A Nonsymmetric Pincer-Catalyzed Suzuki−Miyaura Arylation of Benzyl Halides and Other Nonactivated Unusual Coupling Partners[†]

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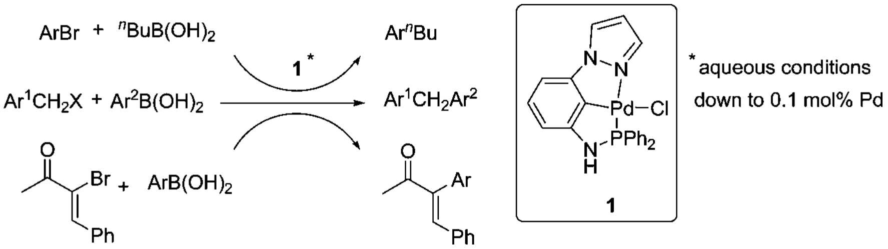
Received July 27, 2008



The catalytic activity of a PCN-type palladium pincer complex is evaluated in the construction of C(sp^2)-C(sp^2) and C(sp^2)-C(sp^3) bonds by Suzuki−Miyaura cross-couplings employing nontypical substrates such as benzyl halides, α-haloenones, or alkylboronic acids as coupling partners. Most of the reported reactions are achieved in aqueous media, with all of the advantages implied.

Introduction

Suzuki−Miyaura cross-coupling of arylboronic acids with haloarenes or aryl triflates is one of the most powerful reactions for C−C bond construction.[1] Many transition metal complexes have been used to promote this reaction,[2] and although some of them are very efficient, allowing low catalyst loadings and mild reaction conditions, most of these suffer from poor stability toward air, moisture, or in general, reaction conditions. In consequence, the search of new catalysts to perform this transformation has become a challenging area in organic synthesis in the past decade.[3] Palladacycles are a fascinating group of organometallic compounds with applications not only in synthetic chemistry but also in other areas such as materials science or biological and supramolecular chemistry.[4] Among them, the so-called palladium pincer complexes, that is, palladacycles containing tridentate ligands, have become an emerging and very promising family of compounds because of the excellent balance between stability and reactivity which enable them to catalyze various organic transformations.[5]

Since the first report on an application of palladium pincer complexes in a C(sp^2)-C(sp^2) coupling reaction,[6] several groups have shown interest in developing these kinds of catalysts and precatalysts, symmetric NCN[7] or PCP[8] types being the most commonly employed. In contrast, although the presence of two different donors can provide a unique reactivity, there are very few reports on the synthesis and applications of nonsymmetric PCN pincer complexes.[9] In this context, following our research for more efficient and environmentally friendly catalytic systems,[10] we recently described the preparation and characteriza-

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[†] Dedicated to Professor Luis Castedo on the occasion of his 70th birthday.

[1] *Metal-Catalyzed Cross-Coupling Reactions*, 2nd ed.; de Meijere, A., Diederich, F., Eds.; Wiley-VCH: New York, 2004.

[2] (a) Miyaura, N.; Suzuki, A. *Chem. Rev.* **1995**, *95*, 2457–2483. (b) *Cross-Coupling Reactions*; Miyaura, N., Ed.; Springer: Berlin, 2002. (c) *Homogeneous Catalysis with Metal Phosphine Complexes*; Pignolet, L. H., Ed.; Plenum: New York, 1983. (d) *Homogeneous Catalysis*; Parshall, G. W., Ittel, S., Eds.; John Wiley and Sons: New York, 1992.

[3] Kota, S.; Lahiri, K.; Kashinath, D. *Tetrahedron* **2002**, *58*, 9633–9695.

[4] Dupont, J.; Consorti, C.; Spencer, J. *Chem. Rev.* **2005**, *105*, 2527–2571.

[5] For a revision on the use of pincer complexes in organic synthesis, see: Singleton, J. T. *Tetrahedron* **2003**, *59*, 1837–1857.

[6] Ohff, M.; Ohff, A.; van der Boom, M. E.; Milstein, D. *J. Am. Chem. Soc.* **1997**, *119*, 11687–11688.

[7] Some examples of NCN pincer catalyst employed in Suzuki−Miyaura couplings: (a) Luo, Q.; Eibauer, S.; Reiser, O. *J. Mol. Catal.* **2007**, *268*, 65–69. (b) Liau, C.-Y.; Chan, K.-T.; Zeng, J.-Y.; Hu, C.-H.; Tu, C.-Y.; Lee, H. M. *Organometallics* **2007**, *26*, 1692–1702. (c) Bianchini, C.; Lenoble, G.; Oberhauser, W.; Parisel, S.; Zanobini, F. *Eur. J. Inorg. Chem.* **2005**, 4794–4800. (d) Churruca, F.; SanMartin, R.; Tellitu, I.; Domínguez, E. *Synlett* **2005**, 3116–3120.

[8] For some examples of PCP pincer catalyst employed in Suzuki−Miyaura couplings, see: (a) Bedford, R. B.; Draper, S. M.; Scully, P. N.; Welch, S. L. *New. J. Chem.* **2000**, *24*, 745–747. (b) Bolliger, J. L.; Blacque, O.; French, C. M. *Angew. Chem., Int. Ed.* **2007**, *46*, 6514–6517. (c) Kimura, T.; Uozomi, Y. *Organometallics* **2006**, *25*, 4883–4887. (d) Benito-Garagorri, D.; Cocokic, V.; Kirchner, K. *Organometallics* **2006**, *25*, 3817–3823. (e) Gong, J.-F.; Zhnag, Y.-H.; Song, M.-P.; Xu, C. *Organometallics* **2007**, *26*, 6487–6492. (f) Sheloumov, A. M.; Tundo, P.; Dolgushin, F. M.; Koridze, A. A. *Eur. J. Inorg. Chem.* **2008**, 572–576.

10.1021/jo8016633 CCC: $40.75

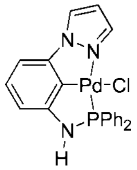


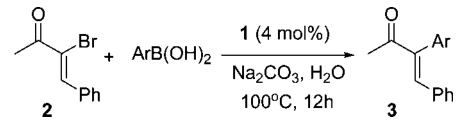
FIGURE 1. Pincer-type complex **1**.

tion of the PCN-type palladium pincer complex **1** (Figure 1),[11] which was subsequently employed in a range of standard Hiyama, Sonogashira, and Suzuki reactions. To our delight, in addition to a remarkably high efficiency, palladacycle **1** displayed hydrophilic properties that made it suitable for performing transformations in aqueous media.[12]

In principle, any carbon-halogen bond, regardless of the carbon hybridization, is vulnerable to the attack of the nucleophilic partner if the appropriate metal-containing catalyst or precatalyst is employed. Nevertheless, difficulties are often encountered when inactivated alkyl electrophiles are employed in Suzuki couplings, generally caused by a slower oxidative addition of the alkyl halide, competing β-elimination side reactions, and a more difficult reductive elimination step.[13] Interestingly, when alkyl boronic esters or acids are employed in this context, Suzuki coupling is usually interfered with by a more troublesome transmetalation step between the boronic counterpart and the intermediate Pd species.[14]

Thus, although biaryl Suzuki coupling is reasonably well developed, the lack of efficient procedures for the reaction with alkyl halides or primary alkyl boronic acids and other nonstandard substrates has fueled much research.[14–16] In this context, Nájera et al. reported an elegant use of oxime-derived palladacycles in a series of Suzuki-type reactions employing nonactivated partners such as benzyl halides or alkylboronic acids.[17] However, concerning pincer complexes, to the best of our knowledge, only two examples have been found in the literature. Moreover, in the latter reports both pincers were symmetric and each was applied to catalyze only one Suzuki reaction with a single nonactivated substrate.[18] Herein we wish to describe the novel use of a nonsymmetric PCN pincer complex as a Suzuki–Miyaura coupling precatalyst of such nonactivated and unusual substrates.

TABLE 1. Suzuki Coupling of α-Bromoenone and Arylboronic Acids Employing Complex 1



entry	Ar	**3** (%)[a]
1	Ph	**3a** (74)
2	4-MeOPh	**3b** (90) *86*
3	1-Naph	**3c** (38)

[a] Determined by ^{1}H NMR on the basis of the amount of starting aryl halide. Diethylene glycol dimethyl ether was used as internal standard. Isolated yield is shown in italics.

Results and Discussion

To start with, we chose α-bromoenones **2** as electrophilic partners because of two main reasons. First, a C(sp^2)-C(sp^2) bond would be formed, not very dissimilar to the biaryl version of the Suzuki coupling in which **1** had provided excellent results.[11] Second, palladium-catalyzed cross-coupling of α-haloenones with arylboronic acids has been scarcely studied.[19,20] In fact, this is the first report concerning the use of a pincer-type palladacycle in the latter transformation. Thus, easily available bromoenone **2**[19b] was reacted with several aryl bromides in the presence of a catalytic amount of complex **1** employing Na$_2$CO$_3$ as base and neat water as solvent. To our delight, the α-arylation of the stating material took place in these conditions in moderate to good yields. It is noteworthy that the use of neat water as solvent, apart from the previously mentioned advantages in terms of sustainability, safety or economy, provides a really easy workup and purification procedure.

Encouraged by the promising results obtained with α-bromocetones, and in order to improve the versatility of the complex **1**, our attention then focused on C(sp^2)-C(sp^3) bond construction by Suzuki coupling. First, we tested the effectiveness of the latter palladacycle in the coupling of arylbromides with butylboronic acid. In this regard, all our efforts to accomplish the reaction in neat water were unsuccessful, and although stronger reaction conditions were employed, such as higher temperatures or catalyst loadings, in all cases the starting materials were recovered. However, PCN pincer **1** turned out to be highly efficient when *o*-xylene was used as solvent. Accordingly, a number of electronically different aryl bromides were effectively coupled with *n*-butylboronic acid, as shown in

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(9) A PCN pincer applied to Heck reaction: (a) Consorti, C. S.; Ebeling, G.; Flores, F. R.; Rominger, F.; Dupont, J. *Adv. Synth. Cat.* **2004**, *246*, 617–634. Biaryl Suzuki couplings catalyzed by a PCN palladium complex: (b) DaSilvera Neto, B. A.; Lopes, A. S.; Ebeling, G.; Gonzalves, R. S.; Costa, V. E. U.; Quina, F. H.; Dupont, J. *Tetrahedron* **2005**, 10975–10982. (c) Mancilha, F. S.; DaSilvera Neto, B. A.; Lopes, A. S.; Moreira, P. F.; Quina, F. H.; Gonzalves, R. S.; Dupont, J. *Eur. J. Org. Chem.* **2006**, 4924–4033. (d) Rosa, G. R.; Rosa, C. H.; Rominger, F.; Dupont, J.; Monteiro, A. L. *Inorg. Chem. Acta* **2006**, *359*, 1947–1954. (e) Rosa, G. R.; Ebeling, G.; Dupont, J.; Monteiro, A. L. *Synthesis* **2003**, 2894–2897. The synthesis of chiral PCN pincer complexes designed to catalyze asymmetric reactions: (f) Motoyama, Y.; Shimozono, K.; Nisiyama, H. *Inorg. Chim. Acta* **2006**, *359*, 1725–1730.

(10) (a) Churruca, F.; SanMartin, R.; Tellitu, I.; Domínguez, E. *Tetrahedron Lett.* **2006**, *47*, 3233–3237. (b) Churruca, F.; Sanmartin, R.; Inés, B.; Tellitu, I.; Domínguez, E. *Adv. Synth. Catal.* **2006**, *348*, 1836–1840. See also ref 7d.

(11) Inés, B.; SanMartin, R.; Churruca, F.; Domínguez, E.; Urtiaga, M. K.; Arriortua, M. I. *Organometallics* **2008**, *28*, 2833–2839.

(12) A review focused on organic reactions in aqueous media: (a) Li, C.-J. *Chem. Rev.* **2005**, *105*, 3095–3165. For a revision on the use of aqueous environments in Suzuki–Miyaura biaryl coupling, see: (b) Franzén, R.; Xu, Y. *Can. J. Chem.* **2005**, *83*, 266–272.

(13) For a minireview focused on cross-couplings with nonactivated alkyl halides, see: Frisch, A. C.; Beller, M. *Angew. Chem., Int. Ed.* **2005**, *44*, 674–688.

(14) Kataoka, N.; Shelby., Q.; Stambuli, J. P.; Hartwing, J. F. *J. Org. Chem.* **2002**, *67*, 5553–5566.

(15) Some examples of the Suzuki–Miyaura reaction employing alkyl boronic acids: (a) Kondolff, I.; Doucet, H.; Santelli, M. *Tetrahedron* **2004**, *60*, 3813–3818. (b) Molander, G. A.; Yun, C.-S. *Tetrahedron* **2002**, *58*, 1465–1470. (c) Andrus, M. B.; Song, M. B. *Org. Lett.* **2001**, *3*, 3761–3764.

(16) The use of benzyl halides in the Suzuki–Miyaura coupling: (a) Chang, C.-P.; Huang, Y. L.; Hong, F.-E. *Tetrahedron* **2005**, *61*, 3835–3839. (b) Bandgar, B. P.; Bettigeri, S. V.; Phopase, J. *Tetrahedron Lett.* **2004**, *45*, 6959–6962. (c) Langle, S.; Abarbi, M.; Duchene, A. *Tetrahedron Lett.* **2003**, *44*, 9255–9258. (d) Miyaura, N.; Yano, T.; Suzuki, A. *Tetrahedron Lett.* **1980**, *21*, 2865–2858. (e) Chahen, L.; Doucet, H.; Santelli, M. *Synlett* **2003**, 1668–1672.

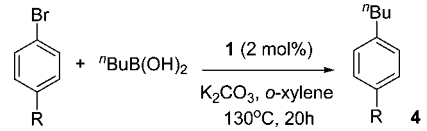
(17) (a) Botella, L.; Nájera, C. *J. Organomet. Chem.* **2002**, *663*, 46–57. (b) Botella, L.; Nájera, C. *Angew. Chem., Int. Ed.* **2002**, *41*, 179–181.

(18) For the use of a NCN symmetric pincer in a Suzuki coupling with one benzyl derivative, see: (a) Luo, Q.; Eibauer, S.; Reiser, O. *J. Mol. Catal. A: Chem.* **2007**, *268*, 65–69. (b) A PCP palladium pincer has been used in a Suzuki coupling with bromoundecane as electrophilic partner. See ref 8d.

(19) (a) Felpin, F.-X. *J. Org. Chem.* **2005**, *70*, 8575–8578. (b) Banks, J. C.; Van Mele, D.; Frost, C. G. *Tetrahedron Lett.* **2006**, *47*, 2863–2866. (c) Burns, M. J.; Fairlamb, J. S.; Kapdi, A. R.; Sehnal, P.; Taylor, R. J. K. *Org. Lett.* **2007**, *9*, 5397–5400.

(20) Suzuki–Miyaura coupling of α-haloenones catalyzed by a bentzothiazole-based palladium precatalyst: Dawood, K. M. *Tetrahedron* **2007**, *63*, 9642–9651.

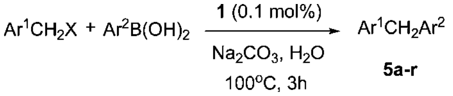
TABLE 2. Suzuki Coupling of Aryl Bromides and *n*-Butylboronic Acid Employing Complex 1



entry	R	**4** (%)[a]
1	MeCO	**4a** (97) *94*
2	MeO	**4b** (61)
3	NO_2	**4c** (68)
4	CN	**4d** (74)

[a] Determined by ^{1}H NMR on the basis of the amount of starting aryl halide. Diethylene glycol dimethyl ether was used as internal standard. Isolated yield is shown in italics.

TABLE 3. Diarylmethanes 5a−r Prepared by Suzuki Coupling Employing Pincer Complex 1



$$\mathrm{Ar^1CH_2X + Ar^2B(OH)_2 \xrightarrow[\substack{Na_2CO_3,\ H_2O \\ 100^\circ C,\ 3h}]{\mathbf{1}\ (0.1\ mol\%)} Ar^1CH_2Ar^2}$$

5a-r

entry	X	Ar^1	Ar^2	**5** (%)[a]
1	Br	Ph	Ph	**5a** (67) *65*
2[b]	Cl	Ph	Ph	**5a** (35) *32*
3	Br	Ph	4-OMePh	**5b** (92)
4[b]	Cl	Ph	4-OMePh	**5b** (51)
5	Br	Ph	3,4-OMePh	**5c** (82) *81*
6[b]	Cl	Ph	3,4-OMePh	**5c** (53)
7	Br	Ph	1-Naph	**5d** (71)
8[b]	Cl	Ph	1-Naph	**5d** (42)
9	Br	2-Naph	Ph	**5e** (82) *80*
10	Br	2-Naph	4-OMePh	**5f** (82)
11	Br	2-Naph	3,4-OMePh	**5g** (81) *79*
12	Br	2-Naph	1-Naph	**5h** (>99) *99*
13	Br	2-Naph	2,4,6-MePh	**5i** (22) *20*
14	Br	4-NO_2Ph	1-Naph	**5j** (69)
15	Br	4-CNPh	Ph	**5k** (61)
16	Br	4-CNPh	4-OMePh	**5l** (94)
17	Br	4-CNPh	1-Naph	**5m** (84) *82*
18	Br	4-CF_3Ph	Ph	**5n** (82)
19	Br	4-CF_3Ph	4-OMePh	**5o** (86)
20	Br	4-CF_3Ph	1-Naph	**5p** (>99) *99*
21	Br	4-MePh	Ph	**5q** (73)
22	Br	4-MePh	4-OMePh	**5r** (59)

[a] Determined by ^{1}H NMR on the basis of the amount of starting aryl halide. Diethylene glycol dimethyl ether was used as internal standard. Isolated yields are shown in italics. [b] 2 mol % of **1** was used, and the reaction was carried out in a sealed tube.

Table 2. In this case, best results were achieved when K_2CO_3 was employed as base,[21] and higher temperatures and longer reaction times were required probably as a result of the aforementioned difficulty in the transmetalation step.

Diarylmethanes are common structural elements of biologically active compounds[22] and pharmaceuticals.[23] In addition, methylene-linked biaryl systems are frequently used as subunits in the design of supramolecular structures such as catenanes and rotaxanes.[24] Despite multiple and important applications of molecules bearing this simple moiety, several drawbacks are associated with the methodologies aimed for their synthesis.[25] For instance, although the palladium-catalyzed coupling of a series of aryl and heteroaryl halides with *B*-benzyl-9-BBN allowed the access to a range of diarylmethanes, the requirement of 2 equiv of the organoboron derivative and other problems regarding functional group tolerance make this method, at least in terms of atom economy, nonideal for preparative purposes.[26] This type of compounds has also been prepared by the coupling of benzyl phosphates[27] or carbonates[28] with aryl boronic acids, but in these cases the principal disadvantage is the requirement of an additional step for the preparation of the electrophilic precursors. On the other hand, benzyl halides have been coupled with diverse organometallic compounds such as stannanes[29] or Grignard reagents,[30] with the corresponding limitation to certain functional groups imposed by this type of nucleophilic reagents. Molander et al. described an elegant synthesis of a series of diarylmethanes employing benzyl halides and potassium aryltrifluoroborates,[31] but once again no commercial availability of the nucleophilic partners is the principal drawback of this procedure. As commented above, the Suzuki coupling of benzyl halides with arylboronic acids has been scarcely studied,[32] and therefore our next efforts were aimed to evaluate the catalytic activity of pincer **1** in this reaction.

Surprisingly, when benzyl bromide and phenylboronic acid were reacted in the presence of **1**, employing Na_2CO_3 as base and only water as solvent, diphenylmethane **5a** was obtained in good yields. Moreover, the catalytic loading was successfully reduced to 0.1 mol % after a short screening.[21] These optimized conditions were applied to an array of commercially available benzyl halides and arylboronic acids. As shown in Table 3 the good yields obtained with electronically dissimilar boronic acids indicate that the procedure is effective regardless electronic nature of this component of the coupling. However, the reaction revealed to be vulnerable to steric effects, as the employment of 2,4,6-trimethylphenylboronic acid reduced the conversion dramatically (entry 13).[33] On the other hand, regarding the alkyl halide, electronically different bromides can be readily coupled: unsubstituted ones (entries 3, 5, 7, and 9), benzyl bromides bearing an electron-withdrawing group (entries 14−20), or even deactivated electron-rich bromides, which are considered important for a more precise measuring of the catalytic activity (entries 21 and 22). Not only benzyl bromide but also 2-bromomethylnaphthalene can be used as starting material for Suzuki reaction catalyzed by **1**, yielding the corresponding products in good yields (entries 9−12). Even benzyl chloride provided the

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(21) Different bases, solvents and catalytic amounts were assayed. See Supporting Information for more details.

(22) (a) MacPhail, K. L.; Rivett, D. E. A.; Lack, D. E.; Davies-Colema, M. T. *Tetrahedron* **2000**, *56*, 9391–9396. (b) Juteau, H.; Gareau, Y.; Labelle, M.; Sturino, C. F.; Sawyer, N.; Tremblay, N.; Lamontagne, S.; Carriere, M.-C.; Denis, D.; Metters, K. M. *Bioorg. Med. Chem.* **2001**, *9*, 1977–1984.

(23) (a) Long, Y.-Q.; Jiang, X.-H.; Dayam, R.; Sanchez, T.; Shoemaker, R.; Ncamati, N. *J. Med. Chem.* **2004**, *47*, 2561–2573. (b) Wai, J.; Egbertson, M. S.; Payne, L. S.; Fischer, T. E. *J. Med. Chem.* **2000**, *43*, 4923–4926. (c) Rosowsky, A.; Chen, H.; Fu, H.; Queener, S. F. *Bioorg. Med. Chem.* **2003**, *11*, 59–67. (d) Forsch, R. A.; Queener, S. F.; Rosowsky, A. *Bioorg. Med. Chem. Lett.* **2004**, *14*, 1811–1815.

(24) (a) Ma, J. C.; Dougherty, D. A. *Chem. Rev.* **1997**, *97*, 1303–1324. (b) Jäfer, R.; Vögtle, F. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 930–944.

(25) Vanier, C.; Lorgé, F.; Mioskowski, C. *Angew. Chem., Int. Ed.* **2000**, *39*, 1679–1683.

(26) Flaherty, A.; Trunkfield, A.; Barton, W. *Org. Lett.* **2005**, *7*, 4975–4978.

(27) McLaughilin, M. *Org. Lett.* **2005**, *7*, 4875–4878.

(28) Kuwano, R.; Yokogi, M. *Org. Lett.* **2005**, *7*, 945–947.

(29) Itami, K.; Mineno, M.; Kamei, T.; Yoshida, J.-I. *Org. Lett.* **2002**, *4*, 3635–3638.

(30) Dohle, W.; Lindsay, D. M.; Knochel, O. *Org. Lett.* **2001**, *3*, 2871–2873, and references therein.

(31) Molander, G. A.; Elia, M. D. *J. Org. Chem.* **2006**, *71*, 9198–9203.

(32) For some examples regarding the synthesis of diarylmethanes employing benzyl halides and arylboronic acids, see ref 16.

(33) Steric hindrance appears to be more sensitive to *ortho* substituents in the arylboronic acid which indicates that the transmetallation step is more dependent the steric effects than the oxidative addition. See ref 9d for further discussion on this subject.

coupling products in moderate yields, (entries 2, 4, 6, and 8), but in this case, higher pressures and catalyst loadings were required.[34]

Although more experiments will be required to define the relative stability of **1** under reaction conditions, and the temperatures employed in both the coupling of α-bromoenone and of benzyl bromides are around the assumed limit for the formation of palladium nanoparticles,[35] we propose that our pincer complex **1** acts as a precatalyst in the reported transformations.[36] An additional evidence of the latter proposal is the fact that, unlike another pincer reported by our group (CNC),[10b] initial assays of the recycling or reuse of the remaining aqueous layer have provided lower yields in every run, thus suggesting catalyst-decomposition to some extent.

Conclusions

To sum up, the first work regarding the application of a nonsymmetric palladium pincer to catalyze Suzuki couplings employing nonactivated substrates such as primary alkylboronic acids or benzyl halides as electrophilic partners is presented. This PCN pincer complex proves to be specially efficient in the arylation of benzyl bromides, according to the range of diarylmethanes prepared by this method. In addition, the first Suzuki−Miyaura reaction with α-bromoenones catalyzed by a pincer complex is reported. Moreover, due to its hydrophilic properties most of the reactions can be carried out in neat water with all the advantages implied not only in terms of sustainability, safety or economy, but also by an easier workup and purification procedure.

Experimental Section

Typical Procedure. Synthesis of (*E*)-3-(4-Methoxyphenyl)-4-phenylbut-3-en-2-one (3b).[19b] Pincer complex **1**[11] (9 mg, 0.017 mmol) was added to a mixture of bromoenone **2**[19b] (100 mg, 0.44 mmol), 4-methoxyphenyboronic acid (102 mg, 0.67 mmol), Na_2CO_3 (95 mg, 0.89 mmol) and water (0.44 mL) in a 5 mL round-bottom flask open to the atmosphere. After stirring at 100 °C for 12 h, the reaction mixture was cooled and water (5 mL) was added. The aqueous layer was extracted with CH_2Cl_2 (3×6 mL). The combined organic extracts were dried over anhydrous sodium sulfate and concentrated in vacuo. The product was obtained as a yellowish powder (95 mg, 86%) after the purification of the residue by flash column chromatography (EtOAc/hexanes, 1:9).

Typical Procedure. Synthesis of 1-(4-*n*-Butylphenyl)ethanone (4a).[37] Pincer complex **1**[11] (5 mg, 0.01 mmol) was added to a mixture of 4-bromoacetophenone (100 mg, 0.50 mmol), *n*-butylboronic acid (104 mg, 1.0 mmol), K_2CO_3 (138 mg, 1.0 mmol) and *o*-xylene (1 mL) in a 5 mL round-bottom flask under argon. After stirring at 130 °C for 20 h, the reaction mixture was cooled and water (5 mL) was added. The aqueous layer was extracted with CH_2Cl_2 (3×6 mL). The combined organic extracts were dried over anhydrous sodium sulfate and concentrated in vacuo. The product was obtained as an oil (83 mg, 94%) after the purification of the residue by flash column chromatography (EtOAc/hexanes, 1:9).

Typical Procedure. Synthesis of 2,4′-Methylenedinaphthalene (5h). A quantity of 43 μL of a solution of the pincer complex **1**[11] (5 mg) in acetone (1.0 mL) was added to a mixture of 2-(bromomethyl)naphthalene (100 mg, 0.45 mmol), 1-naphthaleneboronic acid (116 mg, 0.68 mmol), Na_2CO_3 (95 mg, 0.90 mmol) and water (0.45 mL) in a 5 mL round-bottom flask open to the atmosphere. After stirring at 100 °C for 3 h, the reaction mixture was cooled and water (5 mL) was added. The aqueous layer was extracted with CH_2Cl_2 (3×6 mL). The combined organic extracts were dried over anhydrous sodium sulfate and concentrated in vacuo. The product was obtained as a white powder (120 mg, 99%) after the purification of the residue by flash column chromatography (EtOAc/hexanes, 4:6). Mp: (EtOAc/hexanes, 4:6) 89−91 °C. ^1H NMR ($CDCl_3$) δ (ppm): 4.7 (s, 2H), 7.43−7.58 (m, 7H), 7.72 (s, 1H), 7.80−7.99 (m, 5H), 7.98 (d, $J = 8.0$ Hz, 1H), 8.11 (d, $J = 7.4$ Hz, 1H). ^{13}C NMR ($CDCl_3$) δ (ppm): 39.1, 124.2, 125.7, 125.5, 125.5, 125.9, 126.0, 126.9, 127.2, 127.4, 127.4, 127.5, 127.6, 127.9, 128.6, 132.1, 132.1, 133.6, 133.9, 136.4, 138.1. MS *m/z* (%): 268.12 (100), 267.12 (67), 265.10 (22), 253.10 (31), 252.09 (31). HRSM *m/z*: calcd for $C_{21}H_{16}$ 268.1252, found 268.1250.

Acknowledgment. This research was supported by the University of the Basque Country/Regional Government of Biscay/Basque Government (Projects DIPE 06/10, UNESCO07/08 and GIU06/87/IT-349-07) and the Spanish Ministry of Education and Science (MEC CTQ2007-64501). B.I. thanks the University of the Basque Country (UPV/EHU) for a predoctoral scholarship. The authors also thank Petronor, S.A. for the generous donation of hexane.

Supporting Information Available: Full experimental details, spectral data of all coupling products and copies of ^1H and ^{13}C NMR spectra. This material is available free of charge via the Internet at http://pubs.acs.org.

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(34) Apart from the difficulty in the transmetalation step the low reactivity of chlorides is attributable to the stronger C−Cl bond compared to C−Br, thus conditioning the oxidative addition step: Singh, R.; Viciu, M. S.; Kramarevo, N.; Navarro, O.; Nolan, S. P. *Org. Lett.* **2005**, *7*, 1829–1832.

(35) It has been proposed that most of the Heck or Suzuki reactions performed with palladium pincer-complexes are really catalyzed by palladium colloidal nanoparticles. This is particularly true for processes that require temperatures higher than 120 °C. See: deVries, J. G. *Dalton Trans.* **2006**, 421–429.

(36) Several authors support the theory that pincer complexes act as mere precatalysts or catalyst precursors releasing more active palladium species. See for example: (a) Sommer, W. J.; Yu, K.; Sears, J. S.; Ji, Y.; Zheng, X.; Davis, R. J.; Sherrill, C. D.; Jones, C. W.; Weck, M. *Organometallics* **2005**, *24*, 4351–4361. (b) Yu, K.; Sommer, W. J.; Richardson, J. M.; Weck, M.; Jones, C. W. *Adv. Synth. Catal.* **2005**, *347*, 161–171. (c) Phan, N. T. S.; Sluys, M. v. d.; Jones, C. W. *Adv. Synth. Catal.* **2006**, *348*, 609–679.

(37) Pérez, I.; Pérez-Sestelo, J.; Sarandeses, L. A. *Org. Lett.* **1999**, *1*, 1267–1269.