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(IPr)Pd(acac)Cl: An Easily Synthesized, Efficient, and Versatile Precatalyst for C−N and C−C Bond Formation

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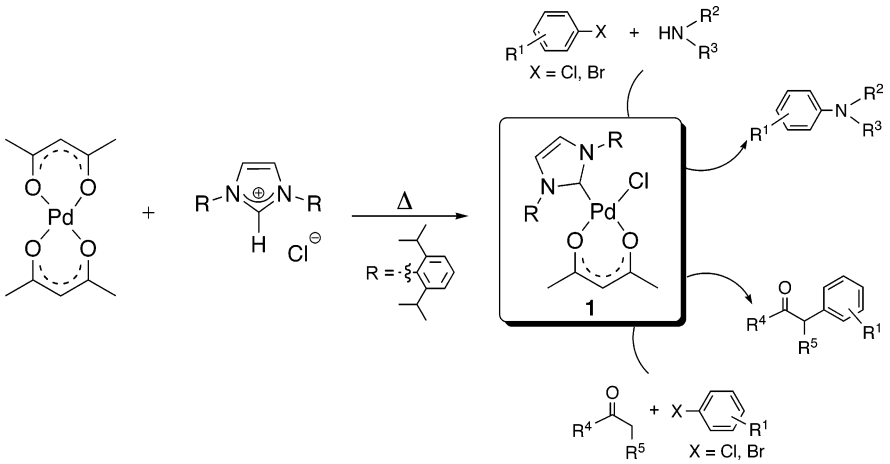

A very straightforward synthesis of (IPr)Pd(acac)Cl from two commercially available starting materials, $Pd(acac)_2$ and IPr·HCl [acac = acetylacetonate; IPr = *N*,*N*′-bis(2,6-diisopropylphenyl)imidazol-2-ylidene], has been developed. The resulting complex, (IPr)Pd(acac)Cl (**1**), has proven to be a highly active Pd^{II} precatalyst in the Buchwald−Hartwig and the α-ketone arylation reactions. A wide range of substrates has been screened, including unactivated, sterically hindered, and heterocyclic aryl chlorides.

Introduction

Palladium-catalyzed cross-coupling reactions have been extensively studied over the past 30 years.[1] Despite the critical advances cross-coupling chemistry has experienced, notably the use of aryl chlorides,[2] it is still a very active area of research and discovery.[3] To perform a coupling reaction, two approaches are available to generate a catalytically active species. One approach employs a Pd^0 source combined with an ancillary ligand to generate the catalyst in situ and the second uses a precatalyst, mostly Pd^{II} complexes, which will be activated in the reaction mixture. The first option often requires an excess of expensive ligands that, in addition, are typically difficult to remove from the reaction mixture. Well-defined complexes can overcome these drawbacks but commonly need multiple-step synthesis. Herein, we report on a Pd^{II} precatalyst, air- and moisture-stable, that can be synthesized directly from two commercially available starting materials, IPr·HCl and $Pd(acac)_2$ [IPr·HCl = *N*,*N*′-bis(2,6-diisopropylphenyl)imidazolium chloride; acac = acetylacetonate]. The resulting palladium complex, (IPr)Pd(acac)Cl (**1**), has proven to be highly efficient in the Buchwald−Hartwig amination and the α-ketone arylation with unactivated aryl chlorides under mild reaction conditions.

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(1) (a) Tsuji, J. *Palladium Reagents and Catalysis*; Wiley: New York, 1998. (b) *Metal-Catalyzed Cross Coupling Reactions*, 2nd ed.; de Meijere, A., Diederich, F., Eds.; Wiley-VCH: New York, 2004.

(2) For a review on palladium-catalyzed cross-coupling reactions of aryl chlorides see: Littke, A. F.; Fu, G. C. *Angew. Chem., Int. Ed.* **2002**, *41*, 4176−4211.

(3) As emphasized by the recent publication of a special issue of *Tetrahedron* dedicated to the subject. Development and Application of Highly Active and Selective Palladium Catalysts; Fairlamb, I. J. S., Ed.; *Tetrahedron* **2005**, *41*, 4176−4211.

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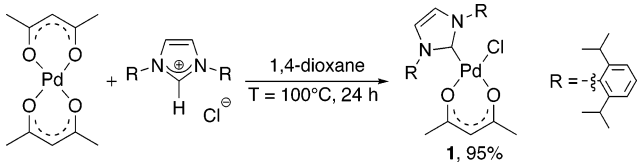
SCHEME 1. One-Step Synthesis of (IPr)Pd(acac)Cl (1)



Results and Discussion

We recently reported the synthesis of the new complex (IPr)-Pd(acac)Cl (**1**), obtained by mixing $Pd(acac)_2$ and free IPr followed by addition of HCl.[4] Despite the simplicity of this route, it requires two steps and the generation of the free carbene is mandatory. We then focused our efforts to develop a synthetic route that would not require the use of a glovebox and therefore would be more attractive to synthetic chemists.

Synthesis of (IPr)Pd(acac)Cl. Our investigations led us to an extremely simple synthetic procedure, shown in Scheme 1. Direct reaction of $Pd(acac)_2$ with an excess of IPr·HCl in refluxing 1,4-dioxane for 24 h yielded **1** quantitatively (>95%).

The use of a glovebox is obviated and the final isolation simply employs a diethyl ether wash and a filtration. Interestingly, using the two commercially available starting materials,[5] we were able to scale-up this synthesis quantitatively on a 2-g scale. Having such a simple preparation for an NHC-containing Pd^{II} precatalyst (NHC = *N*-heterocyclic carbene) in hand, we decided to examine its efficiency in the Buchwald−Hartwig reaction.

Activity of (IPr)Pd(acac)Cl in the Buchwald−Hartwig Reaction. Since pioneering work, notably by Buchwald and Hartwig,[6,7] palladium-catalyzed *N*-aryl amination and α-ketone arylation have gathered increasing interest, especially because these reactions have filled the deficiencies of "classic" organic methodology in this area.[8] Therefore, a large number of synthetic routes leading to biologically active compounds now employ these methods,[9] as recently highlighted by a direct synthesis of 4,5-dianilinophthalimide.[10] First restricted to aryl bromides and iodides, the use of bulky, electron-rich ancillary ligands such as *N*-heterocyclic carbene,[11] trialkylphosphine,[12] biarylphosphine,[13] proazaphosphatrane,[14] or ferrocenyldialkylphosphine[15] has considerably enlarged the scope of these reactions. *N*-Aryl amination is now feasible with more affordable aryl and heteroaryl chlorides and allows for the coupling of all types of amines as well as amides.[16]

Optimization of the reaction conditions for our system revealed that 1,2-dimethoxyethane (DME) and KO^{t}Bu were the best solvent and base, respectively.[17] It is noteworthy that under these reaction conditions no palladium mirror was observed.[18] Results of the coupling reaction for a wide range of amines with aryl bromides and chlorides are summarized in Table 1. Overall, the present catalytic system displayed good efficiency toward cyclic dialkylamines with activated (entry 1), neutral (entry 2), and unactivated bromides (entry 3). In the latter entry, it is noteworthy that in addition to the unfavorable electronic effect, the *ortho* substitution adding steric hindrance does not lead to loss of activity. Next, a secondary dialkylamine, traditionally more reluctant to couple, was reacted with *o*-bromotoluene in excellent yield (entry 4). To further challenge the tolerance of **1** to sterically encumbered substrate, we performed reactions with the 2,6-diisopropylaniline. Gratifyingly, tri- and even tetra-*ortho*-substituted diarylamines were obtained under mild reaction conditions (entries 5 and 6). Encouraged by these promising results, we examined the reactivity of the less reactive aryl chlorides and found that even unactivated chloride could be coupled with sterically hindered amine (entry 8). As observed with the bromides, extremely encumbered substrates could be obtained in good yields in reasonable reaction times (entries 9−11). Finally, we were interested in the synthesis of 1- and 2-naphthylamines as a particularly valuable class of compounds. These are well-known as hole transport materials[19] or photoactive chromophores,[20] and play an important role as pharmacophore in a number of inhibitors.[21] Our catalytic system allowed a rapid coupling of

(4) Navarro, O.; Marion, N.; Stevens, E. D.; Scott, N. M.; Gonzalez, J.; Amoroso, D.; Bell, A.; Nolan, S. P. *Tetrahedron* **2005**, *61*, 9716−9722.

(5) IPr·HCl can be purchased from Strem or Aldrich.

(6) For early references on Pd-catalyzed *N*-aryl amination, see: (a) Guram, A. S.; Rennels, R. A.; Buchwald, S. L. *Angew. Chem., Int. Ed. Engl.* **1995**, *34*, 1348−1350. (b) Louie, J.; Hartwig, J. F. *Tetrahedron Lett.* **1995**, *36*, 3609−3612.

(7) For early references on Pd-catalyzed α-ketone arylation, see: (a) Palucki, M.; Buchwald, S. L. *J. Am. Chem. Soc.* **1997**, *119*, 11108−11109. (b) Hamann, B. C.; Hartwig, J. F. *J. Am. Chem. Soc.* **1997**, *119*, 12382−12383. (c) Satoh, T.; Kawamura, Y.; Miura, M.; Nomura, M. *Angew. Chem., Int. Ed. Engl.* **1997**, *36*, 1740−1742.

(8) For metal free-mediated formation of arylamines and α-aryl ketones, see: Smith, M. B.; March, J. *Advanced Chemistry*: *Reactions, Mechanisms, and Structure*, 5th ed.; Wiley-Interscience: New York, 2000.

(9) Nicolaou, K. C.; Bulger, P. G.; Sarlah, D. *Angew. Chem., Int. Ed.* **2005**, *44*, 4442−4489.

(10) Hennessy, E. J.; Buchwald, S. L. *J. Org. Chem.* **2005**, *70*, 7371−7375.

(11) For selected examples, see: (a) Stauffer, J. R.; Lee, S.; Stambuli, J. P.; Hauck, S. I.; Hartwig, J. F. *Org. Lett.* **2000**, *2*, 1423−1426. (b) Viciu, M. S.; Kissling, R. M.; Stevens, E. D.; Nolan, S. P. *Org. Lett.* **2002**, *4*, 2229−2232. (c) Viciu, M. S.; Germaneau, R. F.; Nolan, S. P. *Org. Lett.* **2002**, *4*, 4053−4056.

(12) Hartwig, J. F.; Kawatsura, M.; Hauck, S. I.; Shaughnessy, K. H.; Alcazar-Roman, L. M. *J. Org. Chem.* **1999**, *64*, 5575−5580.

(13) Huang, X.; Anderson, K. W.; Zim, D.; Jiang, L.; Klapars, A.; Buchwald, S. L. *J. Am. Chem. Soc.* **2003**, *125*, 6653−6655.

(14) (a) Urgaonkar, S.; Nagarajan, M.; Verkade, J. G. *J. Org. Chem.* **2003**, *68*, 452−459. (b) Urgaonkar, S.; Xu, J.-H.; Verkade, J. G. *J. Org. Chem.* **2003**, *68*, 8416−8423. (c) Urgaonkar, S.; Verkade, J. G. *J. Org. Chem.* **2004**, *69*, 9135−9142.

(15) Kataoka, N.; Shelby, Q.; Stambuli, J. P.; Hartwig, J. F. *J. Org. Chem.* **2002**, *67*, 5553−5566.

(16) For comprehensive reviews on aryl amination, see: (a) Hartwig, J. F. In *Handbook of Organopalladium Chemistry for Organic Synthesis*; Negishi, E.-i., de Meijere, A., Eds.; Wiley: New York, 2002; Vol. 1, p 1051. (b) Muci, A. R.; Buchwald, S. L. *Top. Curr. Chem.* **2002**, *219*, 131−209.

(17) Optimization studies were conducted with 4-chlorotoluene and dibutylamine on 1 mmol scale at 50 °C with 1 mol % of **1**. THF was found almost as efficient as DME whereas toluene led to incomplete conversion. Different bases were tested and found less efficient than KO^{t}Bu in the following order: NaO^{t}Bu > KO^{t}Am > KOMe ≈ NaOMe > NaOH ≈ KOH ≈ NaH.

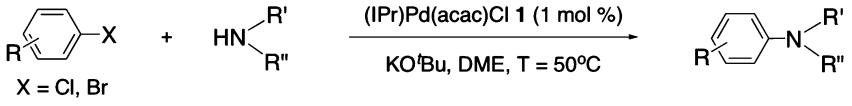
(18) Issues on catalyst decomposition are currently being investigated and will be reported in due course.

(19) (a) Thomas, K. R. J.; Lin, J. T.; Tao, Y.-T.; Ko, C.-W. *J. Am. Chem. Soc.* **2001**, *123*, 9404−9411. (b) Thelakkat, M. *Macromol. Mater. Eng.* **2002**, *287*, 442−461. (c) Lin, B. C.; Cheng, C. P.; Lao, Z. P. M. *J. Phys. Chem. A* **2003**, *107*, 5241−5251. (d) Nomura, M.; Shibasaki, Y.; Ueda, M.; Tugita, K.; Ichikawa, M.; Taniguchi, Y. *Macromolecules* **2004**, *37*, 1204−1210.

(20) (a) Fabbrizzi, L.; Licchelli, M.; Pallavicini, P.; Perotti, A.; Taglietti, A.; Sacchi, D. *Chem. Eur. J.* **1996**, *2*, 75−82. (b) Kubo, K.; Yamamoto, E.; Sakurai, T. *Heterocycles* **1998**, *48*, 1477−1483. (c) Costamagna, J.; Ferraudi, G.; Villagran, M.; Wolcan, E. *J. Chem. Soc., Dalton Trans.* **2000**, 2631−2637. (d) Bernardt, P. V.; Moore, E. G.; Riley, M. J. *Inorg Chem.* **2001**, *40*, 5799−5805.

(21) (a) Bressi, J. C.; et al. *J. Med. Chem.* **2001**, *44*, 2080−2093 [see the Supporting Information for the complete reference]. (b) Honma, T.; et al. *J. Med. Chem.* **2001**, *44*, 4615−4627 [see the Supporting Information for the complete reference]. (c) Regan, J.; et al. *J. Med. Chem.* **2003**, *46*, 4676−4686 [see the Supporting Information for the complete reference].

TABLE 1. ***N*-Aryl Amination of Aryl Bromides and Chlorides**[a]



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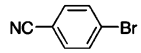
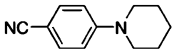
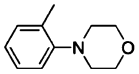
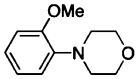
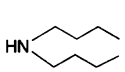
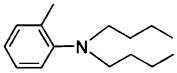
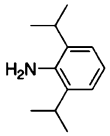
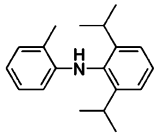
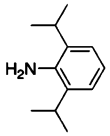
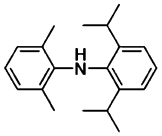
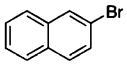
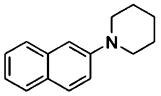
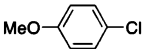
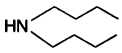
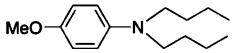
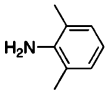
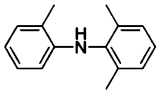
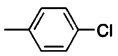
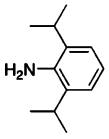
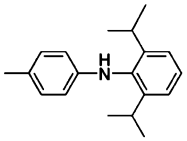
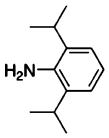
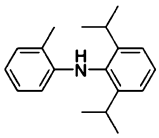
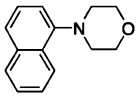
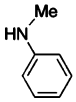
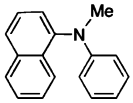
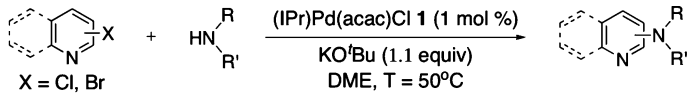
1				2	90
2				0.5	96
3				4	96
4				6	96
5				4	92
6				2	94
7				1.5	88
8				4	86
9				0.5	85
10				6	97
11				4.5	89
12				2	86
13				3	95

[a] Reaction conditions: aryl halide (1 mmol), amine (1.1 mmol), (IPr)Pd(acac)Cl (**1**) (1 mol %), KO^{t}Bu (1.1 mmol), DME (1 mL). [b] Isolated yields, average of two runs.

TABLE 2. ***N*-Aryl Amination of *N*-Containing Heterocyclic Halides**[a]



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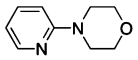
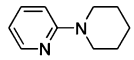
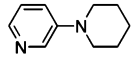
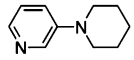
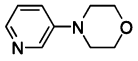
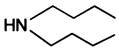
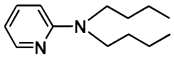
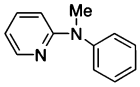
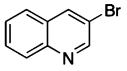
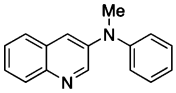
1				0.2	86
2				0.2	95
3				3.5	79
4				4	87
5				4	87
6				4	86
7				4	91
8				6	96

[a] Reaction conditions: aryl halide (1 mmol), amine (1.1 mmol), (IPr)Pd(acac)Cl (**1**) (1 mol %), KO^{t}Bu (1.1 mmol), DME (1 mL). [b] Isolated yields, average of two runs.

this type of substrates producing naphthylamines in good yields under mild conditions (entries 7, 12, and 13).

Heterocylic moieties are widely represented in biologically active molecules.[22] Therefore, heterocyclic halides and particularly heteroaromatic halides are coupling partners of great interest. Table 2 presents the results obtained with aryl bromides and chlorides. In the course of our investigations, we examined the reactivity of the present catalytic system toward *N*-, *O*-, and *S*-containing heterocyclic halides. All attempts to react the two latter with diverse amines invariably failed. Higher temperature or higher catalyst loading did not improve these results. On the other hand, *N*-containing heterocyclic halides were found to be suitable coupling partners. 2-Halopyridines were reacted in extremely short reaction times with secondary cyclic amines (entries 1 and 2), secondary acyclic amine (entry 6), and aniline (entry 7). Even though reactions required longer time, the 3-halopyridine and quinoline, strongly unactivated when compared to 2-halopyridines,[23] could be coupled in high yields (entries 3−5 and 8). Moreover, in the coupling of piperidine and 3-halopyridine we observed similar reaction times regardless of which halide was employed (entries 3 and 4).

Activity of (IPr)Pd(acac)Cl in the α-Ketone Arylation Reaction. To further broaden the reactivity profile of **1**, we tested its efficiency in the α-arylation of ketones. Despite having attracted less attention than the Buchwald−Hartwig reaction, α-ketone arylation has benefited from its developments and has followed the same evolution. Presently, catalytic systems for the α-arylation of almost every type of enolizable compounds are available.[24] Nevertheless, only a few systems can perform well with hindered aryl chlorides.

We first attempted to carry out a reaction with the same catalytic system we used for *N*-aryl amination. Employing this procedure, the reaction between chlorobenzene and propiophenone reached completion after 3 h. Further optimization studies showed that in addition to the nature of the solvent and base, the stoichiometry is crucial to the course of the reaction.[25] The coupling of several ketones with different aryl halides was then examined (Table 3). Remarkably, neutral and activated aryl chlorides reacted rapidly with propiophenone (entries 3 and 4). As expected, a less reactive ketone like α-tetralone required more time to reach full conversion (entries 5 and 6). Next, we focused on the coupling of sterically hindered halides. *Ortho*-substituted 2-chloro- and 2-bromotoluene reacted efficiently with acetophenone (entries 1 and 2) and α-tetralone (entry 10). Even unactivated sterically demanding aryl chlorides could be coupled in relatively short time and high yields (entry 7).

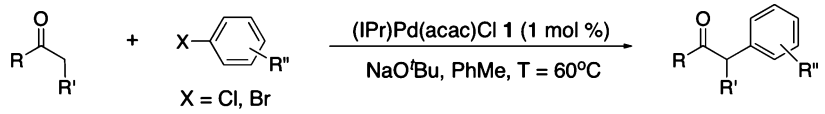
(22) (a) Pozharskii, A. F.; Soldatenkov, A. T.; Katritzky, A. R. *Heterocycles in Life and Society*; Wiley: New York, 1997. (b) Thomas, G. *Medicinal Chemistry*; Wiley: New York, 2000.

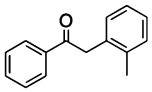
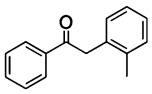
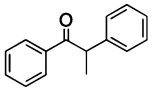
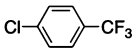
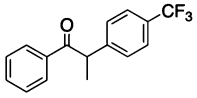
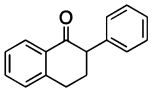
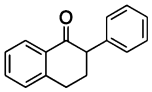
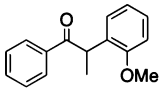
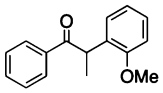
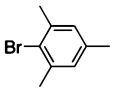
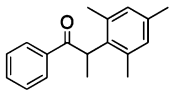
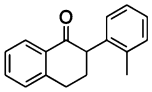
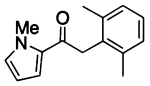
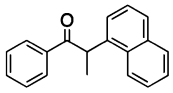
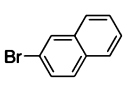
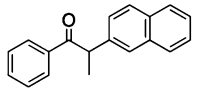
(23) Gribble, G.; Li, J. J. In *Palladium in Heterocyclic Chemistry*: *A Guide for the Synthetic Chemist*; Baldwin, J., Williams, R. M., Bäckvall, J.-E., Eds.; Pergamon: Amsterdam, The Netherlands, 2000.

(24) For a review on α-ketone arylation, see: Culkin, D. A.; Hartwig, J. F. *Acc. Chem. Res.* **2003**, *36*, 234−245.

(25) Optimization studies were conducted with chlorobenzene and propiophenone on 1 mmol scale at 60 °C with 1 mol % of **1**. Toluene was the only solvent that led to a complete conversion in a short reaction time. Different bases were tested and found less efficient than NaO^{t}Bu in the following order: KO^{t}Bu ≈ KO^{t}Am > KOMe ≈ NaOMe. When the reaction was performed with less than 1.5 equiv of NaO^{t}Bu, either it did not reach completion or it required extended time. Attempts to run α-ketone arylation reactions at lower temperature resulted in sluggish conversions.

TABLE 3. α-Ketone Arylation Reactions of Aryl Chlorides and Bromides[a]



entry	ketone	aryl halide	product	time (h)	yield (%)[b]
1				3.5	89
2				2	90
3				1	98
4				0.75	93
5				4	62
6				3.5	72
7				2.5	91
8				1.5	83
9				4.5	84
10				3	87
11				3	96
12				2	96
13				2	97
14				1	95

[a] Reaction conditions: aryl halide (1 mmol), ketone (1.1 mmol), (IPr)Pd(acac)Cl (**1**) (1 mol %), NaO^{t}Bu (1.5 mmol), toulene (1 mL). [b] Isolated yields, average of two runs.

Furthermore, the present catalytic system was found compatible with di-*ortho*-substituted substrates, highlighting its high tolerance for extremely hindered substrates as we previously noticed in the Buchwald−Hartwig reaction. As an added advantage, a heteroaromatic ketone was α-arylated without loss of activity (entry 11). Finally, we focused on the use of polyaromatic halides as coupling partners and produced three propiophenones possessing respectively the 1-naphthyl, 2-naphthyl, and 4-biphenylyl moiety at the α position in near quantitative yields (entries 12−14). Interestingly, we isolated these products without purification by column chromatography on silica gel. Taking advantage of the low solubility of the product in alkanes, a simple pentane wash followed by a filtration was sufficient to isolate pure compounds (entries 12, 13, and 14). To the best of our knowledge, this is the first time that such compounds have been synthesized with a Pd-catalyzed cross-coupling reaction.[26]

Conclusion

In summary, we have described a new synthetic route leading to a Pd^{II} precatalyst in one step from a stable NHC salt and the commercially available $Pd(acac)_2$. The resulting complex, (IPr)-Pd(acac)Cl, has shown excellent catalytic activity in the Buchwald−Hartwig and the α-ketone arylation reactions, using aryl chlorides under mild reaction conditions. The activity of this family of palladium precatalysts in related reactions is currently under investigation.

Experimental Section

Synthesis of (IPr)Pd(acac)Cl (1). A Schlenk flask equipped with a magnetic bar was loaded with the imidazolium salt IPr·HCl (2.96 g, 7 mmol) and $Pd(acac)_2$ (1.53 g, 5 mmol). The vessel was purged by a sequence of three vacuum−argon refill−evacuation cycles and dry dioxane (100 mL) was added with a syringe. The reaction mixture was stirred at 100 °C for 24 h. The solvent was evaporated in vacuo and the remaining solid was dissolved in diethyl ether, some impurities being insoluble. The mixture was then filtered and the solid further washed with diethyl ether (2 × 10 mL). The filtrate was collected and the solvent was evaporated in vacuo to yield 2.99 g (95%) of the desired compound as a yellow powder.

^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51 (t, J = 7.8 Hz, 2H), 7.35 (d, J = 7.8 Hz, 4H), 7.12 (s, 2H), 5.12 (s, 1H), 2.95 (q, J = 6.4 Hz, 4H), 1.84 (s, 3H), 1.82 (s, 3H), 1.34 (d, J = 6.4 Hz, 12H), 1.10 (d, J = 6.4 Hz, 12H). ^{13}C NMR (100 MHz, $CDCl_3$): δ 187.1, 184.1, 156.4, 147.0, 135.5, 134.8, 130.9, 125.7, 124.7, 124.6, 99.9, 29.1, 30.0, 27.6, 26.8, 23.7, 23.5. Anal. Calcd for $C_{32}H_{43}ClN_2O_2Pd$ (MW 629.57): C, 61.05; H, 6.88; N, 4.45. Found: C, 60.78; H, 7.15; N, 4.29.

Buchwald−Hartwig Cross-Coupling of Aryl Halides with Primary and Secondary Amines: General Procedure. In a glovebox, (IPr)Pd(acac)Cl (**1**) (0.01 mmol, 6.3 mg), potassium *tert*-butoxide (1.1 mmol, 124 mg), and anhydrous 1,2-dimethoxyethane (DME) (1 mL) were added in turn to a vial equipped with a magnetic bar and sealed with a screw cap fitted with a septum. Outside the glovebox, the amine (1.1 mmol) and the aryl halide (1 mmol) were injected in turn through the septum. If one of the two starting materials was a solid, it was added to the vial inside the glovebox and DME and the second starting material were added outside the glovebox under argon. The reaction mixture was then stirred at 50 °C unless otherwise indicated. When the reaction reached completion, or no further conversion could be observed by gas chromatography, water was added to the reaction mixture, the organic layer was extracted with *tert*-butylmethyl ether (MTBE) dried over magnesium sulfate, and the solvent was evaporated in vacuo. When necessary the product was purified by flash chromatography on silica gel. The reported yields are the average of at least two runs.

α-Ketone Arylation of Aryl Halides: General Procedure. In a glovebox, (IPr)Pd(acac)Cl (**1**) (0.01 mmol, 6.3 mg), sodium *tert*-butoxide (1.5 mmol, 144 mg), and anhydrous toluene (1 mL) were added in turn to a vial equipped with a magnetic bar and sealed with a screw cap fitted with a septum. Outside the glovebox, the ketone (1.1 mmol) and the aryl halide (1 mmol) were injected in turn through the septum. If one of the two starting materials was a solid, it was added to the vial inside the glovebox and toluene and the second starting material were added outside the glovebox under argon. The reaction mixture was then stirred at 60 °C. When the reaction reached completion, or no further conversion could be observed by gas chromatography, water was added to the reaction mixture, the organic layer was extracted with *tert*-butylmethyl ether (MTBE) dried over magnesium sulfate, and the solvent was evaporated in vacuo. When necessary, the product was purified by flash chromatography on silica gel. The reported yields are the average of at least two runs.

2-(2,6-Dimethylphenyl)-1-(1-methyl-1*H*-pyrrol-2-yl)-ethanone (Table 3, entry 10). The above general procedure yielded, after a pentane wash, 218 mg (96%) of the title compound.

^{1}H NMR (300 MHz, $CDCl_3$): δ 7.12−7.10 (m, 1H, H^{Ar}), 7.04−7.02 (m, 3H, H^{Ar}), 6.75 (s, 1H, H^{Ar}), 6.14−6.12 (m, 1H, H^{Ar}), 4.28 (s, 2H, C(O)−CH_2), 3.96 (s, 3H, N−CH_3), 2.32 (s, 6H, C^{Ar}−CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 188.0 (C, *C*═O), 137.3 (C, C^{Ar}), 132.9 (C, C^{Ar}), 131.0 (CH, C^{Ar}), 130.7 (C, C^{Ar}), 128.0 (CH, C^{Ar}), 126.8 (CH, C^{Ar}), 118.8 (CH, C^{Ar}), 108.0 (CH, C^{Ar}), 39.7 (CH_2, C(O)−*C*H_2), 37.8 (CH_3, N−*C*H_3), 20.6 (CH_3, C^{Ar}−*C*H_3). Anal. Calcd for $C_{15}H_{17}NO$ (MW 227.30): C, 79.26; H, 7.54; N, 6.16. Found: C, 79.39; H, 7.24; N, 5.74.

2-(Naphthalen-2-yl)-1-phenylpropan-1-one (Table 3, entry 13). The above general procedure yielded, after a pentane wash, 253 mg (97%) of the title compound.

^{1}H NMR (300 MHz, $CDCl_3$): δ 7.96 (d, J = 5.7 Hz, 2H, H^{Ar}), 7.73−7.69 (m, 4H, H^{Ar}), 7.39−7.31 (m, 4H, H^{Ar}), 7.26 (t, J = 5.7 Hz, 2H, H^{Ar}), 4.77 (q, J = 5.1 Hz, 1H, C*H*−CH_3), 1.58 (d, J = 5.1 Hz, 3H, CH−CH_3). ^{13}C NMR (75 MHz, $CDCl_3$): δ 200.3 (C, *C*═O), 139.1 (C, C^{Ar}), 136.5 (C, C^{Ar}), 133.7 (C, C^{Ar}), 132.9 (CH, C^{Ar}), 132.4 (C, C^{Ar}), 128.9 (CH, C^{Ar}), 128.8 (CH, C^{Ar}), 128.5 (CH, C^{Ar}), 127.8 (CH, C^{Ar}), 127.7 (CH, C^{Ar}), 126.5 (CH, C^{Ar}), 125.2 (CH, C^{Ar}), 126.0 (CH, C^{Ar}), 125.8 (CH, C^{Ar}), 48.0 (CH, *C*H−CH_3), 19.6 (CH_3, CH−*C*H_3). Anal. Calcd for $C_{19}H_{16}O$ (MW 260.33): C, 87.66; H, 6.19. Found: C, 87.90; H, 6.35.

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Supporting Information Available: Details for experimental procedures and products isolation. This material is available free of charge via the Internet at http://pubs.acs.org.

JO060190H

(26) (a) **3i** was previously synthesized by thermolysis of benzoylbenzocycloheptene, see: Battye, P. J.; Jones, D. W. *J. Chem. Soc., Perkin Trans. 1* **1986**, *8*, 1479−1489. (b) **3j** has not been reported. (c) **3k** was previously synthesized by a Friedel-Craft/methylation sequence, see: Garcia-Garibay, M. A.; Shin, S.; Sanrame, C. N. *Tetrahedron Lett.* **2000**, *56*, 6729−6737.