield 4-tert-butylpyridine-$N$-oxide as yellow solid (15.73 g, 85 %). Spectral data were in agreement with literature.$^1$

$^1$H-NMR (400 MHz; CDCl$_3$): $\delta$ 8.12 (d, $J = 7.1$ Hz, 2H), 7.23 (d, $J = 7.1$ Hz, 2H), 1.29 (s, 9H); $^{13}$C-NMR (101 MHz; CDCl$_3$): $\delta$ 151.0, 138.6, 123.2, 34.7,

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Supporting Information: Substituted 2,2'-bipyridines by nickel-catalysis: 4,4'-di-tert-butyl-2,2'-bipyridine

30.6; **Anal. Calc.** for C₉H₁₃NO requires: C, 71.49; H, 8.67; N, 9.26; **found:** C, 68.26; H, 8.83; N, 8.79; **M.P.** = 95-96 °C (lit.² 101-102 °C (cyclohexane)).

4-(tert-Butyl)-2-chloropyridine [81167-60-4] (2a) was prepared according to the literature procedure with added details below.¹ In a 250 mL round bottom flask open to the air, 4-tert-butylpyridine-N-oxide (15.73 g, 104 mmol) was added slowly to ice cold POCl₃ (70 mL).

**Caution: reaction is exothermic and the reaction undergoes a colorless to orange color change!** The orange solution was heated to reflux under argon for 18 h during which time the color changed to dark red. Excess POCl₃ was removed by bulb-to-bulb short path distillation (20 °C, 60 mtorr) with the receiving flask chilled to -78 °C. **Failure to remove the majority of excess POCl₃ will decrease yield!** The remaining POCl₃ was quenched by slowly adding ice-cold saturated sodium carbonate solution to the remaining red-brown oil after distillation. Enough water was added to dissolve all precipitate that resulted after quenching with the ice-cold saturated sodium carbonate solution, and the organics were extracted with ether (4 x 100 mL). The combined organic extracts were washed with water (100 mL), then brine (100 mL), dried over MgSO₄, filtered and evaporated to dryness by rotary evaporation (28 °C, 74 torr) to yield 4-tert-butyl-2-chloropyridine as dark red and viscous oil (12.67 g, 72%). The oil was purified by bulb-to-bulb short path distillation (38 °C, 100 mtorr) to yield 4-tert-butyl-2-chloropyridine as colorless liquid (11.23 g, 64%). Spectral data were in agreement with literature.¹

| **1H-NMR** (500 MHz; CDCl₃): δ 8.25 (d, J = 5.2 Hz, 1H), 7.26 (s, 1H), 7.17 (dd, J = 5.2, 1.4 Hz, 1H), 1.27 (s, 10H); | **13C-NMR** (126 MHz; CDCl₃): δ 163.6, 151.9, 149.5, 121.4, 119.8, 35.1, 30.5; |
| **Anal. Calc.** for C₉H₁₂ClN requires: C, 63.72; H, 7.13; N, 8.26; **found:** C, 63.80; H, 7.21; N, 8.18. |

2. Methods

NMR chemical shifts are reported in ppm and referenced to the residual solvent peak CDCl₃ (δ = 7.26 ppm ¹H or δ = 77.16 ppm ¹³C) as an internal standard or trifluorotoluene (δ = 0.000 ppm) as an external standard (¹⁹F). NMR spectra were recorded on Bruker model Avance NMR spectrometer operating at 400.13 MHz or 500.13 MHz proton NMR frequency, and data analysis was performed using the iNMR software package (version 4.0.4).

Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

GC analyses of crude reaction mixtures were performed on an Agilent 7890A GC equipped with dual DB-5 columns (20 m x 180 μm x 0.18 μm), dual FID detectors and using hydrogen as the carrier gas. The analysis method used in all cases was 1 μL injection of sample, injection temp of 300 °C, 100:1 split ratio, initial inlet pressure was 20.3 psi but varied as the column flow was held constant at 1.8 mL/min for the duration of the run. Initial oven temperature of 50 °C was held for 0.46 min followed by a temperature ramp up to 300 °C at 65 °C/min and finally the temperature was held at 300 °C for 0.69 min. Total run time was approx. 5 min. FID temperature was 325 °C.

The University of Rochester CENTC Elemental Analysis Facility, Rochester, NY, performed elemental analyses.

**Sampling procedure for analysis of crude reaction mixtures.** A 100 μL gas tight syringe was used to withdraw a 10 μL aliquot of reaction mixture. The aliquot was quenched with water (50 μL), diluted with ether (1 mL), and filtered through a short pad of celite (approx.1/2 in.) in a pipette packed with glass wool.

3. Spectra
Figure S1. $^1$H-NMR: 4-tert-butylpyridine-N-oxide.
Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

Figure S2. $^{13}$C-NMR: 4-tert-butylpyridine-N-oxide.
Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

Figure S3. $^1$H-NMR: 4-(tert-butyl)-2-chloropyridine (2) [81167-60-4].
Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

Figure S4. $^{13}$C-NMR: 4-(tert-butyl)-2-chloropyridine (2) [81167-60-4].
Supporting Information: Substituted 2,2'-bipyridines by nickel-catalysis: 4,4'-di-tert-butyl-2,2'-bipyridine

Figure S5. $^1$H-NMR: 4,4'-Di-tert-butyl-2,2'-bipyridine [72914-19-3] (3a).
Supporting Information: Substituted 2,2'-bipyridines by nickel-catalysis: 4,4'-di-tert-butyl-2,2'-bipyridine

Figure S6. $^{13}$C-NMR: 4,4'-Di-tert-butyl-2,2'-bipyridine [72914-19-3] (3a).
Supporting Information: Substituted 2,2'-bipyridines by nickel-catalysis: 4,4'-di-tert-butyl-2,2'-bipyridine

Figure S7. $^1$H-NMR: 5,5’-Bis(trifluoromethyl)-2,2’-bipyridine [142946-80-3] (3b).
Supporting Information: Substituted 2,2'-bipyridines by nickel-catalysis: 4,4'-di-tert-butyl-2,2'-bipyridine

Figure S8. $^{13}$C-NMR: 5,5'-Bis(trifluoromethyl)-2,2'-bipyridine [142946-80-3] (3b).
Supporting Information: Substituted 2,2'-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2'-bipyridine

**Figure S9.** $^{19}$F-NMR: 5,5’-Bis(trifluoromethyl)-2,2’-bipyridine [142946-80-3] (3b).
Figure S10. $^1$H-NMR: 2,2’-Bipyridine [366-18-7] (3e).
Supporting Information: Substituted 2,2’-bipyridines by nickel-catalysis: 4,4’-di-tert-butyl-2,2’-bipyridine

Figure S11. $^{13}$C-NMR: 2,2’-Bipyridine [366-18-7] (3c).