Available online at www.sciencedirect.com

SCIENCE DIRECT®

Tetrahedron Letters 45 (2004) 809–811

Tetrahedron
Letters

Pd/C-catalyzed Heck reaction in ionic liquid accelerated by microwave heating

Xingang Xie, Jiangping Lu, Bo Chen, Junjie Han, Xuegong She* and Xinfu Pan*

Department of Chemistry, State key Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou 730000, PR China

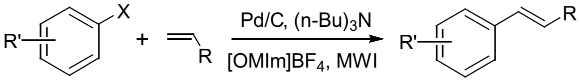
Received 17 September 2003; revised 15 October 2003; accepted 7 November 2003

Abstract—Pd/C-catalyzed Heck reaction was conducted in ionic liquid 1-octanyl-3-methylimidazolium tetrafluoroborate ([OMIm]BF_4) in absence of phosphine ligand, which was promoted by microwave irradiation. The ionic liquid containing catalyst system can be used five times with a little loss of activity.

One of the prime principles of green chemistry is to develop an alternative reaction medium, which is the basis for the development of many cleaner chemical technologies. Particularly, ionic liquids have recently gained recognition as possible environmentally safe alternatives to volatile organic solvents.[1] Due to the unique property of ionic liquids that they have essentially no vapor pressure, they are the optimal reaction media in laboratories and factories. And ionic liquids, especially those derived from the combination of quaternary ammonium salts and weakly coordinating anion have been demonstrated to be ideal immobilizing agents for various 'classical' transition-metal catalyst precursors in reactions to enhance the reaction rate and selectivity.[2] In addition, the ionic liquids with the catalyst can be easily recovered and recycled without the loss of activity for several times. So currently much attention is focused on organic reactions promoted by ionic liquid.[3] The Pd catalyzed C–C coupling reactions of aromatic and vinylic systems (Heck reaction[4]) is one of the popular points. Some exciting results about Heck reaction in ionic liquids have been demonstrated. All of them showed a competitive and potential foreground.[5] However, they all needed a long reaction time and it was difficult to recycle the catalyst. These disadvantages limited their application.

Microwave is known to accelerate many organic reactions in polar solvents such as DMF, water, etc.[6] A few microwave-assisted Heck reaction have been reported and only the aryl iodides and the active aryl bromide had been tested.[7] Since ionic liquid can be considered as a very high polar solvent, it can absorb the power of microwave effectively. At the same time, ionic liquid can immobilize Pd catalyst and maybe prolong its life.[8] Recently, Larhed and Choudary reported remarkable results about microwave irradiation promoting Heck reaction in ionic liquid.[9] But they used phosphine ligands[9a] or Mg–Al layered double hydroxides (LDH)[9b] to activate the catalyst, and were all performed in sealed vials. When we used the ionic liquid 1-octanyl-3-methylimidazolium tetrafluoroborate [OMIm]BF_4[10] as reaction medium and the reaction was conducted in an open system with 5% Pd/C as catalyst, modest to good yields were obtained in a shorter time (Scheme 1).

The catalyst system was applied to the Heck olefination of different aryl halides with butyl acrylate at first (Scheme 2). The reaction was carried out simply by treatment of a solution of aryl halides, butyl acrylate, (n-Bu)$_3$N, and 3 mol% Pd/C in ionic liquid [OMIm]BF_4 with microwave irradiation. After the reaction, the product was extracted by diethyl ether and purified by column chromatography on silica gel as usual. The results were summarized in Table 1. Iodobenzene (entry a) proceeded in 86% yield. o-Iodo-methyl-benzoic acid (entry b) yielded in 35% probably due to the steric effect

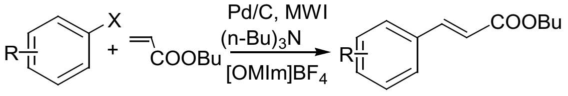


Scheme 1.

---

* Corresponding authors. E-mail: shexg@lzu.edu.cn

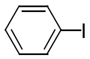
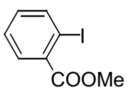
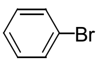
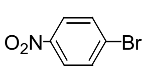
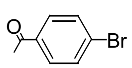
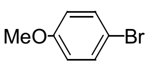
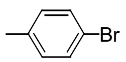
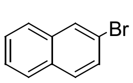
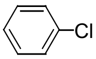
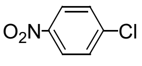
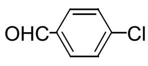
0040-4039/$ - see front matter © 2003 Elsevier Ltd. All rights reserved.
doi:10.1016/j.tetlet.2003.11.042



Scheme 2.

of O-ester group. Aryl bromides proceeded in moderate to satisfactory yields (entries c–h). The reactant having an electronic-withdrawing group (entries d, e) reacted better and gained higher yield than those having an electronic-donating group (entries f, g). However, the most inactive *p*-bromoanisole (entry f) proceeded in 56% yield when we increase the power of microwave irradiation to 375 W. Unfortunately, aryl chloride did not react well even at 375 W microwave irradiation except *p*-nitrochlorobenzene (entry j). We increase the power of microwave irradiation and prolong the irradiation time, but still no reaction occurred to entries i and k. All of the reactions were clean and the (*E*)-butyl cinnamates were the only products.

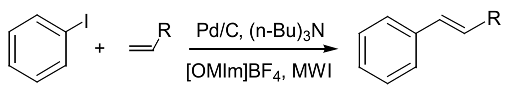
Table 1. The olefination of different aryl halides

Entry[a]	Ar–X	Time (min)	Isolate yield[b] (%)
a		1.5	86
b		1.5	35
c		1.5	80
d		1.5	89
e		1.5	61
f		1.5	30 (56)[c]
g		1.5	33
h		1.5	79
i		2.0	0[c]
j		2.0	27 (42[c])
k		2.0	0[c]

[a] All the experiments were done according to Ref. 11.

[b] All the products were identified by 300M ^{1}H NMR and mass spectrometry.

[c] Entries f, i, j, k were irradiated by 375 W microwave.

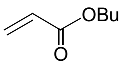
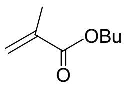
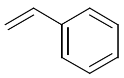
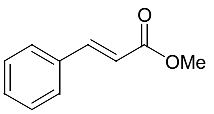


Scheme 3.

To extend the reaction scope, the arylation of several olefins with iodobenzene was investigated (Scheme 3). As exhibited in Table 2, 2-methyl-butyl acrylate (Table 2, entry 2) yielded in 79%. The ratio of *E*/*Z* is 6.5/1. Styrene (Table 2, entry 3) proceeded in 70% yield and *trans*-stilbene was the only product. When 1,2-disubstituted olefin, methyl-cinnamate (Table 2, entry 4) was tested, the yield was only 27%. From above results, we can see that the steric effect of olefins played role in Heck reaction.

Since Pd/C remained completely in ionic liquid after the reaction, the catalyst system can be reused. Iodobenzene and butyl acrylate was chosen as reactants. After extraction of the product of the first-time reaction, the catalyst system was irradiated by 225 W microwave for 0.5 min. Then another partial of iodobenzene, butyl acrylate, and (n-Bu)$_3$N were added. The procedure was repeated four times and the catalyst system proceeded well with a little loss of activity (Table 3, entry 1, runs 1–4). When the catalyst system was washed with water

Table 2. The arylation of different olefins with iodobenzene

Entry	Olefins	Time (min)	Isolated yield[a] (%)
1		1.5	86
2		1.5	79[b]
3		1.5	70
4		1.5	27

[a] All the products were identified by 300M ^{1}H NMR and mass spectrometry.

[b] The ratio of *E*/*Z* is 6.5/1.

Table 3. Recycle of the catalyst system

Entry	Isolated yield (%)				
	Run 1	Run 2	Run 3	Run 4	Run 5
1	86	80	72	67	71[b]
2[a]	81	76	71	70[c]	64[c]

[a] In entry 2, 1.5 mol% Pd/C was used.

[b] Catalyst system was washed with water before reuse.

[c] The irradiation time was increased to 2 min.

before reuse,[5a] the yield increased than its former recycle (entry 1, run 5). Especially, when we decreased the amount of Pd/C to 1.5 mol%, the reaction still proceeded well and high yields were obtained in the following four runs (Table 3, entry 2).

In summary, we developed a facile methodology to accelerate Pd/C-catalyzed Heck reaction in ionic liquid by using microwave irradiation. One major advantage of our protocol is the catalyst system can be recycled and the green character of ionic liquids. And this way can shorten the reaction time with high yield due to the high efficiency of microwave irradiation.

Acknowledgements

This work was supported by NSFC (QT program), SRF for ROCS.SEM, Gansu Science foundation (no. YS031-A21-001) and Lanzhou University foundation (no. 5715220101).

References and notes

1. Yadav, J. S.; Reddy, B. V. S.; Sunitha, S. *Adv. Synth. Catal.* **2003**, *345*, 349.
2. Dupont, J.; de Souza, R. F.; Suarez, P. A. Z. *Chem. Rev.* **2002**, *102*, 3668, 3672.
3. (a) Carmichael, A. J.; Haddleton, D. M.; Bon, S. A. F.; Seddon, K. R. *Chem. Commun.* **2000**, 1237–1238; (b) Berger, A.; de Souza, R. F.; Degado, M. R.; Dupont, J. *Tetrahedron: Asymmetry* **2001**, *12*, 1825–1828; (c) Song, C. E.; Roh, E. G. *Chem. Commun.* **2000**, 837–838; (d) Song, C. E.; Oh, C. R.; Roh, E. G.; Chou, D. *J. Chem. Commun.* **2000**, 1743; (e) Fukuyama, T.; Shinmen, M.; Nishitani, S.; Sato, M.; Ryu, I. *Org. Lett.* **2002**, *4*, 1691–1694; (f) Handy, S. T.; Zhang, X. *Org. Lett.* **2001**, *3*, 233–236.
4. Heck, R. F. *J. Am. Chem. Soc.* **1968**, *90*, 5518.
5. (a) Hagiwara, H.; Shimizu, Y.; Hoshi, T.; Suzuki, T.; Ando, M.; Ohkubo, K.; Yokoyama, C. *Tetrahedron Lett.* **2001**, *42*, 4349–4351; (b) Bouguillon, S.; Ganchequi, B.; Estrine, B.; Hénin, F.; Muzart, J. *J. Organomet. Chem.* **2001**, *634*, 153–156; (c) Selvakumar, K.; Zapf, A.; Beller, M. *Org. Lett.* **2002**, *4*, 3031–3033.
6. (a) Stauss, C. R.; Trainor, R. W. *Aust. J. Chem.* **1995**, *48*, 1665; (b) Bose, A. K.; Banik, B. K.; Lavlinskaia, N.; Jayaraman, M.; Manhhas, M. S. *Chem. Tech.* **1997**, *27*, 18.
7. (a) Larhed, M.; Hallberg, A. *J. Org. Chem.* **1996**, *61*, 9582–9584; (b) Garg, N.; Larhed, M.; Hallberg, A. *J. Org. Chem.* **1998**, *63*, 4158–4162; (c) Wang, J.; Liu, Z.; Hu, Y.; Wei, B.; Lin, B. *J. Chem. Res. (S)* **2000**, 484–485.
8. (a) Xu, L.; Chen, W.; Xiao, J. *Organometallics* **2000**, *19*, 1123–1127; (b) Mathews, C. J.; Smith, P. J.; Welton, T.; White, A. J. P.; Williams, D. J. *Organometallics* **2001**, *20*, 3848–3850.
9. (a) Karl, S. A.; Per Emilsson, V.; Larhed, M.; Hallberg, A. *J. Org. Chem.* **2002**, *67*, 6243–6246; (b) Choudary, B. M.; Madhi, S.; Chowdri, N. S.; Kantam, M. L.; Sreedhar, B. *J. Am. Chem. Soc.* **2002**, *124*, 14127–14136.
10. Holbrey, J. D.; Seddon, K. R. *J. Chem. Soc., Dalton Trans.* **1999**, 2133–2139.
11. General procedure: 1 mmol aryl halide, 2 mmol butyl acrylate, 2 mmol (n-Bu)$_3$N, and 66 mg 5% Pd/C were added into 1.5 mL [OMIm]BF$_4$ in a 25 mL round flask. The mixture was stirred for several minutes at room temperature. Then it was equipped with a condensation tube and irradiated by microwave (225 or 375 W) for 1.5 min without stirring and inert atmosphere protection. After the reaction, the product was extracted by diethyl ether followed by decantation of the upper organic layer. The Pd/C was kept and suspended in the ionic liquid layer. The diethyl ether layers was collected and concentrated in vacuum. Then the product was purified by column chromatography as usual.