



DIMERIC OR MONONUCLEAR CYCLOPALLADATED (PRE)CATALYSTS: WHICH IS MORE ACTIVE IN THE SUZUKI-MIYaura REACTION?

Cite this: *INEOS OPEN*,
2025, 8 (1–3), XX–XX
DOI: 10.32931/ioXXXXX

M. P. Timerkaeva, K.A. Kochetkov, and O. N. Gorunova*

*Nesmeyanov Institute of Organoelement Compounds, Russian Academy of Sciences,
ul. Vavilova 28, str. 1, Moscow, 119334 Russia*

Received XX Month 20XX

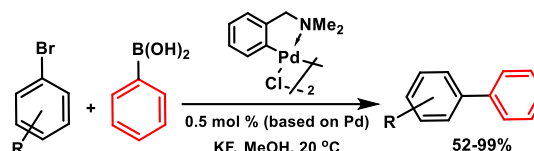
Accepted 13 November 2024

<http://ineosopen.org>

Abstract

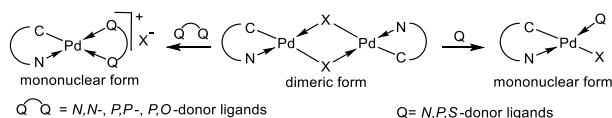
The high catalytic activity of commercially available dimeric *C,N*-palladacycle based on *N,N*-dimethylbenzylamine in the Suzuki–Miyaura cross-coupling between aryl bromides and phenylboronic acid under mild reaction conditions is demonstrated.

Key words: dimeric *C,N*-palladacycle, *N,N*-dimethylbenzylamine, Suzuki–Miyaura cross-coupling.



Introduction

Cross-couplings are one of the most popular methods for the construction of C–C bonds and play a crucial role in organic synthesis [1–3]. The high catalytic activity of cyclopalladated compounds (CPCs) in C–C bond forming reactions is well known [4–6]. While the early success in these processes was associated with the use of phosphapalladacycles as (pre)catalysts [7, 8], currently the focus has shifted towards *C,N*-palladacycles [5, 6, 9, 10], and the Suzuki–Miyaura (SM) reaction occupies a leading position among all C–C bond formation methods. Changing the spatial environment of the metal center in a catalyst, for example, opening the bridges in dimeric monometallacyclic CPCs (Scheme 1), can serve as one of the ways to increase the catalytic activity [11, 12]. At the same time, there are some examples of higher catalytic activity of the initial dimeric *C,N*-palladacycles compared to that of their numerous mononuclear derivatives [13–15].



Scheme 1. Opening of the bridges in dimeric CPCs.

Surprisingly, despite the structural diversity of benzylamine-based *C,N*-palladacycles, their mononuclear derivatives with different donor ligands were mainly used in the SM cross-coupling [16–23], while the dimeric complexes of this type were almost not tested [9]. Recently, we have demonstrated the high efficiency as the (pre)catalysts for the SM reaction of a series of dimeric benzylamine-based *C,N*-palladacycles containing various substituents at the α -carbon atom and differing in the nature of the amino group [24].

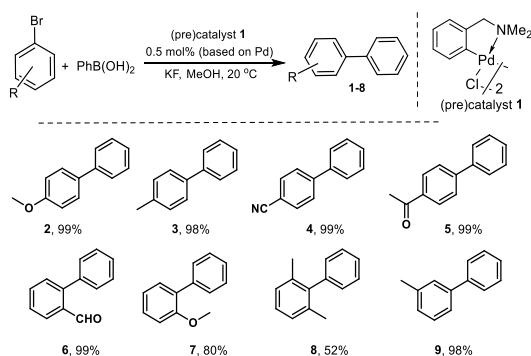
The goal of this work was to study the catalytic activity in the SM reaction of a commercially available dimeric *C,N*-palladacycle based on *N,N*-dimethylbenzylamine and compare it with that of its mononuclear derivatives.

Results and discussion

Dimeric CPC **1**, obtained by the cyclopalladation of *N,N*-dimethylbenzylamine with $\text{Pd}(\text{OAc})_2$ in 81% yield, using the previously described method [21], was chosen as a model (pre)catalyst. The catalytic activity of this commercially available CPC in the Heck reaction was evaluated [25–28], while its activity in the SM cross-coupling has been scarcely studied. Only two attempts to introduce its μ -trifluoroacetate analog into the SM reaction have been reported to date. In the first case, it showed low efficiency for the coupling of 4-bromoanisole with $\text{PhB}(\text{OH})_2$ (toluene, K_2CO_3 , 110 °C, 17 h): the substrate conversion to the target product was only 10% [29]. In the second case, although this palladacycle was introduced into the SM reaction in the form of a μ -trifluoroacetate dimer, a phosphine ligand was added to the reaction system, and therefore a mononuclear phosphine derivative was formed *in situ* [20].

At the first stage, we compared the activity of dimer **1** as a (pre)catalyst in the SM reaction with that of some of its known derivatives under the described conditions. The results showed that the catalytic activity of dimeric CPC **1** was not inferior to that of its mononuclear derivatives with carbenes under the same conditions [16–19]. For example, the SM cross-coupling between 4-bromoanisole and $\text{PhB}(\text{OH})_2$ (1 mol % based on Pd, Cs_2CO_3 , MeOH, 20 °C, 0.5 h), catalyzed by the carbene derivative of this *C,N*-palladacycle, afforded the target product in 93% yield [17]. When this reaction was carried out in the presence of dimer **1** under analogous conditions, the cross-coupling product was formed in 90% yield, which suggests the high catalytic activity of dimer **1** itself.

The subsequent experiments showed that (pre)catalyst **1** exhibits the high catalytic activity under mild reaction conditions in the SM cross-coupling of a variety of aryl bromides containing both electron-donating and electron-withdrawing substituents, including sterically hindered substrates (Scheme 2).



Scheme 2. Suzuki–Miyaura reactions catalyzed by dimer **1**.

Experimental section

General procedure for the Suzuki–Miyaura cross-coupling. A mixture of aryl halide (0.03 g), PhB(OH)_2 (1.5 equiv.), KF (5 equiv.), and dimer **1** (0.5 mol % based on Pd) in MeOH (1 mL) was stirred at room temperature in the air for 1 h and then evaporated to dryness. The residue obtained was dissolved in dichloromethane (5 mL) and washed with water (3×5 mL). The organic fraction was dried over anhydrous MgSO_4 and evaporated to dryness. Individual biphenyls **2–9** were isolated by column chromatography (SiO_2 , gradient elution with a petroleum ether–dichloromethane mixture from 8:1 to 1:1). The structure and purity of the isolated biphenyls were confirmed using ^1H NMR spectroscopy by comparison with the reported spectral data [21, 23, 30].

Conclusions

Thus, dimeric CPC **1** demonstrates the same efficiency in the Suzuki–Miyaura reaction as its known mononuclear derivatives. Moreover, it offers a number of advantages, such as the commercial availability and ease of preparation, oxidative stability, and the absence of expensive auxiliary ligands. The reduced loadings and the possibility of conducting reactions at room temperature in the air make this dimeric *C,N*-palladacycle an attractive (pre)catalyst for the Suzuki–Miyaura cross-coupling. These results indicate the need for preliminary evaluation of the catalytic activity of the initial dimeric CPCs before their further transformation into mononuclear derivatives.

Acknowledgements

This work was performed with financial support from the Ministry of Science and Higher Education of the Russian Federation (agreement no. 075-00-277-24-00) using the equipment of the Center for Collective Use of INEOS RAS.

Corresponding author

* E-mail: olg111@yandex.ru Tel: +7(499)135-5033 (O. N. Gorunova).

References

1. A. T. Kal Koshvandi, M. M. Heravi, T. Momeni, *Appl. Organomet. Chem.*, **2018**, 32, e4210. DOI: 10.1002/aoc.4210
2. M. J. Buskes, M.-J. Blanco, *Molecules*, **2020**, 25, 3493. DOI: 10.3390/molecules25153493
3. P. Devendar, R.-Y. Qu, W.-M. Kang, B. He, G.-F. Yang, *J. Agric. Food Chem.*, **2018**, 66, 8914–8934. DOI: 10.1021/acs.jafc.8b03792
4. *Palladacycles. Synthesis, Characterization and Application*, J. Dupont, M. Pfeffer (Eds.), Wiley, Weinheim, **2008**. DOI: 10.1002/9783527623211
5. *Palladacycles: Catalysis and Beyond*, A. Kapdi, D. Maiti (Eds.), Elsevier, Amsterdam, **2019**. DOI: 10.1016/C2017-0-03671-6
6. A. Kumbhar, *J. Organomet. Chem.*, **2019**, 881, 79–129. DOI: 10.1016/j.jorganchem.2018.09.020
7. W. A. Herrmann, C. Brossmer, K. Öfele, C.-P. Reisinger, T. Priemermeier, M. Beller, H. Fischer, *Angew. Chem., Int. Ed.*, **1995**, 34, 1844–1848. DOI: 10.1002/anie.199518441
8. R. B. Bedford, S. L. Hazelwood, M. E. Limmert, D. A. Albiison, S. M. Draper, P. Noelle Scully, S. J. Coles, M. B. Hursthouse, *Chem. Eur. J.*, **2003**, 9, 3216–3227. DOI: 10.1002/chem.200304997
9. M. P. Timerkaeva, O. N. Gorunova, *INEOS OPEN*, **2023**, 6, 126–137. DOI: 10.32931/io2321r
10. C. Nájera, *ChemCatChem*, **2016**, 8, 1865–1881. DOI: 10.1002/cctc.201600035
11. F. Yang, Y. Zhang, R. Zheng, J. Tang, M. He, *J. Organomet. Chem.*, **2002**, 651, 146–148. DOI: 10.1016/S0022-328X(02)01195-6
12. K. Wang, H. Yang, F. Bauer, B. Breit, W. Fang, *Chem. Eur. J.*, **2023**, 29, e202300719. DOI: 10.1002/chem.202300719
13. J. L. Serrano, L. García, J. Pérez, P. Lozano, J. Correia, S. Kori, A. R. Kapdi, Y. S. Sanghvi, *Organometallics*, **2020**, 39, 4479–4490. DOI: 10.1021/acs.organomet.0c00580
14. B. Bermúdez-Puente, L. A. Adrio, F. Lucio-Martínez, F. Reigosa, J. M. Ortigueira, J. M. Vila, *Molecules*, **2022**, 27, 3146. DOI: 10.3390/molecules27103146
15. I. Babahan, R. Firinci, N. Özdemir, M. E. Günay, *Inorg. Chim. Acta*, **2021**, 522, 120360. DOI: 10.1016/j.ica.2021.120360
16. K.-E. Lee, H.-T. Jeon, S.-Y. Han, J. Ham, Y.-J. Kim, S. W. Lee, *Dalton Trans.*, **2009**, 6578–6592. DOI: 10.1039/b907324h
17. Y.-J. Kim, J.-H. Lee, T. Kim, J. Ham, Z. N. Zheng, S. W. Lee, *Eur. J. Inorg. Chem.*, **2012**, 6011–6017. DOI: 10.1002/ejic.201200988
18. K.-A. Green, P. T. Maragh, K. Abdur-Rashid, A. J. Lough, T. P. Dasgupta, *Inorg. Chim. Acta*, **2016**, 449, 38–43. DOI: 10.1016/j.ica.2016.04.048
19. M. Dangelov, M. Stoyanova, P. Petrov, M. Putala, N. G. Vassilev, *J. Organomet. Chem.*, **2016**, 817, 1–14. DOI: 10.1016/j.jorganchem.2016.05.002
20. R. B. Bedford, C. S. J. Cazin, S. J. Coles, T. Gelbrich, P. N. Horton, M. B. Hursthouse, M. E. Light, *Organometallics*, **2003**, 22, 987–999. DOI: 10.1021/om020841+
21. K. Karami, M. M. Salah, *Appl. Organomet. Chem.*, **2010**, 24, 828–832. DOI: 10.1002/aoc.1713
22. J. Jansa, T. Řezníček, L. Dostál, Z. Růžicková, F. Bureš, R. Jambor, *Appl. Organomet. Chem.*, **2016**, 30, 1036–1042. DOI: 10.1002/aoc.3539
23. A. Naghipour, M. Sayadi, A. Sedghi, S. J. Sabounchei, H. Babaei, B. Notash, *Inorg. Chim. Acta*, **2021**, 515, 120039. DOI: 10.1016/j.ica.2020.120039
24. O. N. Gorunova, M. P. Timerkaeva, K. A. Kochetkov, V. V. Dunina, *Russ. Chem. Bull.*, **2024**, 73, 733–737. DOI: 10.1007/s11172-024-4184-z
25. I. P. Beletskaya, A. N. Kashin, N. B. Karlstedt, A. V. Mitin, A. V. Cheprakov, G. M. Kazankov, *J. Organomet. Chem.*, **2001**, 622, 89–96. DOI: 10.1016/S0022-328X(00)00876-7
26. D. A. Albiison, R. B. Bedford, P. N. Scully, *Tetrahedron Lett.*, **1998**, 39, 9793–9796. DOI: 10.1016/S0040-4039(98)02175-3
27. S. Iyer, C. Ramesh, *Tetrahedron Lett.*, **2000**, 41, 8981–8984. DOI: 10.1016/S0040-4039(00)01594-X
28. F. Yang, Y. Zhang, R. Zheng, J. Tang, M. He, *J. Organomet.*

- Chem.*, **2002**, 651, 146–148. DOI: 10.1016/s0022-328x(02)01195-6
29. R. B. Bedford, C. S. J. Cazin, S. J. Coles, T. Gelbrich, M. B. Hursthouse, V. J. M. Scordia, *Dalton Trans.*, **2003**, 3350–3356. DOI: 10.1039/B304053D
30. L. Ackermann, R. Born, *Angew. Chem., Int. Ed.*, **2005**, 44, 2444–2447. DOI: 10.1002/anie.200462371

This article is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.

