Amination

DOI: 10.1002/anie.201003764

Palladium-Catalyzed Cross-Coupling of Aryl Chlorides and Tosylates with Hydrazine**

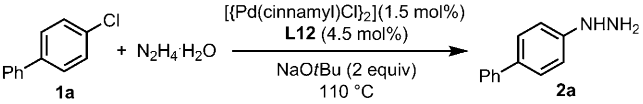
*Rylan J. Lundgren and Mark Stradiotto**

Aryl hydrazines are highly valuable intermediates in the synthesis of a number of important nitrogen-containing heterocyclic frameworks such as indoles (through the Fischer indole synthesis),[1] indazoles, aryl pyrazoles, and aryl triazoles.[2] In some cases, hydrazine reacts with haloarenes directly in nucleophilic aromatic substitution reactions; however, such reactions typically occur at high temperatures, and/or only with highly electron-deficient haloarenes, or at selected positions of halogenated heterocycles.[3,4] The prevailing method for the preparation of aryl hydrazines relies on the stoichiometric oxidation of anilines to their corresponding diazonium salts and subsequent reduction.[5] The transition-metal-catalyzed cross-coupling of aryl halides and hydrazine represents an attractive alternative to the traditional synthesis of aryl hydrazines. However, despite the tremendous progress made in the field of Buchwald–Hartwig amination reactions over the past decade,[6] no such reaction has been reported.

Hydrazine presents a number of potential problems in palladium-catalyzed cross-coupling reactions. First, hydrazine is an aggressive reductant of both organic and inorganic substrates,[7] and could reduce key $Pd^{II}Ar(X)$ species, thereby promoting the generation of catalytically inactive Pd^0 aggregates, as well as reducing aryl halide substrates by hydrodehalogenation. Second, aryl hydrazines can undergo metal-mediated N–N bond cleavage,[8] thus resulting in the formation of undesired aniline by-products. Finally, and most importantly, the product aryl hydrazines still possess three reactive N–H bonds that can undergo further C–N cross-coupling, thus leading to polyarylated products. Some of these challenges have been circumvented by the use of hydrazine surrogates with attenuated reactivity such as benzophenone hydrazone[9] or protected hydrazides,[10] although such strategies are not ideal from efficiency or economic standpoints. In addition, aryl- or alkyl-substituted hydrazines, which are less prone to undergo some of the above described detrimental side reactions, have been employed as substrates.[11] Herein, we report on a palladium catalyst system and reaction conditions that allow, for the first time, the cross-coupling of aryl chlorides and tosylates with hydrazine. The reactions proceed rapidly under relatively mild conditions with excellent monoarylation selectivity, thus providing direct access to aryl hydrazines.

We began by screening a variety of ligands (Scheme 1) and reaction conditions (Table 1) in the hope of effecting the cross-coupling of 4-phenylchlorobenzene with readily available hydrazine sources. A series of structurally diverse phosphane and N-heterocyclic carbene ligands were tested employing [{Pd(cinnamyl)Cl}$_2$] (1.5 mol%) and the ligand (3 mol%) at 110°C in 1,4-dioxane with 2 equivalents of hydrazine hydrate and NaO*t*Bu. Electron-rich monophosphanes or carbenes including P(*t*Bu)$_3$ (**L1**), IPr (**L2**), *t*Bu-JohnPhos (**L3**), SPhos (**L4**), Q-Phos (**L5**), as well as bisphosphanes DuPhos (**L6**), binap (**L7**), DiPPF (**L8**), and Taniaphos (**L9**) all gave poor results: either resulting in low conversions of the starting aryl chloride, or providing mainly the hydrodehalogenated product. The electron-rich bisphosphine ligand Josiphos (**L10**)[6b,10a] or DalPhos P,N ligands (**L11** and **L12**)[6l,m] provided a breakthrough in reactivity: high

Table 1: Optimization of the palladium-catalyzed cross-coupling of 4-phenylchlorobenzene and $N_2H_4 \cdot H_2O$.[a]



Entry	Variation from standard conditions	Conv. [%]	Yield [%]
1	none	> 99	73
2	9 mol% of **L12**	> 99	61
3	toluene instead of 1,4-dioxane	> 99	79
4	DMA instead of 1,4-dioxane	< 10	0
5	DCE instead of 1,4-dioxane	0	0
6	0.3 M of ArCl instead of 0.1 M	65	35
7	4 equiv of hydrazine instead of 2 equiv	51	24
8	3 equiv of NaO*t*Bu instead of 2 equiv	90	66
9	KOH instead of NaO*t*Bu	45	24
10	Cs_2CO_3 instead of NaO*t*Bu	65	14
11	ArBr instead of ArCl	95	45
12[b]	$N_2H_4 \cdot HCl$ instead of $N_2H_4 \cdot H_2O$	> 99	80
13[b]	$N_2H_4 \cdot HCl$ instead of $N_2H_4 \cdot H_2O$, 65 °C	99	76
14[b,c]	[PdCl$_2$(MeCN)$_2$] instead of [{Pd-(cinnamyl)Cl}$_2$]	> 99	69
15[b,c]	[Pd(dba)$_2$] instead of [{Pd(cinnamyl)Cl}$_2$]	99	60
16	no [Pd], no ligand	< 10	0

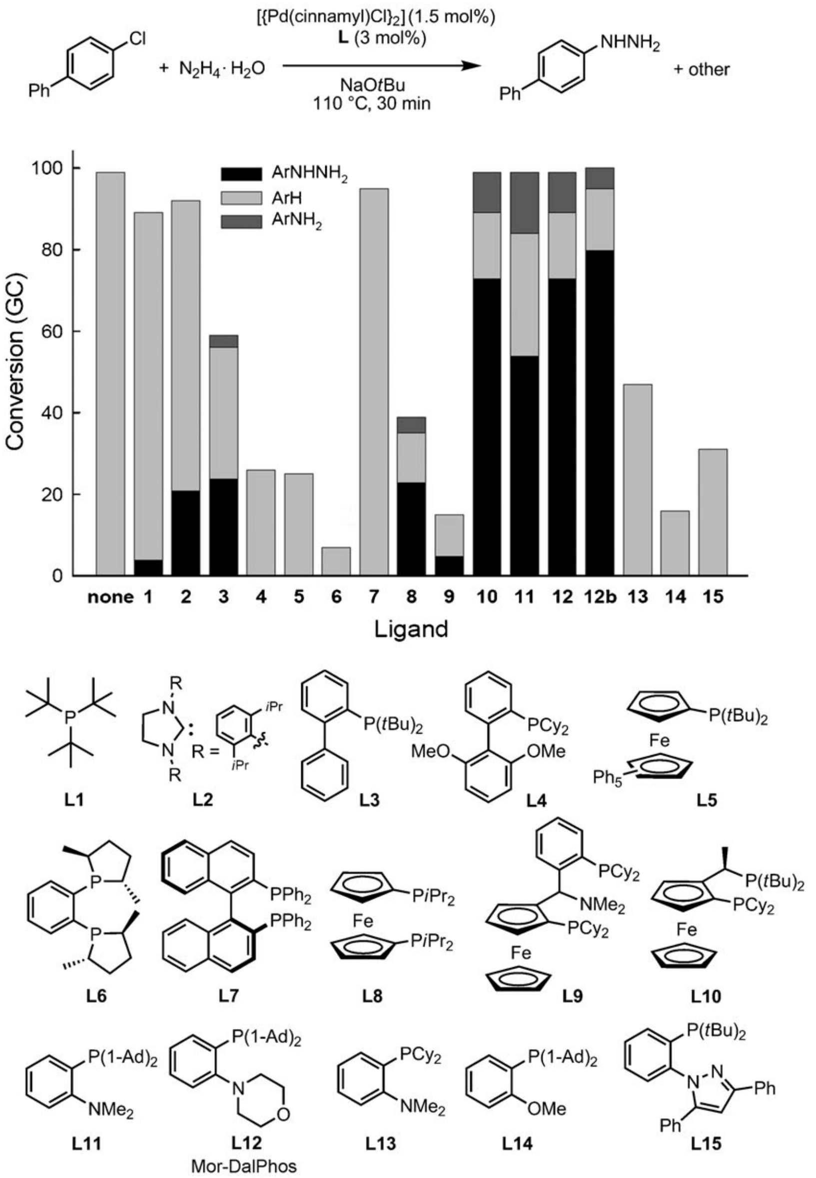
[a] Standard reaction conditions: reactions were carried out on a 0.2 mmol scale, [Pd]/**L** = 1:1.5, $N_2H_4 \cdot H_2O$ (2 equiv), and NaO*t*Bu (2 equiv), 110°C, in 1,4-dioxane (0.1 M in substrate). Conversions and yields were determined by GC analysis. [b] Employing $N_2H_4 \cdot HCl$ and NaO*t*Bu (3.5 equiv). [c] At 90°C. dba = *trans,trans*-dibenzylideneacetone.

---

[*] R. J. Lundgren, Prof. Dr. M. Stradiotto
Department of Chemistry, Dalhousie University
Halifax, Nova Scotia B3H 4J3 (Canada)
Fax: (+1) 902-494-7190
E-mail: mark.stradiotto@dal.ca

[**] We are grateful to the NSERC of Canada and Dalhousie University for their support of this work. K. D. Hesp and V. M. Marx (Dalhousie) are acknowledged for helpful discussions.

Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/anie.201003764.



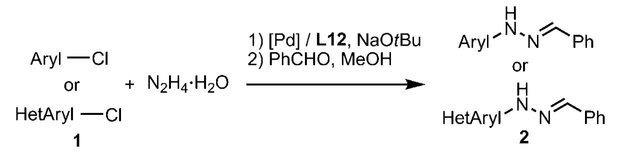
Scheme 1. Ligand screening for the palladium-catalyzed cross-coupling of 4-phenylchlorobenzene and $N_2H_4{\cdot}H_2O$. Reaction conditions: reactions were carried out on a 0.15 mmol scale, 110 °C, in 1,4-dioxane (0.1 M in substrate). Conversions were determined by GC analysis. **12b** = 6 mol% of **L12** employed. Ad = adamantyl, Cy = cyclohexyl.

conversions with lower amounts of arene side product were achieved. Other related P-phenyl ligands (**L13–15**), as well as cataCXium ligands A, PICy, POMetB (see the Supporting Information) were ineffective, thus demonstrating the extreme sensitivity of the reaction to the structure of the ligand.

The coupling of 4-phenylchlorobenzene proved to be sensitive to the reaction conditions. When **L12** (Mor-DalPhos) was employed, toluene (Table 1, entry 3) or 1,4-dioxane could be used interchangeably, but the use of *N,N*-dimethylacetamide (DMA) or 1,2-dichloroethane (DCE) inhibited the transformation (Table 1, entries 4 and 5). The use of excess $N_2H_4{\cdot}H_2O$ or NaO*t*Bu both resulted in diminished conversions and yields (Table 1, entries 7 and 8). Other bases such as KOH and Cs_2CO_3 were inferior to NaO*t*Bu (Table 1, entries 9 and 10). Interestingly, aryl chlorides appear to be superior substrates compared to aryl bromides, where incomplete conversion of 4-phenylbromobenzene and 45% yield of the desired product was observed (Table 1, entry 11).[12] Conveniently, solid $N_2H_4{\cdot}HCl$ could also be employed with additional base (Table 1, entries 12 and 13). The palladium source proved less important, with [{Pd(cinnamyl)Cl}$_2$] only slightly outperforming [$PdCl_2(MeCN)_2$] or [$Pd(dba)_2$] (Table 1, entries 14 and 15).

After having defined a catalyst system and the reaction conditions for the cross-coupling of aryl chlorides and hydrazine, we sought to explore the scope of the reaction (Table 2). To simplify isolation and purification, the product aryl hydrazines were isolated as their corresponding hydrazone derivatives after treatment with benzaldehyde.[13] Cross-coupling of electron-neutral aryl chlorides proceeded with good yields by employing 5 mol% of [Pd] at 90 °C. Substrates included biaryl derivatives with ether and CF_3 substituents (Table 2, entries 4 and 5), as well as heterocycles such as pyrrole and pyridine (Table 2, entries 6 and 8). Electron-poor substrates like 4-trifluoromethylchlorobenzene (Table 2, entry 7) gave poorer yields because of increased hydrodehalogenation, while the electron-rich substrate 4-chloroanisole (Table 2, entry 9) reacted slowly. 4-Fluorochlorobenzene could be employed as a substrate with moderate success when the reaction was conducted in 1,4-dioxane (49% yield, Table 2, entry 10); in toluene, a significant amount of defluorinated product was observed. Other examples of aryl chlorides substituted at the 3-position with alkyl, oxygen, sulfur, or fluoro groups resulted in good yields (72–88%; Table 2, entries 11–13). *ortho*-Substitution was also tolerated;

Table 2: Scope of the palladium-catalyzed cross-coupling of aryl chlorides and hydrazine.[a]



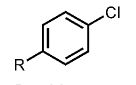
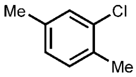
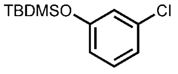
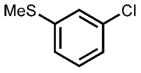
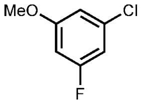
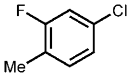
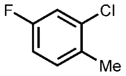
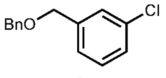
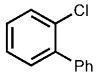
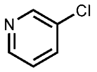
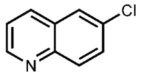
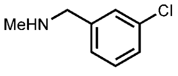
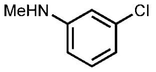
Entry	ArCl	[Pd] [mol%]	T [°C]	t [h]	Prod., yield [%][b]
					
1	R = H	5	90	1	**2b**, 86
2	R = Me	5	90	1	**2c**, 93

Table 2: (Continued)

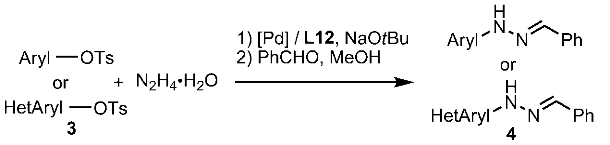
Entry	ArCl	[Pd] [mol %]	*T* [°C]	*t* [h]	Prod., yield [%][b]
3	R = Ph	3	90	1	**2a**, 86
4	R = 4-OMeC$_6$H$_4$	5	90	0.5	**2d**, 82
5[c]	R = 4-CF$_3$C$_6$H$_4$	3	90	0.5	**2e**, 83
6	R = *N*-pyrrole	5	90	1	**2f**, 78
7	R = CF$_3$	5	90	1	**2g**, 50 (44)[d]
8	R = 3-pyridine	5	65	2	**2h**, 97
9[c]	R = OMe	10	110	1	**2i**, 27
10[c,e]	R = F	5	90	0.33	**2j**, 49
11		5	90	1	**2k**, 88
12[c,f]		5	90	0.5	**2l**, 83
13		10	110	0.5	**2m**, 95
14		5	90	1	**2n**, 72
15		5	90	1	**2o**, 77
16		5	90	0.5	**2p**, 75
17		5	65	1	**2q**, 83
18[c]		10	90	1	**2r**, 71
19		5	65	1.5	**2s**, 69
20[f]		3	65	1	**2t**, 81
21		5	90	0.5	**2u**, 75
22		5	90	0.5	**2v**, 58

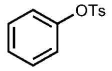
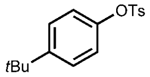
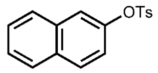
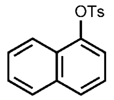
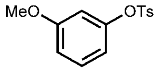
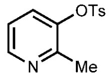
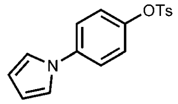
[a] Reaction conditions: ArCl/N$_2$H$_4$·H$_2$O/NaO*t*Bu = 1:2:2–1.8, [Pd] = [{Pd(cinnamyl)Cl}$_2$], [Pd]/**L12** = 1:1.5, in toluene (0.1 M in substrate). [b] Yield of isolated product. [c] Employing N$_2$H$_4$·HCl and NaO*t*Bu (3.5 equiv). [d] > 95 % conversion of ArCl, yield at 2.5 mol % of [Pd] in brackets. [e] In 1,4-dioxane. [f] Isolated aryl hydrazine. TBDMS = *tert*-butyldimethylsilyl.

2-chloro-*p*-xylene was cross-coupled cleanly and gave the desired product in 88 % yield after derivatization (Table 2, entry 11), while the bulky substrate 2-phenylchlorobenzene could be employed with success using 10 mol % of [Pd] (Table 2, entry 18). Chloropyridine and quinoline substrates such as 3-chloropyridine and 6-chloroquinoline were also suitable substrates (Table 2, entries 19 and 20). Importantly, unlike 2- or 4-halopyridines, such chloro-substituted heterocycles are not amenable to nucleophilic aromatic substitution with hydrazine, thus indicating that such cross-coupling strategies are complementary to established methods that employ hydrazine. Aminoaryl chloride substrates were also readily cross-coupled in moderate to good yields without significant interference from the pendant NH functionality (Table 2, entries 21 and 22). This protocol is also suitable for larger-scale reactions; for example, 92 % yield (2.09 g) of **2p** was obtained when the reactions were conducted on a 10 mmol scale.

Aryl tosylates, which are readily available and easily prepared from phenols, could also be employed in the present reaction by using a similar catalytic protocol (Table 3).

Table 3: Scope of the palladium-catalyzed cross-coupling of aryl tosylates and hydrazine.[a]

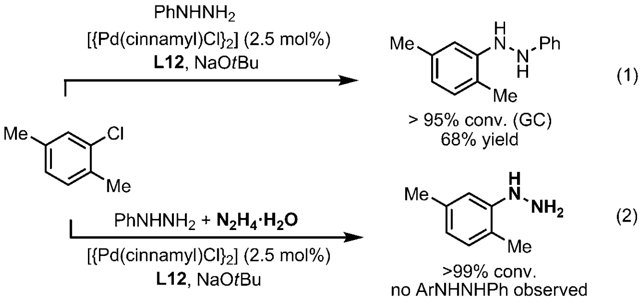


Entry	ArOTs	[Pd] [mol %]	*T* [°C]	*t* [h]	Prod., yield [%][b]
1[c]		5	65	1	**2a**, 64
2[c]		5	65	1	**4a**, 73
3		5	65	0.5	**4b**, 67
4[d]		5	65	0.5	**4c**, 97
5		5	65	0.5	**4d**, 51
6		5	50	0.5	**4e**, 79
7		5	65	0.5	**2f**, 59

[a] Reaction conditions: identical to Table 2. [b] Yield of isolated product. [c] Employing N$_2$H$_4$·HCl and NaO*t*Bu (3.5 equiv). [d] Isolated aryl hydrazine. Ts = 4-toluenesulfonyl.

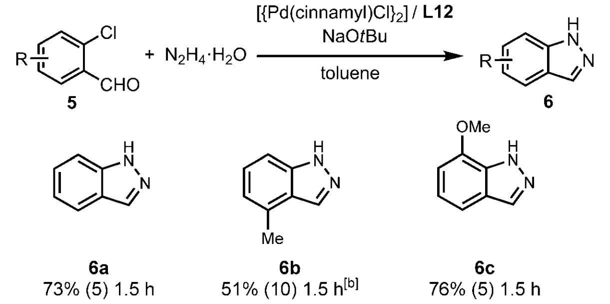
Moderate to excellent yields (51-97 %) for a range of aryl tosylate substrates were obtained, including *ortho*-, *meta*-, and *para*-substituted derivatives (Table 3, entries 2 and 5–7).[14] Heteroaromatic substrates such as 2-methyl-3-pyridyl tosylate were also suitable reaction partners (Table 3, entry 6).

Diarylation of hydrazine was anticipated to be a potential challenge to overcome; however, throughout both screening experiments and the substrate scope studies, no significant amount of material arising from multiple arylation of hydrazine was observed. This observation is interesting in light of the fact that [{Pd(cinnamyl)Cl}$_2$]/**L12** is a highly capable catalyst for the cross-coupling of aryl hydrazines. For example, 2-chloro-*p*-xylene could be coupled to phenylhydrazine in 68 % yield under our standard reaction conditions [Scheme 2, Eq. (1)]. However, in the presence of $N_2H_4\cdot H_2O$ the only product that was observed was 2,5-dimethylphenylhydrazine [Scheme 2, Eq. (2)]. Given the similar steric environment of hydrazine and phenylhydrazine at the terminal nitrogen atom, we postulate that the origin of the high chemoselectivity observed with $[\{Pd(cinnamyl)Cl\}_2]$/**L12** is primarily electronic in nature—with the more nucleophilic hydrazine substrate reacting preferentially.[15]



Scheme 2. Palladium-catalyzed cross-coupling of $PhNHNH_2$ and $N_2H_4\cdot H_2O$. Reaction conditions: $RNHNH_2$ (1.2 equiv), NaO*t*Bu (1.3 equiv), **L12** (0.075 equiv), toluene (0.1 M in substrate, 90 °C, 30 min.

Finally, we exploited our newly developed method to prepare 1-*H*-indazoles directly from 2-chlorobenzaldehydes and hydrazine (Scheme 3).[16] While there exist many metal-catalyzed tandem indazole syntheses, our protocol allows for the generation of substituted NH-indazoles, which are attractive substrates for further elaboration. Moderate to good yields were observed in short reaction times (1–1.5 h) and under relatively mild reaction conditions (65–90 °C).[17]



Scheme 3. Reaction conditions: ArCl/$N_2H_4\cdot H_2O$/NaO*t*Bu = 1:2:2, [Pd]/**L** = 1:1.5, [ArCl] = 0.20 M in toluene at 65 °C, mol % of [Pd] employed is indicated in brackets. [b] Employing $N_2H_4\cdot HCl$ and NaO*t*Bu (3.5 equiv) at 90 °C.

In conclusion, we have developed the first palladium-catalyzed cross-coupling of aryl chlorides and tosylates with hydrazine. The reaction relies on the use of appropriately designed ligands to overcome the difficulties associated with the use of hydrazine, and proceeds rapidly under mild conditions with excellent chemoselectivity. Given the readily available nature of aryl chlorides and tosylates, and the importance of aryl hydrazines in heterocycle synthesis, we believe that this method will find widespread application. Studies directed to the further development of the scope and utility of this and related challenging C–N cross-coupling reactions are ongoing.

Received: June 20, 2010
Revised: August 17, 2010

Keywords: amination · cross-coupling · homogeneous catalysis · hydrazine · P,N ligands

---

[1] R. J. Sundberg, *Indoles*, Academic Press, San Diego, **1999**, p. 54.

[2] A. R. Katritzky, A. F. Pozharskii, *Handbook of Heterocyclic Chemistry*, 2nd ed., Pergamon, Oxford, **2000**; p. 499.

[3] C. F. H. Allen, *Org. Synth.* **1943**, *2*, 228.

[4] For selected examples, see: a) J. Rodríguez, V. J. Arán, L. Boiani, C. Olea-Azar, M. L. Lavaggi, M. González, H. Cerecetto, J. D Maya, C. Carrasco-Pozo, H. S Cosoy, *Bioorg. Med. Chem.* **2009**, *17*, 8186; b) M. Schlosser, T. Rausis, C. Bobbio, *Org. Lett.* **2005**, *7*, 127; c) S. Charier, O. Ruel, J.-B. Baudin, D. Alcor, J.-F. Allemand, A. Meglio, L. Jullien, *Angew. Chem.* **2004**, *116*, 4889; *Angew. Chem. Int. Ed.* **2004**, *43*, 4785.

[5] G. H. Coleman, *Org. Synth.* **1941**, *1*, 442.

[6] For reviews, see: Pd: a) J. Hartwig, *Organotransition Metal Chemistry*, University Science Books, Sausalito, **2010**, p. 907; b) J. F. Hartwig, *Acc. Chem. Res.* **2008**, *41*, 1534; c) D. S. Surry, S. L. Buchwald, *Angew. Chem.* **2008**, *120*, 6438; *Angew. Chem. Int. Ed.* **2008**, *47*, 6338; d) S. L. Buchwald, C. Mauger, G. Mignani, U. Scholz, *Adv. Synth. Catal.* **2006**, *348*, 23; e) A. R. Muci, S. L. Buchwald, *Top. Curr. Chem.* **2002**, *219*, 131; f) J. F. Hartwig in *Modern Arene Chemistry* (Ed.: D. Astruc), Wiley-VCH, Weinheim, **2002**, p. 107; Cu C–N coupling: g) F. Monnier, M. Taillefer, *Angew. Chem.* **2009**, *121*, 7088; *Angew. Chem. Int. Ed.* **2009**, *48*, 6954; for recent advances concerning the cross-coupling of ammonia, see: h) Q. Shen, J. F. Hartwig, *J. Am. Chem. Soc.* **2006**, *128*, 10028; i) D. S. Surry, S. L. Buchwald, *J. Am. Chem. Soc.* **2007**, *129*, 10354; j) T. Schulz, C. Torborg, S. Enthaler, B. Schäffner, A. Dumrath, A. Spannenberg, H. Neumann, A. Börner, M. Beller, *Chem. Eur. J.* **2009**, *15*, 4528; k) G. D. Vo, J. F. Hartwig, *J. Am. Chem. Soc.* **2009**, *131*, 11049; l) R. J. Lundgren, A. Sappong-Kumankumah, M. Stradiotto, *Chem. Eur. J.* **2010**, *16*, 1983; m) R. J. Lundgren, B. D. Peters, P. G. Alsabeh, M. Stradiotto, *Angew. Chem.* **2010**, *122*, 4165; *Angew. Chem. Int. Ed.* **2010**, *49*, 4071; n) J. I. van der Vlugt, *Chem. Soc. Rev.* **2010**, *39*, 2302.

[7] a) N. N. Greenwood, A. Earnshaw, *Chemistry of the Elements*, Elsevier, Oxford, **1998**, p. 427; b) B. A. Roden, Hydrazine in *Encyclopedia of Reagents for Organic Synthesis* (Ed.: L. A. Paquette), Wiley, Chester, **2001**; palladium-catalyzed hydrodehalogenation employing hydrazine: c) P. P. Cellier, J.-F. Spindler, M. Taillefer, H.-J. Cristau, *Tetrahedron Lett.* **2003**, *44*, 7191.

[8] For examples, see: a) K.-S. Lee, Y.-K. Lim, C.-G. Cho, *Tetrahedron Lett.* **2002**, *43*, 7463; b) G. J. Ellames, J. S. Gibson, J. M. Herbert, A. H. McNeill, *Tetrahedron* **2001**, *57*, 9487; c) F. Alonso, G. Radivoy, M. Yus, *Tetrahedron* **2000**, *56*, 8673.

[9] Pd: a) C. Mauger, G. Mignani, *Adv. Synth. Catal.* **2005**, *347*, 773; b) A. Y. Lebedev, A. S. Khartulyari, A. Z. Voskoboynikov, *J. Org. Chem.* **2005**, *70*, 596; c) C. S. Cho, D. K. Lim, N. H. Heo, T.-J. Kim, S. C. Shim, *Chem. Commun.* **2004**, 104; d) J. B. Arterburn, K. V. Rao, R. Ramdas, B. R. Dible, *Org. Lett.* **2001**, *3*, 1351; e) S. Wagaw, B. H. Yang, S. L. Buchwald, *J. Am. Chem. Soc.* **1999**, *121*, 10251; f) S. Wagaw, B. H. Yang, S. L. Buchwald, *J. Am. Chem. Soc.* **1998**, *120*, 6621; Cu: g) A. Klapars, J. C. Antilla, X. Huang, S. L. Buchwald, *J. Am. Chem. Soc.* **2001**, *123*, 7727; h) C.

Pabba, H.-J. Wang, S. R. Mulligan, Z.-J. Chen, T. M. Stark, B. T. Gregg, *Tetrahedron Lett.* **2005**, *46*, 7553; i) K. Inamoto, M. Katsuno, T. Yoshino, I. Suzuki, K. Hiroya, T. Sakamoto, *Chem. Lett.* **2004**, *33*, 1026.

[10] Pd: a) A. Reichelt, J. R. Falsey, R. M. Rzasa, O. R. Thiel, M. M. Achmatowicz, R. D. Larsen, *Org. Lett.* **2010**, *12*, 792; b) J. Barluenga, P. Moriel, F. Aznar, C. Valdés, *Org. Lett.* **2007**, *9*, 275; c) Y.-K. Lim, J.-W. Jung, H. Lee, C.-G. Cho, *J. Org. Chem.* **2004**, *69*, 5778; d) Y.-K. Lim, K.-S. Lee, C.-G. Cho, *Org. Lett.* **2003**, *5*, 979; e) Z. Wang, R. T. Skerlj, G. J. Bridger, *Tetrahedron Lett.* **1999**, *40*, 3543; Cu: f) M. R. Rivero, S. L. Buchwald, *Org. Lett.* **2007**, *9*, 973; g) R. Martín, M. Rodríguez Rivero, S. L. Buchwald, *Angew. Chem.* **2006**, *118*, 7237; *Angew. Chem. Int. Ed.* **2006**, *45*, 7079; h) O. Loog, U. Mäeorg, *Synlett* **2004**, 2537; i) M. Wolter, A. Klapars, S. L. Buchwald, *Org. Lett.* **2001**, *3*, 3803.

[11] a) N. Halland, M. Nazaré, O. R′kyek, J. Alonso, M. Urmann, A. Lindenschmidt, *Angew. Chem.* **2009**, *121*, 7011; *Angew. Chem. Int. Ed.* **2009**, *48*, 6879; b) D. Viña, E. del Olmo, J. L. López-Pérez, A. San Feliciano, *Org. Lett.* **2007**, *9*, 525; c) C. S. Cho, D. B. Patel, *Tetrahedron* **2006**, *62*, 6388; d) S. Cacchi, G. Fabrizi, A. Goggiamani, S. Sgalla, *Adv. Synth. Catal.* **2007**, *349*, 453; e) X. Liu, M. Barry, H.-R. Tsou, *Tetrahedron Lett.* **2007**, *48*, 8409; f) S. Cacchi, G. Fabrizi, A. Goggiamani, E. Licandro, S. Maiorana, D. Perdicchia, *Org. Lett.* **2005**, *7*, 1497; g) J. J. Song, N. K. Yee, *Org. Lett.* **2000**, *2*, 519; h) H. Rao, Y. Jin, H. Fu, Y. Jiang, Y. Zhao, *Chem. Eur. J.* **2006**, *12*, 3636.

[12] For similar observations, see: a) B. P. Fors, S. L. Buchwald, *J. Am. Chem. Soc.* **2009**, *131*, 12898; b) E. J. Cho, T. D. Senecal, T. Kinzel, Y. Zhang, D. A. Watson, S. L. Buchwald, *Science* **2010**, *328*, 1679.

[13] In some cases, attempts to isolate the aryl hydrazine product by column chromatography resulted in trace contamination with **L12**. Aryl hydrazones are easily hydrolyzed by treatment with acid, see reference [9a].

[14] Electron-rich aryl tosylates were problematic: for example, 4-phenoxyphenyl tosylate resulted in a 21 % yield of the isolated product. Aryl triflates and mesylates were less successful substrates.

[15] For an elegant study on the role of amine binding and acidity in palladium-catalyzed C–N cross-coupling reactions, see: M. R. Biscoe, T. E. Barder, S. L. Buchwald, *Angew. Chem.* **2007**, *119*, 7370; *Angew. Chem. Int. Ed.* **2007**, *46*, 7232.

[16] For a recent review on indazole chemistry, see: A. Schmidt, A. Beutler, B. Snoydovych, *Eur. J. Org. Chem.* **2008**, 4073; for palladium-catalyzed synthesis of N-substituted indazoles, see references [9b,c] and [11a–c,g].

[17] Similar reactions with 2-chloroacetophenone or tosyl salicylaldehyde gave complex mixtures as revealed by gas chromatography (GC) under our standard conditions.