Preliminary Communication

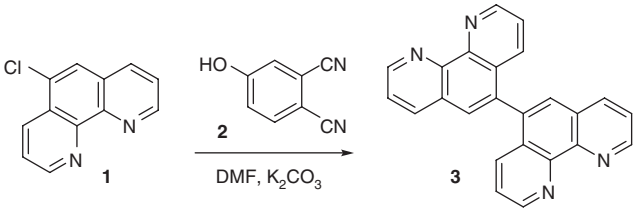
Mehmet Salih Ağırtaş*

A new method for the reaction of cross-coupling: preparation of 5,5′-bi(1,10-phenanthroline)

DOI 10.1515/hc-2016-0225
Received November 8, 2016; accepted December 8, 2016

Abstract: Synthesis and characterization of 5,5′-bi(1,10-phenanthroline) (**3**) are described. Compound **3** was obtained by treatment of 5-chloro-1,10-phenanthroline (**1**) with 4-hydroxy- phthalonitrile (**2**) in the presence of K_2CO_3 as a base in DMF at room temperature for 25 h.

Keywords: catalysis; cross-coupling; phenanthroline; synthesis.



Scheme 1

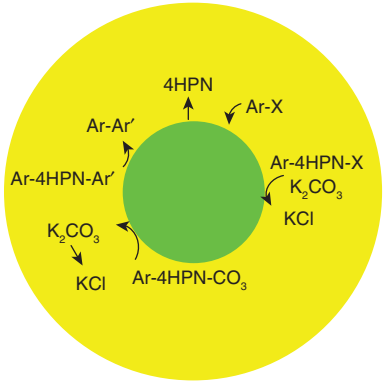


Figure 1 Catalytic cycle for cross-coupling of phenanthroline **1** (Ar-X) and 4-hydroxyphthalonitrile **2** (4HPN).

Introduction

1,10-Phenanthroline and its derivatives are valuable compounds for metal complexation, due to their high coordination numbers and flexible coordination modes [1, 2]. This class of compounds has found extensive utility as chelating ligands in coordination chemistry and as building blocks in supramolecular chemistry [3]. Metal complexes of phenanthroline and its derivatives have also found interesting biological applications, in particular, as agents for recognition and cleavage of DNA [4, 5] and as inhibitors of telomerase [6]. We report here the synthesis and characterization of 5,5′-bi(1,10-phenanthroline) (**3** in Scheme 1) using a new method that is an alternative to Suzuki-Miyaura cross-coupling reactions. To the best of our knowledge, compound **3** has not been described previously [7, 8].

5-Chloro-1,10-phenanthroline (**1**) was allowed to react with 4-hydroxyphthalonitrile (**2**) in the presence of K_2CO_3 in dry DMF under nitrogen atmosphere at room temperature for 25 h. Product **3** was obtained by using a conventional workup that did not involve chromatography. Currently, we are studying the scope and limitations of this new methodology that is more convenient and uses less expensive reagents than the classical Suzuki-Miyaura approach.

The reaction of Suzuki-Miyaura cross-coupling of phenylboronic acid and bromoaryl substrates requires the use of palladium complexes [9–13] that are difficult to prepare and handle. By contrast, the preparation of 4-hydroxyphthalonitrile is easy, and it is a commercial reagent.

A mechanism for this new cross-coupling reaction is suggested in Figure 1. As can be seen, the initial step involves the oxidative addition of 1 to **2**. In the final step product **3** is formed with a concomitant release of substrate **2**. As a result, compound **2** acts as a catalyst.

Experimental details

5-Chloro-1,10-phenanthroline, K_2CO_3, CH_2Cl_2, THF, DMF and 4-hydroxyphthalonitrile were purchased from Merck (Istanbul, Turkey) and Sigma (Interlab A.S., Istanbul, Turkey). Solvents were purified according to standard procedures [14] and stored over 4Å

***Corresponding author: Mehmet Salih Ağırtaş,** Department of Chemistry, Faculty of Science, Yuzuncu Yıl University, 65080 Van, Turkey, e-mail: salihagirtas@hotmail.com

molecular sieves. Melting point was measured on an electrothermal apparatus. IR spectrum was recorded on a Thermo Scientific FT-IR spectrophotometer, Waltham, MA, USA. ^{1}H NMR spectrum was recorded on a Bruker 300 spectrometer (Bruker, Karlsruhe, Germany) with tetramethylsilane as the internal standard. Mass spectrum was recorded on a Bruker Microflex LT instrument (Bruker, Karlsruhe, Germany) using MALDI and 2,5-dihydroxybenzoic acid as the matrix.

Synthesis of 5,5′-bi(1,10-phenanthroline)

A mixture of 5-chloro-1,10-phenanthroline (**1**, 1 g, 4.66 mmol) and 4-hydroxyphthalonitrile (**2**, 0.67 g, 4.66 mmol) in *N*,*N*-dimethylformamide (DMF, 25 mL) was stirred at room temperature under nitrogen atmosphere. After stirring for 15 min, K_2CO_3 (2.5 g, 18 mmol) was added portion-wise to the mixture over a period of 2 h. After stirring the reaction mixture for an additional 25 h, the mixture was poured into water (150 mL) and extracted with dichloromethane. The extract was washed with 10% $NaHCO_3$ and then with water, dried over anhydrous sodium sulfate and concentrated to give analytically pure product **3**: yield 1.0 g (60%); mp 129–132 °C; ^{1}H NMR (300 MHz, DMSO-d_6): δ 9.18 (dd, J = 1.7 Hz and 4.3 Hz, 2H), 9.10 (dd, J = 1.7 Hz and 4.3 Hz, 2H), 8.65 (dd, J = 1.7 Hz and 8.4 Hz, 2H), 8.46 (dd, J = 1.7 Hz and 8.1 Hz, 2H), 8.25 (s, 2H), 7.90 (dd, J = 4.3 Hz and 8.4 Hz, 2H), 7.78 (dd, J = 4.3 Hz and 8.1 Hz, 2H); IR: υ_{max} 3020, 1589, 1554, 1481, 1400, 1373, 1284, 1037, 933, 906, 794, 736 cm^{-1}; MS: *m/z* 358.10 [M]$^+$. Anal. Calcd for $C_{24}H_{14}N_4$: C, 80.43; H, 3.94; N, 15.63. Found: C, 80.61; H, 4.03; N, 15.56. Compound **3** is soluble in acetonitrile, dichloromethane, chloroform and DMF.

Acknowledgements: The author thanks the Yüzüncü Yıl University Office of Scientific Research Projects for the financial support to his research laboratory.

References

[1] Irina, A. D.; Matthew, C.; Nataliya, M. S.; Vyacheslav V. S. Convenient synthesis of 5-aryl(alkyl)sulfanyl-1,10-phenanthrolines from 5,6-epoxy-5,6-dihydro-1,10-phenanthroline, and their activity towards fungal β-D-glycosidases. *Tetrahedron Lett*. **2011**, *67*, 7470–7478.

[2] Luman, C. R.; Castellano, F. N. Phenanthroline Ligands; McCleverty, J. A. M., Thomas, J., Eds.; Compr. Coord. Chem. II; Elsevier: Oxford, UK, **2004**, vol. *1*, 25–39.

[3] Chelucci, G.; Thummel, R. P. Chiral 2,2′-bipyridines, 1,10-phenanthrolines, and 2,2′:6′,2″-terpyridines: syntheses and applications in asymmetric homogeneous catalysis. *Chem. Rev.* **2002**, *102*, 3129–3170.

[4] Kao, H.-C.; Hsu, C.-J.; Hsu, C.-W.; Lin, C.-H.; Wang, W.-J. Aza-bridged bis-1, 10-phenanthroline acyclic derivatives: synthesis, structure, and regioselective alkylation. *Tetrahedron Lett.* **2010**, *51*, 3743–3747.

[5] Bencini, A.; Lippolis, V. 1, 10-Phenanthroline: a versatile building block for the construction of ligands for various purposes. *Coord. Chem. Rev.* **2010**, *254*, 2096–2180.

[6] Krapcho, A. P.; Sparapani, S.; Leenstra, A.; Seitz, J. D. Displacement reactions of 2-chloro- and 2,9-dichloro-1,10-phenanthroline: synthesis of a sulfur-bridged bis-1,10-phenanthroline macrocycle and a 2,20-amino-substituted-bis-1,10-phenanthroline, *Tetrahedron Lett*. **2009**, *50*, 3195–3197.

[7] Toyota, S.; Woods, C. R.; Benaglia, M.; Siegel, J. S. Synthesis of unsymmetrical 2,8- and 2,9-dihalo-l,10-phenanthrolines and derivatives. *Tetrahedron Lett*. **1998**, *39*, 2697–2700.

[8] Rice, C. R.; Anderson, K. M. A new synthesis of a potentially versatile ligand 2,2′-bi-(1,10- phenanthroline): crystal structure and complexation chemistry. *Polyhedron* **2000**, *19*, 495–498.

[9] Ratniyom, J.; Chaiprasert, T.; Pramjit, S.; Yotphan, S.; Sangtrirutnugul, P.; Srisuratsiri, P.; Kongsaeree, P.; Supavadee Kiatisevi, S. Air-stable imidazole-imine palladium complexes for Suzukie Miyaura coupling: toward an efficient, green synthesis of biaryl compounds. *J. Organomet. Chem*. **2014**, *752*, 161–170.

[10] Kotha, S.; Lahiri, K.; Kashinath, D. Recent applications of the Suzuki–Miyaura cross-coupling reaction in organic synthesis. *Tetrahedron* **2002**, *58*, 9633–9695.

[11] Huang, F.; Batey, R. A. Cross-coupling of organoboronic acids and sulfinate salts using catalytic copper (II) acetate and 1, 10-phenanthroline: synthesis of aryl and alkenylsulfones. *Tetrahedron* **2007**, *63*, 7667–7672.

[12] Chen, L.; Gao, Z.; Li, Y. Immobilization of Pd (II) on MOFs as a highly active heterogeneouscatalyst for Suzuki–Miyaura and Ullmann-type coupling reactions. *Catal. Today* **2015**, 245, 122–128.

[13] Thathonga, Y.; Jitchatia, R.; Wongkhan, K. Air-stable anthracene-phosphine oxide adduct ligand in Pd catalysed Suzuki-Miyaura reactions. *APCBEE Procedia* **2012**, *3*, 154–160.

[14] Armarego, W. L. F.; Chai, C. L. L. Purification of laboratory chemicals, 7th ed., *Butterwordh-Heinemann*, Oxford, **2013**.