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Cobalt-Catalyzed Cross-Coupling Between In Situ Prepared Arylzinc Halides and 2-Chloropyrimidine or 2-Chloropyrazine

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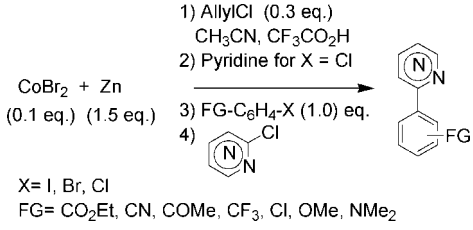
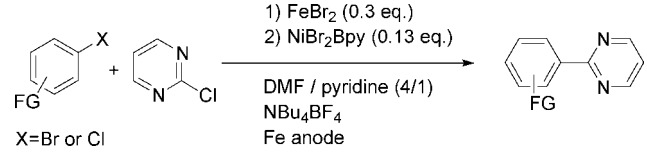


A cobalt-catalyzed cross-coupling of aryl halides with 2-chloropyrimidines or 2-chloropyrazines is reported in satisfactory to high yields. The key step of this procedure is the formation of aromatic organozinc reagents and their coupling with 2-chlorodiazines using the same cobalt halide as catalyst and Zn dust under mild reaction conditions. This new cobalt-catalyzed coupling reaction represents a practical and interesting alternative to previously known methods for the synthesis of 2-aryldiazines.

Aryldiazines, particularly those bearing functional groups, have been shown to possess interesting properties in pharmacology, agrochemical, supramolecular chemistry, and material science.[1] Then, during the last decades, some research groups have directed their work toward the development of new synthetic methodologies. Some strategies are based on the generation of the heterocyclic ring using ring closure reactions.[2] However, these methods generally require rather high reaction temperatures and suffer from a poor functional group tolerance. A few years ago, our group developed a direct nickel-catalyzed electrochemical coupling reaction between functionalized arylhalides and 2-halo-pyrimidines or -pyrazines leading to 2-arylpyrimidines and 2-arylpyrazines (Scheme 1).[3] However, electrochemical reactions are generally considered as being more difficult to handle than conventional methods and electrochemical synthesis are rarely applied by organic chemists in a larger scale. Thus, functionalized arylpyrimidines and arylpyrazines are, in practical terms, the most often obtained using palladium or nickel-catalyzed cross-coupling reactions involving stoichiometric organometallic reagents such as organomagnesium, organozinc, organoboron (organoboronic acids and organotrifluoroborates), or organostannanes compounds.[4] In these cross-coupling protocols, the major difficulty lies in the preparation of the organometallic reagent and more particularly in the case of functionalized derivatives. Although significant advances have been achieved, the development of new access to functionalized aryldiazines is still a major challenge. Very recently, the arylation of electron-deficient nitrogen heterocycles with iodoarenes promoted by potassium terbutoxide was described without the addition of any exogenous transition metal species.[5] However, poor regioselectivity has been observed with respect to the heteroarene. Recently, we have devised an expedient route to functionalized biaryl and heteroaryl-aryl compounds on the basis of cobalt catalysis associated to PPh_3 as ligand.[6] This combination generates an extremely powerful catalyst for the coupling of a large variety of aromatic reagents. However, this protocol cannot be applied to 2-chloropyrimidine and 2-chloropyrazine as coupling partners.

SCHEME 1. Direct Electrochemical Coupling Reaction



Alternatively, the use of cobalt as a highly reactive catalyst for carbon−carbon forming reaction has also been demonstrated by Cahiez,[7] Knochel,[8] Oshima,[9] Cheng,[10] and our group.[11]

In 2003, our group has described a very easy method to access to substituted organozinc reagents (Scheme 2) from corresponding aryl halides using $CoBr_2$ catalysis. Aryl bromides or iodides can be efficiently converted to the corresponding organozinc

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(1) (a) Katritsky, A. R.; Rees, C. W. *Comprehensive Heterocyclic Chemistry*; Pergamon: New York, 1984; Vol. 2. (b) Quéguiner, G.; Marsais, F.; Snieckus, V.; Epsztajn, J. *Adv. Heterocycl. Chem.* **1991**, *52*, 187–304. (c) Mongin, F.; Quéguiner, G. *Tetrahedron* **2001**, *57*, 4059–4090. (d) Turck, A.; Plé, N.; Mongin, F.; Quéguiner, G. *Tetrahedron* **2001**, *57*, 4489–4505.

(2) (a) Wang, T.; Cloudsdale, I. S. *Synth. Commun.* **1997**, *27*, 2521–2526. (b) Hill, M. D.; Movassaghi, M. *Chem.—Eur. J.* **2008**, *683*, 6–6844. (c) Bhatti, I. A.; Busby, R. E.; bin Mohamed, M.; Parrick, J.; Shaw, C. J. G. *J. Chem. Soc., Perkin Trans. 1* **1997**, *24*, 3581–3586. (d) Cesar, J. *J. Comb. Chem.* **2005**, *7*, 517–519.

(3) Gosmini, C.; Nedelec, J. Y.; Périchon, J. *Tetrahedron Lett.* **2000**, *41*, 201–203.

(4) (a) Bonnet, V.; Mongin, F.; Trécourt, F.; Quéguiner, G.; Knochel, P. *Tetrahedron* **2002**, *58*, 4429–4438. (b) Mongin, F.; Mojovic, L.; Guillamet, B.; trécourt, F.; Quéguiner, G. *J. Org. Chem.* **2002**, *67*, 8991–8994. (c) Molander, G. A.; Biolatto, B. *J. Org. Chem.* **2003**, *68*, 4302–4314. (d) Billingsley, K.; Buchwald, S. L. *J. Am. Chem. Soc.* **2007**, *129*, 3358–336. (e) Ceide, S. C.; Montalban, A. G. *Tetrahedron Lett.* **2006**, *47*, 4415–4418. (f) Dawood, K. M.; Kirschning, A. *Tetrahedron* **2005**, *61*, 12121–12130. (g) Darabantu, M.; Boully, L.; Turck, A.; Plé, N. *Tetrahedron* **2005**, *61*, 2897–2905. (h) Itami, K.; Yamazaki, D.; Yoshida, J.-I. *J. Am. Chem. Soc.* **2004**, *126*, 15396–15397. (i) Yanagisawa, S.; Ueda, K.; Taniguchi, T.; Itami, K. *Org. Lett.* **2008**, *10*, 4673–4676. (j) Seggio, A.; Jutand, A.; Priem, G.; Mongin, F. *Synlett* **2008**, *2955*, 2960. (k) Alacid, E.; Nańera, C. *Org. Lett.* **2008**, *10*, 5011–5014.

(5) Yanagisawa, S.; Ueda, K.; Taniguchi, T.; Itami, K. *Org. Lett.* **2008**, *10*, 4673–4676.

(6) Amatore, M.; Gosmini, C. *Angew. Chem., Int. Ed* **2008**, *47*, 2089–2092.

(7) Cahiez, G.; Chaboche, C.; Duplais, C.; Giulliani, A.; Moyeux, A. *Adv. Synth. Catal.* **2008**, *350*, 1484–1488. (b) Cahiez, G.; Avedissian, H. *Tetrahedron Lett.* **1998**, *39*, 6159–6162.

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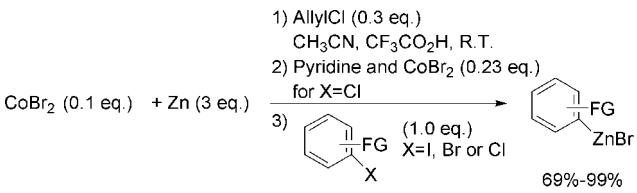
SCHEME 2. $CoBr_2$-Catalyzed Synthesis of Organozinc Reagents from Corresponding Arylhalides

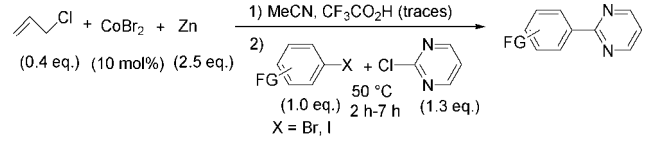


reagents in a single step.[12] The reaction requires commercially available zinc dust which is common activated by traces of acid in the presence of cobalt bromide in acetonitrile at room temperature. However, this process fails to activate less reactive compounds such as aromatic chlorides. To circumvent the low reactivity of aryl chlorides, a new procedure involving a cobalt catalysis in a mixture of acetonitrile and pyridine was set up to successfully prepare aryl zinc chlorides.[13]

Our previous results concerning the interesting reactivity of aryl zinc species obtained under cobalt catalysis[14] led us to surmise that 2-aryldiazines could be obtained via the cobalt-catalyzed cross-coupling of arylzinc derivatives and 2-chloropyrimides and 2-chloropyrazines under suitable conditions. The mild reaction conditions, high chemoselectivity, and low cost of cobalt-catalyzed cross-coupling reactions would make very attractive this new heterocyclic reaction. Furthermore, these reactions often require simple ligands rather than more customized, which are often used with palladium-based systems. Herein, we wish to report a very efficient Co(II)-mediated cross-coupling reaction devoted to the direct synthesis of 2-arylpyrimidines and 2-arylpyridazines using various functionalized aromatic halides. The results of our investigations are reported in this paper.

For initial studies, we first involved a two-step coupling reaction between an aryl zinc bromide ($EtOCOC_6H_4ZnBr$) and 2-chloropyrimidine without further addition of cobalt catalyst. In these conditions, the corresponding 2-arylpyrimidine was obtained in good yield (80% GC yield). Then, as previously reported in the case of the synthesis of functionalized diarylmethanes, we worked out an operationally simplified Barbier-type procedure for the synthesis of 2-arylpyrimidines due to the lower reactivity of 2-chloropyrimidine. As previously reported,[12b] the presence of allylchloride in the medium decreases the formation of the reduction byproduct ArH in the beginning of the reaction. The role played by this additive has not been clarified so far. An inert atmosphere is not required in this process as long as ArZnX is consecutively engaged in a coupling reaction. The temperature influences the reaction rate but not the yield. When the reaction was carried out at room temperature for 8 h, the 2-arylpyrimidine was obtained in 70% GC yield. The reaction rate was improved (5 h) by increasing the reaction temperature to 50 °C.

TABLE 1. Cross-Coupling Reaction between 2-Chloropyrimidine and Aryl Bromides or Aryl Iodides



entry	ArX	reaction time (h)	product No.	yields vs ArX (GC) %
1	C_6H_5Br	4	**1**	80 (85)
2	*p*-$EtO_2CC_6H_4Br$	5	**2**	60 (70)
3	*m*-$EtO_2CC_6H_4Br$	6	**3**	65 (70)
4	*o*-$EtO_2CC_6H_4Br$	6	**4**	(5)
5	*p*-$MeO_2CC_6H_4Br$	6	**5**	70 (80)
6	*p*-NCC_6H_4Br	6	**6**	57 (68)
7	*o*-NCC_6H_4Br	6	**7**	(5)
8	*m*-NCC_6H_4Br	6	**8**	74 (80)
9	*p*-$F_3CC_6H_4Br$	6	**9**	60 (70)
10	*m*-$F_3CC_6H_4Br$	6	**10**	70 (80)
11	*p*-$MeCOC_6H_4Br$	2	**11**	41 (52)
12	*p*-$MeOC_6H_4Br$	6	**12**	70 (85)
13	*m*-$MeOC_6H_4Br$	7	**13**	71 (80)
14	*o*-$MeOC_6H_4Br$	5	**14**	51 (71)
15	*p*-ClC_6H_4Br	6	**15**	63 (64)
16	*m*-ClC_6H_4Br	6	**16**	50 (52)
17	*p*-FC_6H_4Br	4	**17**	90 (91)
18	*m*-FC_6H_4Br	4	**18**	55 (60)
19	*p*-$MeOC_6H_4I$	4	**12**	32 (40)
20	*p*-$EtO_2CC_6H_4I$	5	**2**	52 (60)

Various 2-arylpyrimidines have been obtained using a one- or two-step procedure, depending on the nature of the arylhalide. With arylbromides or aryliodides, the reaction had been carried out in the presence of the 2-chloropyrimidine at 50 °C. In these conditions, despite the presence of the 2-chloropyrimidine, the oxidative addition of Co(I), obtained by Co(II) reduction, proceeds first into the C−X bond of the arylhalide, allowing the formation of the arylzinc compound and then into the C−Cl bond of the 2-chloropyrimidine to achieve the cross-coupling reaction with the arylzinc halide. As the 2-chloropyrimidine is present in the medium from the beginning of the reaction, the arylzinc derivative is involved in the cross-coupling reaction as soon as formed; thereby, the formation of byproduct resulting from the reduction or the homocoupling reactions of the arylzinc reagents is limited.

The results obtained in acetonitrile from aryl bromides or iodides bearing various substituents are reported in Table 1.

These results show that the expected 2-arylpyrimidines were obtained in good yields when *para*- or *meta*-substituted aryl bromides were used. No noticeable influence of the substituent electronic effect was observed on the reaction parameters. To our disappointment, except in the case of an *ortho* director group

(8) (a) Dunet, G.; Knochel, P. *Synlett* **2007**, *1383*, 1386. (b) Korn, T. J.; Schade, M. A.; Wirth, S.; Knochel, P. *Org. Lett.* **2006**, *8*, 725–728. (c) Korn, T. J.; Knochel, P. *Angew. Chem., Int. Ed.* **2005**, *44*, 2947–2951. (d) Reddy, C. K.; Knochel, P. *Angew. Chem., Int. Ed.* **1996**, *35*, 1700–1701. (e) Avedissian, H.; Berillon, L.; Cahiez, G.; Knochel, P. *Tetrahedron Lett.* **1998**, *39*, 6163–6166.

(9) (a) Kobayashi, T.; Ohmiya, H.; Yorimitsu, H.; Oshima, K. *J. Am. Chem. Soc.* **2008**, *130*, 11276–11277. (b) Affo, W.; Ohmiya, H.; Takuma, F.; Ikeda, Y.; Nakamura, T.; Yorimitsu, H.; Oshima, K.; Imamura, Y.; Mizuta, T.; Miyoshi, K. *J. Am. Chem. Soc.* **2006**, *128*, 8068–8077. (c) Ohmiya, H.; Yorimitsu, H.; Oshima, K. *Chem. Lett.* **2004**, *33*, 1240–1241. (d) Tsuji, T.; Yorimitsu, H.; Oshima, K. *Angew. Chem., Int. Ed.* **2002**, *41*, 4137–4139.

(10) (a) Chang, H. T.; Jeganmohan, M.; Cheng, C. H. *Chem.—Eur. J.* **2007**, *13*, 4356–4363. (b) Chang, H. T.; Jayanth, T. T.; Wang, C. C.; Cheng, C. H. *J. Am. Chem. Soc.* **2007**, *129*, 12032–12041. (c) Shukla, P.; Hsu, Y. C.; Cheng, C. H. *J. Org. Chem.* **2006**, *71*, 655–658. (d) Wong, Y.-C.; Jayanth, T. T.; Cheng, C.-H. *Org. Lett.* **2006**, *8*, 5613–5616. (e) Chang, K.-J.; Rayabarapu, D. K.; Cheng, C.-H. *J. Org. Chem.* **2004**, *69*, 4781–4787. (f) Chang, K.-J.; Rayabarapu, D. K.; Cheng, C.-H. *Org. Lett.* **2003**, *5*, 3963–3966. (g) Liu, C.-C.; Korivi, R. P.; Cheng, C.-H. *Chem.—Eur. J.* **2008**, *14*, 9503–9506. (h) Jeganmohan, M.; Cheng, C.-H. *Chem.—Eur. J.* **2008**, *14*, 10876–10886.

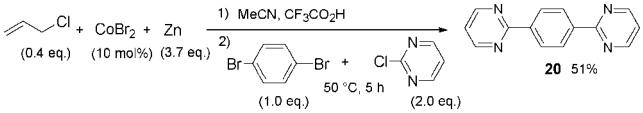
(11) Gosmini, C.; Bégouin, J. M.; Moncomble, A. *Chem. Commun.* **2008**, *3221*, 3233.

(12) (a) Fillon, H.; Gosmini, C.; Périchon, J. *J. Am. Chem. Soc.* **2003**, *125*, 3867–3870. (b) Kazmierski, I.; Gosmini, C.; Paris, J. M.; Périchon, J. *Tetrahedron Lett.* **2003**, *44*, 6417–6420.

(13) (a) Gosmini, C.; Amatore, M.; Claudel, S.; Périchon, J. *Synlett* **2005**, *2171*, 2174. (b) Kazmierski, I.; Gosmini, C.; Paris, J. M.; Périchon, J. *Synlett* **2006**, *881*, 884.

(14) (a) Amatore, M.; Gosmini, C. *Chem. Commun.* **2008**, *5019*, 5021. (b) Kazmierski, I.; Bastienne, M.; Gosmini, C.; Paris, J. M.; Périchon, J. *J. Org. Chem.* **2004**, *69*, 936–942. (c) Fillon, H.; Gosmini, C.; Périchon, J. *Tetrahedron* **2003**, *59*, 8199–8202.

SCHEME 3. Cross-Coupling Reaction between 2-Chloropyrimidine and 1,4-Dibromobenzene



such as a methoxy (Table 1, entry 14), cross-coupling of aryl halides bearing an *ortho* substituent resulted in poor yields of desired product (Table 1, entries 4 and 7). However, the formation of the arylzinc reagent took place, but no cross-coupling reaction occurred with the 2-chloropyrimidine. Lower yields were obtained from aryl iodides (Table 1, entries 19 and 20), probably owing to the higher reactivity of the resulting arylzinc iodides, which favored the formation of reduction or dimerization byproduct.

Furthermore, we noticed that, at the time of the arylzinc formation, 4-bromoacetophenone reacted faster and gave rise to more dimeric products that account for the shorter reaction times (Table 1, entry 11).

The cross-coupling between ethyl *para*-bromobenzoate and a functionalized chloropyrimidine such as the 4-chloro-2-methylthiopyrimidine gave the ethyl 4-[2-(methylthio) pyrimidin-4-yl]benzoate (**19**) in 75% yield.

The cross-coupling reaction with the 1,4-dibromobenzene was achieved with a slight modification of the reaction conditions (Scheme 3); increasing the amount of zinc allowed the formation of a dizinc compound that reacted with 2 equiv of 2-chloropyrimidine, leading to the expected disubstituted product with a 51% yield.

Modifications of the coupling reaction conditions were required to allow the use of less reactive compounds such as aryl chlorides. Moreover, 2-chloropyrimidine being more reactive than aryl chlorides, the cross-coupling cannot occur under a Barbier-type procedure. Alternatively, the cross-coupling was achieved in a two-step procedure in a mixture of acetonitrile-pyridine at 50 °C. Actually, the formation of arylzinc compounds from aryl chlorides was only successful in this mixture as previously described.[13a] The addition of pyridine allows the stabilization of Co(I) and, thus, the activation of poorly reactive aromatic halides. Therefore, it was necessary to form the arylzinc reagent in a first step before adding the 2-chloropyrimidine in the reaction medium to achieve the cross-coupling reaction.

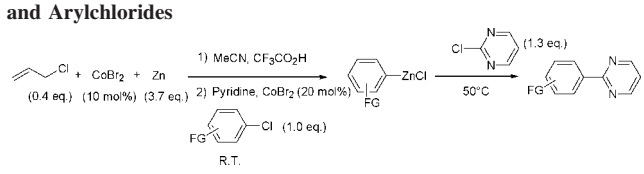
On the basis of these observations, the process was finally extended to aryl chlorides. The cross-coupling reaction was efficient, with aryl chlorides bearing an electron-withdrawing group (Table 2).

Satisfactory yields were observed from arylchlorides substituted by various functional groups in *meta*- and *para*-positions. Because of the lower reactivity of arylzinc chlorides, lower yields were observed compared to the corresponding arylbromides. In addition, increased Co(I) stabilization by pyridine contributes to its decreased reactivity.

The process was finally extended to 2-chloropyrazine. Because this compound is more reactive than 2-chloropyrimidine regarding the oxidative addition of Co(I) into the C−Cl bond, the reaction could be carried out in a Barbier-type procedure only with electron-rich aryliodides. In this manner, *p*-iodoanisole could be 69% coupled (Scheme 4).

In the case of arylbromides and arylchlorides, the cross-coupling could be conducted in a two-step procedure. As highlighted in Table 3, the corresponding 2-arylpyrazines were obtained in satisfactory yields, which do not seem to greatly depend on the nature of the halogen. However, we noticed that the use of an excess of arylhalide (1.3 equiv) versus the 2-chloropyrazine was necessary contrary to the 2-chloropyrimidine.

TABLE 2. Cross-Coupling Reaction between 2-Chloropyrimidine and Arylchlorides



entry	ArCl	reaction time (h)	product No.	yields vs ArX (GC) %
1	C_6H_5Cl	5	**1**	53 (68)
2	*p*-$MeO_2CC_6H_4Cl$	5	**5**	61 (70)
3	*m*-$MeO_2CC_6H_4Cl$	6	**21**	55 (58)
4	*p*-NCC_6H_4Cl	5	**6**	55 (61)
5	*m*-NCC_6H_4Cl	5	**8**	50 (57)
6	*m*-$F_3CC_6H_4Cl$	6	**10**	55 (60)
7	*p*-$MeCOC_6H_4Cl$	3	**11**	60 (81)

SCHEME 4. Cross-Coupling Reaction between *p*-Iodoanisole and 2-Chloropyrazine

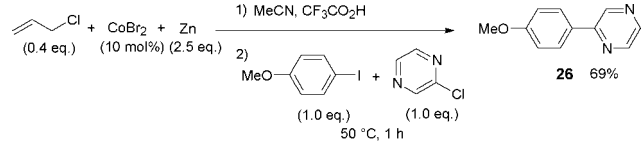
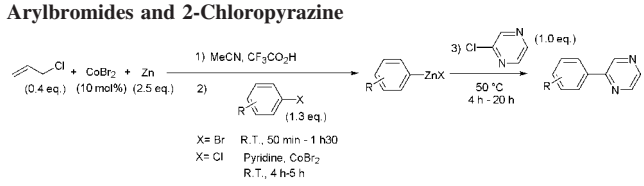


TABLE 3. Cross-Coupling Reaction between Arylchlorides or Arylbromides and 2-Chloropyrazine



entry	ArX	reaction time of coupling (h)	product No.	yields vs ArX (GC) %
1	*p*-$EtO_2CC_6H_4Br$	3	**22**	55 (63)
2	*p*-$MeO_2CC_6H_4Br$	6	**23**	59 (62)
3	*p*-NCC_6H_4Br	5	**24**	58 (67)
4	*p*-$F_3CC_6H_4Br$	5	**25**	58 (66)
5	*p*-$MeOC_6H_4Br$	1	**26**	80 (86)
6	*m*-$MeOC_6H_4Br$	7	**27**	57 (64)
7	*p*-MeC_6H_4Br	2	**28**	60 (78)
8	*p*-ClC_6H_4Br	5	**29**	50 (55)
9	*p*-$F_3CC_6H_4Cl$	5	**25**	60 (65)
10	*p*-NCC_6H_4Cl	4	**24**	90 (95)
11′	*p*-$MeO_2CC_6H_4Cl$	12	**23**	60 (88)

In conclusion, we reported in this paper an efficient cross-coupling of functionalized aryl halides and 2-chlorodiazines such as 2-chloropyrimidine and 2-chloropyrazine via an intermediate aryl zinc species using an eco-friendly and inexpensive cobalt catalyst without ligand. Depending on the nature of the substrate involved, this process even allows the synthesis of a wide variety of 2-aryldiazines in a Barbier fashion for more convenience. The tolerance of our protocol toward a wide variety of functional groups enables the synthesis of a broad spectrum of valuable compounds. This versatile process compares favorably with other procedures that use palladium or nickel catalysis. Further studies are in progress to extend this process to other azines and heterocycles.

Experimental Section

General Procedure for the Synthesis of 2-Arylpyrimidines or 2-Arylpyrazines in a Barbier Procedure. To a solution of $CoBr_2$ (10 mol %, 0.75 mmol, 165 mg) and zinc powder (20 mmol, 1.3 g) in acetonitrile (6 mL) were successively added at room temperature allylchloride (3 mmol, 250 μL) and trifluoroacetic acid (100 μL), causing an immediate rise in temperature and color change to dark gray. After stirring the resulting mixture for 3 min, aryl bromide or iodide (7.5 mmol) and 2-chloropyrimidine (10 mmol, 1.15 g) or 2-chloropyrazine (7.5 mmol, 0.66 mL) were added. The medium was then stirred at 50 °C until aryl halide was consumed.

General Procedure for Synthesis of 2-Arylpyrimidines or 2-Arylpyrazines in a Two-Step Procedure. (a). Synthesis of ArZnX. To a solution of $CoBr_2$ (10 mol %, 0.75 mmol, 165 mg) and zinc powder (20 mmol, 1.3 g) in acetonitrile (6 mL) were successively added at room temperature allylchloride (3 mmol, 250 μL) and trifluoroacetic acid (100 μL), causing an immediate rise in temperature and color change to dark gray. After stirring the resulting mixture for 3 min, aryl halide (7.5 mmol) was added (in the case of aryl chloride, supplementary $CoBr_2$ (23 mol %, 1.7 mmol, 372 mg) and pyridine (4 mL) were added). The medium was then stirred at room temperature until complete conversion of aryl halide.

(b). Cross-Coupling Reaction. 2-Chloropyrimidine (10 mmol, 1.15 g) or 2-chloropyrazine (5 mmol, 0.45 mL) was added and the medium was stirred at 50 °C until ArZnCl or ArZnBr was consumed. In all cases, the amounts of the corresponding ArZnX and coupling product were measured by GC (addition of iodine) using an internal reference (dodecane, 200 μL). The reaction mixture was poured into a saturated aqueous solution of NH_4Cl and extracted with dichloromethane. The organic layer was washed with a saturated aqueous solution of NaCl and dried over $MgSO_4$. Evaporation of solvent and purification by column chromatography on silica gel (pentane/diethyl ether or pentane/dichloromethane) afforded the coupling product. Representative experimental data from the synthesis of 4-pyrimidin-2-ylbenzoic acid ethyl ester (**2**): ^{1}H NMR (300 MHz, $CDCl_3$) δ/ppm 1.43 (t, J = 7.1 Hz, 3H), 4.42 (q, J = 7.1 Hz, 2H), 7.25 (t, J = 4.8 Hz, 1H), 8.17 (d, J = 8.6 Hz, 2H), 8.53 (d, J = 8.6 Hz, 2H), 8.85 (d, J = 4.8 Hz, 2H). ^{13}C NMR (75 MHz, $CDCl_3$) δ/ppm 14.4 (CH_3), 61.2 (CH_2), 119.7 (CH), 128.1 (2CH), 129.8 (2CH), 132.3 (C), 141.4 (C), 157.4 (2CH), 163.8 (C), 166.4 (C). HRMS Calcd for $C_{13}H_{12}N_2O_2$, 228.0899; found, 228.0899.

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Supporting Information Available: Characterization data (IR, ^{1}H and ^{13}C NMR, spectroscopic data, and HMRS) of the products: **2**, **3**, **6**, **8**, **9**, **10**, **11**, **13**, **14**, **16**, **17**, **18**, **19**, **20**, **21**, **22**, **24**, **25**, **27**. Copies of ^{1}H and ^{13}C NMR spectra of all products listed in Tables 13. This material is available free of charge via the Internet at http://pubs.acs.org.

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