Tetrahedron Letters 52 (2011) 1931–1933

Contents lists available at ScienceDirect

Tetrahedron Letters

journal homepage: www.elsevier.com/locate/tetlet

Palladium-catalyzed cross-coupling reactions of 2-diazonaphthoquinones with arylboronic acids

Mitsuru Kitamura *, Rie Sakata, Tatsuo Okauchi

Department of Applied Chemistry, Kyushu Institute of Technology, 1-1 Sensuicho, Tobata, Kitakyushu 804-8550, Japan

ARTICLE INFO

Article history:
Received 10 January 2011
Revised 8 February 2011
Accepted 10 February 2011
Available online 13 February 2011

Keywords:
Arylboronic acids
Cross-coupling
Diazo compounds
Diazonaphthoquinones
Palladium catalysis

ABSTRACT

Palladium-catalyzed cross-coupling reactions of 2-diazonaphthoquinones and arylboronic acids proceeded by the treatment with $Pd(OAc)_2$ in acetic acid to afford 2-aryl-1-naphthols.

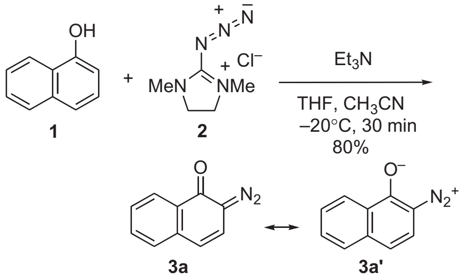
Introduction of substituents to aromatic compounds is an important process in organic synthesis. The electrophilic aromatic substitution reaction is used for this purpose in general.[1] For the synthesis of biaryl compounds, the cross-coupling reaction of aryl halides/sulfonates derived from the corresponding aryl compounds is widely used.[2]

Regioselective arylation of 1-naphthol is one of the difficult issues that remained in the synthesis of the substituted phenol derivatives. The products, 2-aryl-1-naphthols, are attractive candidates for germicide and fungicide to replace 2-phenylphenol.[3] Barton reported that 2-phenyl-1-naphthol could be synthesized directly from 1-naphthol by the reaction with pentaphenyl bismuth in 48% yield.[4,5] Oi et al. have reported Rh(I)-mediated coupling of 1-naphthol and bromobenzene, in which a mixture of 2-phenyl and 2,8-diphenyl-1-naphthol was obtained.[6] Although the syntheses of 2-halo-1-naphthol have been reported,[7] the cross-coupling reaction for the synthesis of 2-aryl-1-naphthol has not been investigated in our knowledge.

Recently, we reported that 2-diazonaphthoquinone could be regioselectively synthesized from the corresponding 1-naphthols by the diazo-transfer with 2-azido-1,3-dimethylimidazolinium chloride (ADMC) **2** (Scheme 1).[8,9] We expected that 2-aryl-1-naphthol derivatives could be synthesized regioselectively if N_2 moiety in 2-diazonaphthoquinone **3a** was substituted with suitable aryl metal compounds. That is, we supposed that the Pd(0)-catalyzed coupling of diazonaphthoquinone with arylboronic acids would proceed similar to Suzuki–Miyaura coupling[10] if the diazonaphthoquinone behaved like aryl diazonium **3a**′.[11,12] We became interested in and thus examined the palladium-catalyzed cross-coupling reaction of aryl boronic acids with diazonaphthoquinones. In this Letter, we describe the outcome of this investigation.

We initially attempted to couple diazonaphthoquinone **3a** and *p*-tolylboronic acid [*p*-Tol-B$(OH)_2$] (Table 1). First, we examined the reaction by using an excess amount of *p*-tolylboronic acid (1.2 equiv) relative to diazonaphthoquinone in the presence of Pd(0) catalyst (Runs 1–3) in several solvents (MeOH, CH_3CN, and AcOH); the yields of coupling product **4a** were low.

When $Pd(OAc)_2$ was used as a catalyst, the yield of **4a** was greater than when Pd(0) catalyst was used in MeOH, CH_3CN, and AcOH, respectively, and biaryl **5a** was formed as a by product (Runs 4–6). Among the solvents, we investigated in the presence of $Pd(OAc)_2$ (Runs 4–9), the yield of **4a** was high in CH_3CN and AcOH



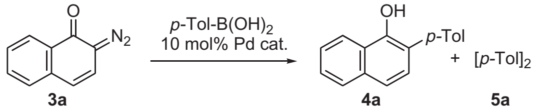
Scheme 1. Synthesis of diazonaphthoquinone **3a**.

---

* Corresponding author.
E-mail address: kita@che.kyutech.ac.jp (M. Kitamura).

0040-4039/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2011.02.047

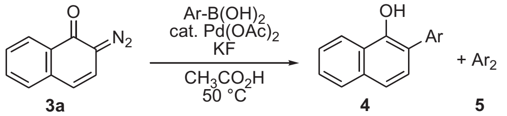
Table 1
Optimization of the coupling of diazonaphthoquinone **3a** and *p*-Tol-B$(OH)_2$



Run	Pd cat.	Additive	Solvent	Conditions	Yield[a] (%)	
					4a	**5a**
1[b]	$Pd(PPh_3)_4$	–	MeOH	rt 21 h	3	0
2[b]	$Pd_2(dba)_3$	–	CH_3CN	50 °C 3.5 h	8	0
3[b]	$Pd_2(dba)_3$	–	AcOH	rt 9.5 h	2	0
4[b]	$Pd(OAc)_2$	–	MeOH	Reflux 1.5 h	8	8
5[b]	$Pd(OAc)_2$	–	CH_3CN	50 °C 1 h	32	11
6[b]	$Pd(OAc)_2$	–	AcOH	50 °C 2 h	31	Trace
7[b]	$Pd(OAc)_2$	–	1,4-Dioxane	rt 9.5 h	6	6
8[b]	$Pd(OAc)_2$	–	DMF	60 °C 2 h	2	2
9[b]	$Pd(OAc)_2$	–	Toluene	rt 2.5 h	trace	0
10[c]	$Pd(OAc)_2$	–	AcOH	50 °C 1 h	43	7
11[c]	$Pd(OCOCF_3)_2$	–	AcOH	50 °C 40 min	45	5
12[c]	$PdCl_2$	–	AcOH	50 °C 7 h	19	3
13[c]	$Pd(OAc)_2$	KF	AcOH	50 °C 3 h	67	11
14[c]	$Pd(OAc)_2$	TBAF	AcOH	50 °C 8 h	65	10

[a] Isolated yield.
[b] Molar ratio: **3a**/*p*-Tol-B$(OH)_2$/M cat. = 1.2/1/0.1.
[c] Molar ratio: **3a**/*p*-Tol-B$(OH)_2$/M cat./additive = 1/3/0.1/3.

Table 2
Pd-catalyzed coupling of diazonaphthoquinone **3a** and various aryl boronic acids[a]



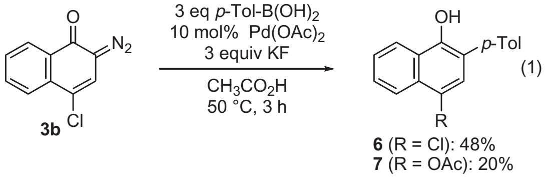
Run	Ar	Time (h)	Yield[b] (%)			
			4		**5**	
1	Ph	3	**4b**	76	**5b**	Trace
2	*o*-MeC_6H_4	3	**4c**	56	**5c**	2
3	*o*-$MeOC_6H_4$	3	**4d**	40	**5d**	0
4	*m*-$MeOC_6H_4$	2	**4e**	53	**5e**	3
5	*p*-$MeOC_6H_4$	4	**4f**	25	**5f**	4
6	*p*-$CF_3C_6H_4$	5	**4g**	34	**5g**	16
7	1-Naphthyl	4	**4h**	47	**5h**	7

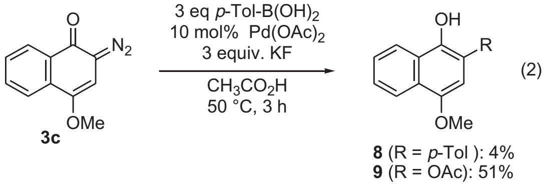
[a] Molar ratio: **3a**/Ar-B$(OH)_2$/$Pd(OAc)_2$/KF = 1/3/0.1/3.
[b] Isolated yield.

(32% and 31%, respectively), and thus, we chose AcOH as the solvent for further study because the reaction media were cleaner than those when using CH_3CN as a solvent. Next, the coupling reaction was examined by using an excess amount of boronic acid relative to diazonaphthoquinone **3** (Runs 10–14). The yield of **4a** was increased to 43% when 3 equiv of boronic acid was used (Run 10). As a palladium catalyst, $Pd(OCOCF_3)_2$ showed almost the same ability as $Pd(OAc)_2$, whereas $PdCl_2$ was ineffective (Runs 11 and 12). In Suzuki–Miyaura coupling, the addition of F^- is sometimes effective.[13] In the coupling of **3a**, the yield of **4a** was increased to 67% or 65% by the addition of KF or tetrabutylammonium fluoride (TBAF), respectively (Runs 13 and 14).

A series of aryl boronic acids were then subjected to the optimized reaction conditions (Table 1, Run 13) with diazonaphthoquinone **3a** (Table 2). When mono methyl or the non-substituted phenyl boronic acid was used, the coupling products were obtained in good yields (Runs 1 and 2).[14] In the series of monomethoxyphenyl boronic acids (Runs 3–5), the reaction proceeded smoothly, although a lower yield was observed for the *para*-substituted boronic acid (Run 5). The reaction with phenyl boronic acid having an electron-deficient group, such as a trifluoromethyl group, proceeded affording the corresponding coupling product **4g**, but the yield was not high (Run 6). 1-Naphthyl boronic acid was used for the coupling reaction (Run 7).

Then, the reaction of 4-substituted 2-diazonaphthoquinone with *p*-tolyl boronic acid was examined. The reaction of 4-chloro diazonaphthoquinone **3b** proceeded smoothly to give the coupling products in 68% as a mixture of **6** and **7** (eq. 1). In the reaction of 4-methoxy diazonaphthoquinone **3c**, the expected coupling product **8** was obtained in 4% yield, and naphthalene triol derivative **9** was obtained in 51% yield (eq. 2).[15]

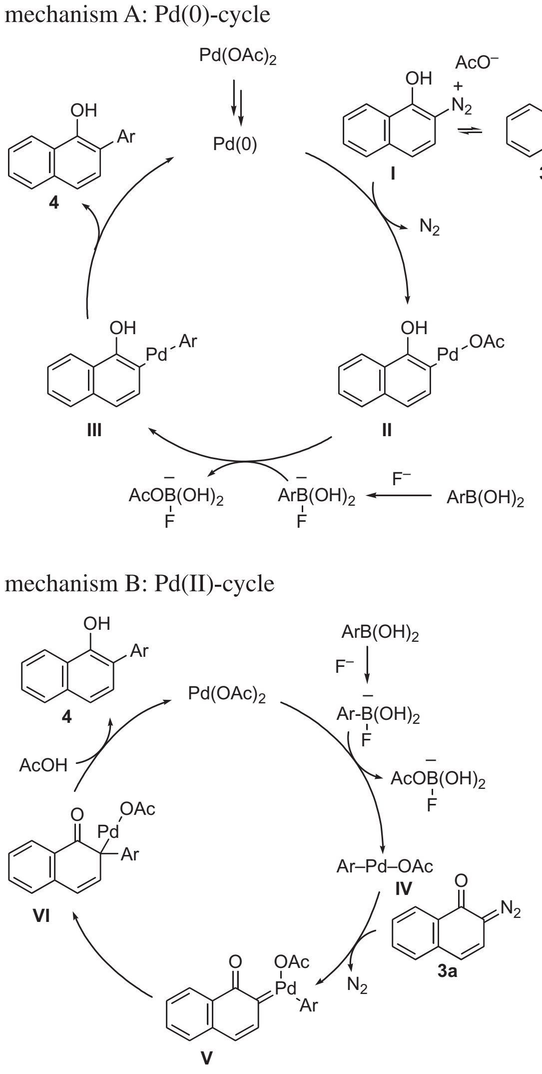




Recently, Wang reported the palladium-catalyzed cross coupling of acyclic α-diazocarbonyl compounds with aryl boronic acid, proposing the Pd(0)–Pd(II) catalytic cycle as the mechanism and palladium carbene complex as a key intermediate.[16] In Scheme 2, possible two reaction mechanisms for the $Pd(OAc)_2$-catalyzed coupling of diazonaphthoquinone **3a** and aryl boronic acid in the presence of acetic acid are depicted. Mechanism A is the general Suzuki–Miyaura coupling mechanism which is based on Pd(0)–Pd(II) cycle initiated by the oxidative addition of protonated diazonaphthoquinone **I** to Pd(0). Transmetallation between aryl palladium **II** and aryl(fluoro)borate proceeded to give diarylpalladium complex **III**,[13] which underwent a reductive elimination, leading to form 2-aryl-1-naphthol **4** and the regeneration of Pd(0) catalyst. Mechanism B is the Pd(II)-catalytic cycle via the migratory insertion of a palladium carbene complex.[16,17] The reaction is initiated by the transmetallation of aryl boronic acid by the aid of F^-[10,13] and $Pd(OAc)_2$ to generate intermediate **IV**,[16] which reacts with diazonaphthoquinone **3a** to form palladium carbene complex **V**. Migratory insertion of the aryl group to the carbene carbon occurs, generating palladium complex **VI**. Finally, the protonation of acetic acid to **VI** affords the coupling product **4** and regenerates $Pd(OAc)_2$.

Because it was more efficient to use of Pd(II) complex than Pd(0) complex in this reaction, as shown in Table 1, we uphold Pd(II)-cycle, that is, mechanism B as the reaction mechanism in the proposed mechanisms. Acetate **9** would be formed by the reaction of **3c** and $Pd(OAc)_2$ instead of **IV**, and the successive migratory insertion of the acethoxy group to the carbene carbon similar to aryl group migration as shown **V**→**VI**.

In conclusion, we have demonstrated the first palladium-catalyzed cross-coupling reaction of diazonaphthoquinone and



Scheme 2. Possible reaction mechanisms.

aryl boronic acid. It provides a novel access to biaryl compounds. Because 2-diazonaphthoquinone can be regioselectively synthesized from 1-naphthol by diazo-transfer,[8] regioselective C-2 arylation of 1-naphthol was possible in two steps (diazotization then cross-coupling with aryl boronic acid). Although the reaction mechanism is unclear, the proposed mechanism, including the migratory insertion of palladium carbene, is recently recognized and established.[16,17] Further studies on the scope and the mechanism of the reaction are currently in progress.

Acknowledgments

This work was supported by the Nagase Science Technology Foundation and a Grant-in-Aid from the Ministry of Education, Culture, Sports, Science, and Technology of Japan.

References and notes

1. (a) Taylor, R. *lectrophilic Aromatic Substitution*; Wiley: NewYork, 1990; (b) Smith, M. B.; March, J. *March's Advanced Organic Chemistry*, 6th ed.; Wiley: Hoboken, 2007. 657.
2. (a) *Metal-Catalyzed Cross-Coupling Reactions*; Diederich, F., Stang, P. J., Eds.; Wiley-VCH: Weinheim, 1998; (b) *Handbook of Organopalladium Chemistry for Organic Synthesis*; Negishi, E., Ed.; Wiley: New York, 2002; (c) *Cross-Coupling Reactions: A Practical Guide*; Miyaura, N., Ed.; Springer: Berlin, 2002; (d) *Metal-catalyzed Cross-coupling Reactions*; de Meijere, A., Diederich, F., Eds., 2nd ed.; Wiley-VCH: Weinheim, 2004.
3. (a) Appel, K. E. *Arch. Toxicol* **2000**, *74*, 6; (b) Brusick, D. *Environ. Mol. Mutagen* **2005**, *45*, 460.
4. (a) Barton, D. H. R.; Bhatnagar, N. Y.; Blazejewski, J.-C.; Charpiot, B.; Finet, J.-P.; Lester, D. J.; Motherwell, W. B.; Papoula, M. T. B.; Stanforth, S. P. *J. Chem. Soc., Perkin Trans. 1* **1985**, 2657; (b) Barton, D. H. R.; Blazejewski, J.-C.; Charpiot, B.; Lester, D. J.; Motherwell, W. B.; Papoula, M. T. B. *J. Chem. Soc., Chem. Commun.* **1980**, 827.
5. Related direct 2-arylation of 1-naphthol derivative using aryl lead compound, see: Bungard, C. J.; Morris, J. C. *J. Org. Chem.* **2006**, *71*, 7354.
6. Oi, S.; Watanabe, S.-i.; Fukita, S.; Inoue, Y. *Tetrahedron Lett.* **2003**, *44*, 8665.
7. Synthesis of 2-bromo-1-naphthol, see: (a) Mashraqui, S. H.; Mudaliar, C. D.; Hariharasubrahmanian, H. *Tetrahedron Lett.* **1997**, *38*, 4865; (b) Carreño, M. C.; García Ruano, J. L.; Sanz, G.; Toledo, M. A.; Urbano, A. *Synlett* **1997**, 1241; (c) Kavala, V.; Naik, S.; Patel, B. K. *J. Org. Chem.* **2005**, *70*, 4267; Synthesis of 2-iodo-1-naphthol, see: (d) Huang, Q.; Fazio, A.; Dai, G.; Campo, M. A.; Larock, R. C. *J. Am. Chem. Soc.* **2004**, *126*, 7460; (e) Saikia, L.; Rajesh, M.; Srinivas, D.; Ratnasamy, P. *Catal. Lett.* **2010**, *137*, 190.
8. Kitamura, M.; Tashiro, N.; Sakata, R.; Okauchi, T. *Synlett* **2010**, 2503.
9. For the reaction with 2-azido-1,3-dimethylimidazolinium salt, see: (a) Kitamura, M.; Tashiro, N.; Okauchi, T. *Synlett* **2009**, 2943; (b) Kitamura, M.; Tashiro, N.; Takamoto, Y.; Okauchi, T. *Chem. Lett.* **2010**, *39*, 732; (c) Kitamura, M.; Yano, M.; Tashiro, N.; Miyagawa, S.; Sando, M.; Okauchi, T. *Eur. J. Org. Chem.* **2011**, 458.
10. (a) Miyaura, N.; Suzuki, A. *Chem. Rev.* **1995**, *95*, 2457; (b) Suzuki, A. *J. Organomet. Chem.* **1999**, *576*, 147; (c) Chemler, S. R.; Trauner, D.; Danishefsky, S. J. *Angew. Chem., Int. Ed.* **2001**, *40*, 4544; (d) Miyaura, N. *Top. Curr. Chem.* **2002**, *219*, 11; (e) Hassan, J.; Sevignon, M.; Gozzi, C.; Schulz, E.; Lemaire, M. *Chem. Rev.* **2002**, *102*, 1359; (f) Kotha, S.; Lahiri, K.; Kashinath, D. *Tetrahedron* **2002**, *58*, 9633; (g) Suzuki, A. In *Modern Arene Chemistry*; Astruc, D., Ed.; Wiley-VCH: Weinheim, 2002; p 53; (h) Bellina, F.; Carpita, A.; Rossi, R. *Synthesis* **2004**, 2419.
11. For a review, see: Roglans, A.; Pla-Quintana, A.; Moreno-Mañas, M. *Chem. Rev.* **2006**, *106*, 4622.
12. (a) Darses, S.; Jeffery, T.; Brayer, J.-L.; Demoute, J.-P.; Genêt, J.-P. *Tetrahedron Lett.* **1996**, *37*, 3857; (b) Darses, S.; Genêt, J.-P.; Brayer, J.-L.; Demoute, J.-P. *Tetrahedron Lett.* **1997**, *38*, 4393; (c) Sengupta, S.; Bhattacharyya, S. *J. Org. Chem.* **1997**, *62*, 3405.
13. (a) Wright, S. W.; Hageman, D. L.; McClure, L. D. *J. Org. Chem.* **1994**, *59*, 6095; (b) Kirschbaum, T.; Briehn, C. A.; Bäuerle, P. *J. Chem. Soc., Perkin Trans. 1* **2000**, 1211.
14. Typical procedure for the Pd-catalyzed coupling of 2-diazonaphthoquinone **3a** and aryl boronic acid (Table 2, Run 1): A acetic acid (2 mL) solution of 2-diazonaphthoquinone **3a** (40.9 mg, 0.24 mmol), 1-naphthyl boronic acid (88.0 mg, 0.72 mmol), KF 41.9 mg, 0.72 mmol), and $Pd(OAc)_2$ (5.4 mmol, 0.024 mmol) under nitrogen atmosphere was warmed to 50 °C and stirred for 3 h. After cooling the mixture to room temperature, sat $NaHCO_3$ aq was added, and the mixture was extracted with CH_2Cl_2 (×3). The combined extracts were washed with brine, dried over anhydrous $MgSO_4$, and evaporated in vacuo. The residue was purified by flash column chromatography (hexane/EtOAc = 80/20) to afford cross-coupling product **4b** (40.1 mg, 76%) and biaryl **5b** (0.2 mg).
15. Diazonaphthoquinone **9** was also obtained in 49% yield by the reaction of **3c** in the absence of p-Tol-B$(OH)_2$ (10 mol % $Pd(OAc)_2$, 3 equiv KF, CH_3CO_2H, 50 °C, 3 h).
16. Peng, C.; Wang, Y.; Wang, J. *J. Am. Chem. Soc.* **2008**, *130*, 1566.
17. (a) Danopoulos, A. A.; Tsoureas, N.; Green, J. C.; Hursthouse, M. B. *Chem. Commun.* **2003**, 756; (b) Albéniz, A. C.; Espinet, P.; Manrique, R.; Pérez-Mateo, A. *Chem. Eur. J* **2005**, *11*, 1565; (c) Greenman, K. L.; Van Vranken, D. L. *Tetrahedron* **2005**, *61*, 6438; (d) López-Alberca, M. P.; Mancheño, M. J.; Fernández, I.; Gómez- Gallego, M.; Sierra, M. A.; Torres, R. *Org. Lett.* **2007**, *9*, 1757; (e) Devine, S. K. J.; Van Vranken, D. L. *Org. Lett.* **2007**, *9*, 2407; (f) Barluenga, J.; Moriel, P.; Valdés, C.; Aznar, F. *Angew. Chem., Int. Ed.* **2007**, *46*, 5587; (g) Chen, S.; Wang, J. *Chem. Commun.* **2008**, 4198; (h) Xiao, Q.; Ma, J.; Yang, Y.; Zhang, Y.; Wang, J. *Org. Lett.* **2009**, *11*, 4732; (i) Zhang, Z.; Liu, Y.; Gong, M.; Zhao, X.; Zhang, Y.; Wang, J. *Angew. Chem., Int. Ed.* **2010**, *49*, 1139.