CHEMISTRY
AN ASIAN JOURNAL
ACES
FULL PAPER

DOI: 10.1002/asia.201300913

Microwave-Accelerated Pd-Catalyzed Desulfitative Direct C2-Arylation of Free (NH)-Indoles with Arylsulfinic Acids

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Abstract: The rapid and efficient direct C2-arylation of free (NH)-indoles with arylsulfinic acids proceeded through a microwave-accelerated palladium-catalyzed desulfitation reaction. By using $PdCl_2$ as a catalyst, silver acetate as an oxidant, and H_2SO_4 as an additive, arylsulfinic acids with both electron-donating and electron-withdrawing groups underwent desulfitative coupling with an array of free (NH)-indoles, thereby selectively providing C2-arylindoles in good yields.

Keywords: arylation · desulfitation · indoles · microwave chemistry · palladium

Introduction

The indole skeleton is frequently found in bioactive synthetic and natural products and is a privileged structure in many pharmaceuticals.[1] Thus, great efforts have been devoted to the transition-metal-catalyzed chemical modification of indole derivatives, in particular through direct C2-H or C3-H arylation reactions. The direct arylation of indole derivatives is an attractive alternative to conventional cross-coupling methods, which require the prefunctionalization of indoles (i.e., halogenation or stoichiometric metalation reactions) prior to the C–C coupling step.[2] Over the past few decades, regioselective direct C-arylation reactions at either the C2 or C3 positions of indole have been successfully achieved by using palladium, rhodium, and copper catalysis with a variety of coupling species.[3] However, the C-arylation of free (NH)-indole derivatives is particularly challenging, because it eliminates the need for protecting groups and reactive functionalities and requires the selective targeting of C–H bonds in the presence of a reactive N–H functionality. In some cases, free (NH)-indoles have been reported to be less reactive than their N-substituted analogues.[3a,q,8,11d] To date, only a few procedures have been used to synthesize arylindoles through the direct C2-H or C3-H functionalization of free (NH)-indole derivatives.[4–8] Among these methods, Sames and co-workers made a significant contribution with the direct C2-arylation of free (NH)-indole with aryl halides, catalyzed by $[\{Rh(coe)_2Cl_2\}_2]$ (coe = cyclooctene) or $[Pd(PPh_3)]$.[5] Sanford's group also developed a new procedure for the synthesis of 2-arylindoles, based on the Pd-catalyzed arylation of free (NH)-indoles with diaryliodonium tetrafluoroborates.[6] Subsequently, Shi and co-workers reported that aryl boronic acids were good coupling partners for the direct C-arylation of free (NH)-indoles in the presence of a palladium catalyst under an oxygen atmosphere.[7] Zhang and co-workers reported the $Pd(OAc)_2$-catalyzed selective C2-arylation of free (NH)-indoles with potassium aryltrifluoroarylborates under mild conditions.[8] Although these reactions are often synthetically useful, they suffer from several notable disadvantages, including moderate scope and functional-group tolerance and the requirement of long reaction times.

Arylsulfinic acids (or salts) are relatively stable and easy to handle and, hence, offer great potential as aryl sources for C–C bond-forming reactions through the release of SO_2, although they are generally used as sulfonylating reagents. These desulfitative C–C bond-formation reactions include Heck-type reactions,[9] the synthesis of aryl ketones,[10] the direct C–H arylation of heteroaromatic compounds,[11] and cross-coupling with aryl triflates and halides.[12] Notably, Deng and co-workers recently reported a method for the synthesis of 2-arylindoles by using sodium sulfinates with N-substituted indoles in the presence of palladium; however, no desired product was observed when free (NH)-indole was used as a substrate.[11d] Herein, we report the microwave-accelerated highly efficient palladium-catalyzed desulfitative C2-arylation of a wide range of free (NH)-indoles with arylsulfinic acids to enrich these synthetic methods (Scheme 1).

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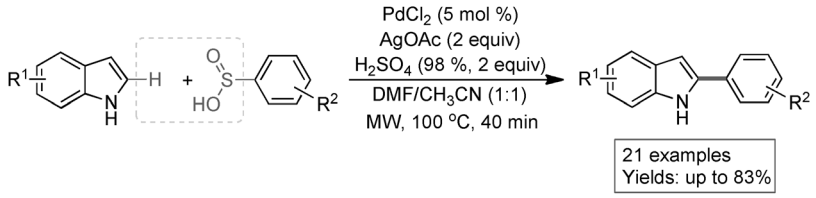
Supporting information for this article is available on the WWW under http://dx.doi.org/10.1002/asia.201300913.

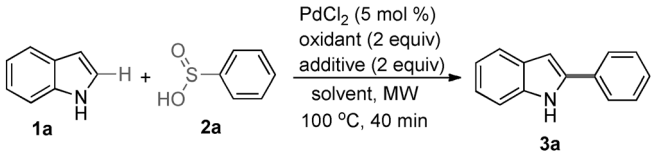


Scheme 1. C2-arylation of free (NH)-indoles with arylsulfinic acids.

Results and Discussion

In our initial study, we investigated the direct C2-arylation of indole (**1a**) with benzenesulfinic acid (**2a**) in the presence of a palladium catalyst (5.0 mol%) under microwave (MW) irradiation at 100°C; a maximum power of 100 W was employed to optimize the reaction conditions with different solvents, additives, and oxidants. Promisingly, when DMF was used as the solvent with AgOAc as the oxidant and H_2SO_4 as an additive, the reaction of compound **1a** with compound **2a** gave 2-arylindole **3a** in 51% yield (Table 1, entry 1). However, other solvents, including EtOH, DCE, and toluene, prohibited the reaction (Table 1, entries 2–4). MeCN and 1,4-dioxane were also ineffective and only gave the desired product in 22% and 10% yield, respectively (Table 1, entries 5 and 6). Much to our pleasure, 82% yield was achieved when a mixture of DMF and MeCN (1:1 v/v) was used as the solvent (Table 1, entry 7). Various acids were chosen to examine the effect of the additive on the product yield. Whereas HNO_3 and TFA were not beneficial for the catalytic reaction (Table 1, entries 9 and 13), H_3PO_4, HCl, and AcOH showed very poor performance (Table 1, entries 10–12). Further screening of oxidants revealed that AgOAc was the optimal oxidant. Other inorganic oxidants Ag_2CO_3, Ag_2O, and $Cu(OAc)_2$ gave inferior results and generated compound **3a** in 25–64% yields (Table 1, entries 14–16). $K_2S_2O_8$ did not afford any product in the model reaction (Table 1, entry 17). Under these reaction conditions, organic oxidants BQ and TBHP were also found to be harmful to this transformation (Table 1, entries 18 and 19). Moreover, conventional heating at 100°C produced 2-arylindole **3a** in 61% yield, but a longer reaction time (24 h) was required compared to that with MW irradiation (40 min) under the same reaction conditions (Table 1, entry 8 versus entry 7).

Table 1. Palladium-catalyzed desulfitative direct C2-arylation of free (NH)-indole with benzenesulfinic acid under various conditions.[a]



Entry	Oxidant	Additive	Solvent	Yield [%][b]
1	AgOAc	H_2SO_4	DMF	51[c]
2	AgOAc	H_2SO_4	EtOH	trace[d]
3	AgOAc	H_2SO_4	DCE	0[d]
4	AgOAc	H_2SO_4	toluene	0
5	AgOAc	H_2SO_4	MeCN	22[d]
6	AgOAc	H_2SO_4	1,4-dioxane	10
7	AgOAc	H_2SO_4	DMF/MeCN (1:1)	82
8	AgOAc	H_2SO_4	DMF/MeCN (1:1)	61[e]
9	AgOAc	HNO_3	DMF/MeCN (1:1)	40[f]
10	AgOAc	H_3PO_4	DMF/MeCN (1:1)	15[g]
11	AgOAc	HCl	DMF/MeCN (1:1)	13[h]
12	AgOAc	AcOH	DMF/MeCN (1:1)	11
13	AgOAc	TFA	DMF/MeCN (1:1)	35
14	Ag_2CO_3	H_2SO_4	DMF/MeCN (1:1)	38
15	Ag_2O	H_2SO_4	DMF/MeCN (1:1)	64
16	$Cu(OAc)_2$	H_2SO_4	DMF/MeCN (1:1)	25
17	$K_2S_2O_8$	H_2SO_4	DMF/MeCN (1:1)	0
18	BQ	H_2SO_4	DMF/MeCN (1:1)	trace
19	TBHP	H_2SO_4	DMF/MeCN (1:1)	0

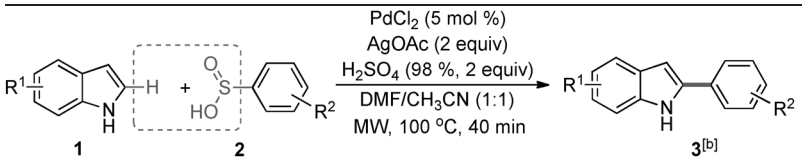
[a] Reaction conditions: Compound **1a** (0.35 mmol), compound **2a** (0.25 mmol), $PdCl_2$ (5 mol%), solvent (2.0 mL), MW irradiation, 40 min. [b] Yield of isolated product. [c] 98% H_2SO_4 was used. [d] Heated at reflux. [e] Heated at 100°C for 24 h. [f] 65% HNO_3 was used. [g] 85% H_3PO_4 was used. [h] 37% HCl was used. DCE = 1,2-dichoroethane, TFA = trifluoroacetic acid, BQ = *p*-benzoquinone, TBHP = *tert*-butyl hydroperoxide.

With the optimized reaction conditions in hand ($PdCl_2$ (5.0 mol%), AgOAc (2 equiv), concentrated H_2SO_4 (2 equiv), DMF/MeCN (2.0 mL, 1:1 v/v), MW irradiation at 100°C, 40 min), this Pd-catalyzed desulfitative direct C2-arylation reaction of indoles was extended to various free (NH)-indoles and a wide range of arylsulfinic acids to explore the scope and limitations of this reaction (Table 2). Electron-rich indoles showed higher reactivity and products **3b**, **3c**, and **3d** were furnished in 70%, 80% and 75% yield, respectively. Moreover, this reaction was also tolerant of fluoro, chloro, and bromo substituents on the aromatic ring of the (NH)-indole: 6-Fluoro-, 5-chloro-, and 5-bromoindoles reacted with benzenesulfinic acid to generate arylated indoles **3e**, **3f**, and **3g**, respectively, in 66–83% yield. Electron-deficient indoles participated in the reaction to give products **3h** and **3i**, but they were less active and the products were only formed in moderate yields.

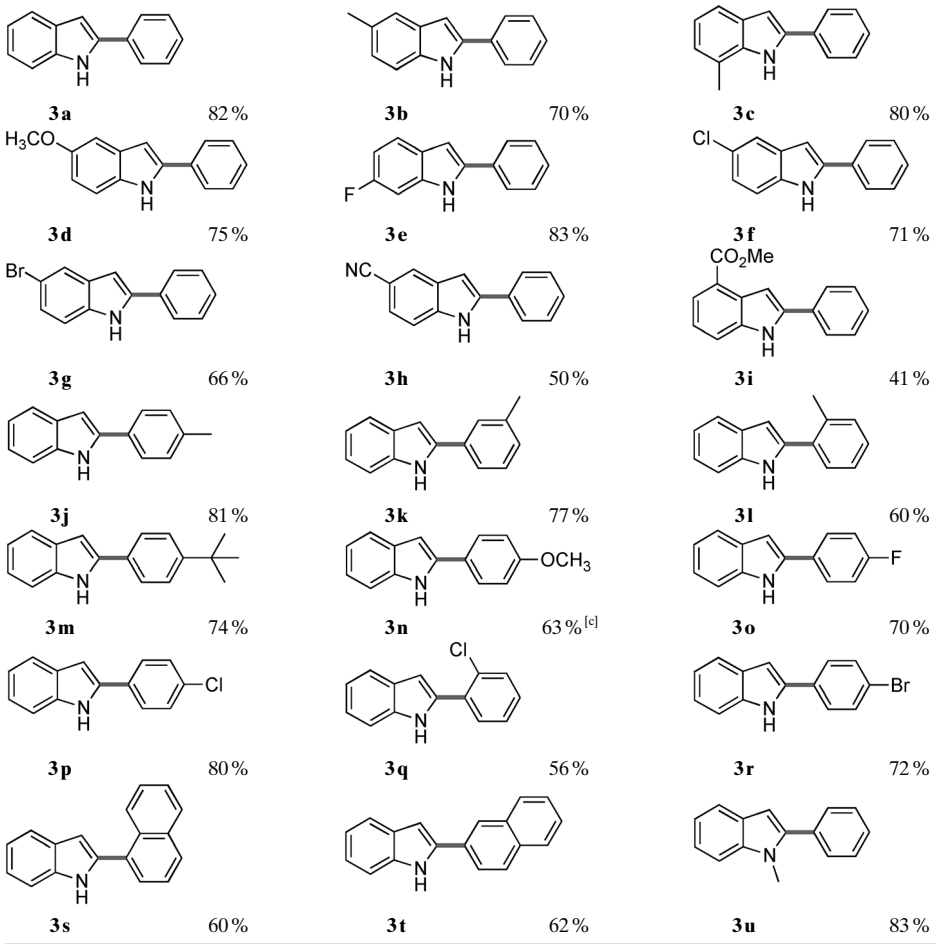
To further expand the scope of this reaction, we examined the reactions of several other arylsulfinic acids. A series of functional groups, including methyl, *tert*-butyl, methoxy, fluoro, chloro, and bromo groups, were tolerated under the optimal reaction conditions and the desired products (**3i**–**3q**) were obtained in moderate-to-good yields. However, arylsulfinic acids with an *ortho*-substituent delivered their corresponding arylated indoles (**3l** and **3q**) in lower yields, thus illustrating that steric hindrance played a role in the reaction. 1- and 2-Naphthylsulfinic acids also efficiently reacted with indole and the products (**3s** and **3t**) were formed in 60% and 62% yield. Furthermore, 1-methylindole was a good substrate for this arylation reaction, as shown in the synthesis of compound **3u** under these reaction conditions.

Although the mechanism of this reaction is not clear at present, on the basis of our data and previous reports,[9a,10a–

Table 2. Palladium-catalyzed direct desulfitative C2-arylation of free (NH)-indoles with arylsulfinic acids.[a]



1 2 3[b]



[a] Reaction conditions: Compound **1** (0.35 mmol), compound **2** (0.25 mmol), $PdCl_2$ (5 mol %), AgOAc (0.50 mmol), H_2SO_4 (0.50 mmol), DMF/MeCN (2.0 mL, 1:1 v/v), MW irradiation, 100 °C, 40 min. [b] Yield of isolated product. [c] 10 mol % $PdCl_2$ was used.

tive functionalization of the indole at the C2 position under acidic conditions.

Conclusions

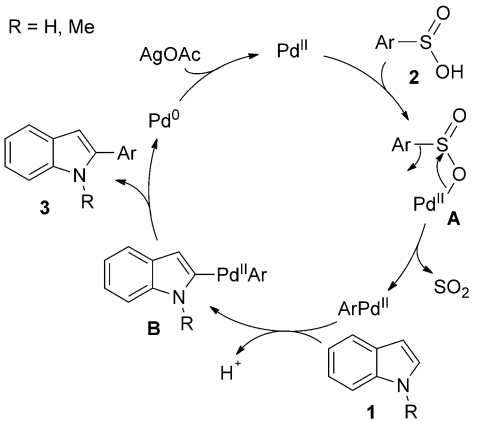
In summary, we have developed a microwave-accelerated palladium-catalyzed desulfitative system for the direct C2-arylation of free (NH)-indoles with arylsulfinic acids, with silver acetate as an oxidant and H_2SO_4 as an additive. This simple catalytic system will enable rapid and effective access to a variety of 2-arylated (NH)-indole products, thereby broadening the scope of Pd-catalyzed desulfitative coupling reactions. The investigation of arylsulfinic acids as the aryl source in other coupling reactions is underway.

Experimental Section

General

^1H and ^{13}C NMR spectra were recorded on a 400 MHz Bruker FT-NMR spectrometer (400 and 100 MHz, respectively). Chemical shifts (δ) are given in ppm and are referenced to tetramethylsilane (TMS) as an internal standard. Peak multiplicities are indicated as follows: s singlet, d doublet, t triplet, m multiplet, q quartet. Coupling constants (J) are reported in Hertz (Hz). Chemicals and solvents were purchased from commercial sup-

[c,11a,13] which provided strong evidence for the C2 and C3 selectivity of indole with Pd,[13] we propose a possible pathway as shown in Scheme 2. The first step is the reaction of Pd^{II} with arylsulfinic acid to provide palladium salt **A**. Elimination of SO_2 from complex **A** generates an $ArPd^{II}$ species, which reacts with indole **1** at the C2-position to give intermediate **B**. Reductive elimination from intermediate **B** furnishes the final coupling product (**3**) and a Pd^0 species. Oxidation of Pd^0 by AgOAc regenerates the Pd^{II} catalyst. However, we cannot rule out another pathway, which involves initial palladation on the indole, followed by reaction with arylsulfinic acid to form intermediate **B** through the release of SO_2 and reductive elimination. Moreover, although the role of H_2SO_4 is not clear at this stage, on the basis of previous reports,[3b,d,r,6–8,14] we reasoned that H_2SO_4 may minimize the decomposition of indole and facilitate the highly regioselec-



Scheme 2. Proposed reaction mechanism.

pliers (Aldrich, USA, or Shanghai Chemical Company, China). The solvents were dried and freshly distilled prior to use. The products were purified by flash chromatography on silica gel (100–200 mesh). All MW reactions were carried out in a Discover SP (CEM) microwave reactor.

Typical Procedure for the Synthesis Arylsulfinic Acids[15]

Benzenesulfinic acid and *p*-methyl benzenesulfinic acid were obtained by the acidification of commercially available sodium benzenesulfinate and *p*-methyl benzenesulfinate, respectively, followed by recrystallization from water. Other arylsulfinic acids were prepared according to the following procedure: Arylsulfonyl chloride (2.0 mmol) and anhydrous sodium sulfite (6.0 mmol) were dissolved in water (8.0 mL) and the reaction mixture was heated at 70–80 °C for 5 h. After the reaction was complete, the aqueous solution was washed with $CHCl_3$, acidified with a concentrated aqueous solution of HCl, cooled to RT, and filtered. The as-formed white precipitate was recrystallized from water, thus yielding the corresponding arylsulfinic acid.

Typical Procedure for the Direct C2-Arylation of Free (NH)-Indoles with Arylsulfinic Acids

In a 10 mL sealable reaction tube that with fitted a Teflon-coated cap and equipped with a magnetic stirrer bar was added an indole (**1**, 0.35 mmol), an arylsulfinic acid (**2**, 0.25 mmol), $PdCl_2$ (0.0125 mmol), AgOAc (0.50 mmol), and DMF/MeCN (2.0 mL, 1:1 v/v) and the desired amount of 98% H_2SO_4 (0.50 mmol) was added by syringe. The reaction vessel was placed in a Discover SP (CEM) microwave reactor and the reaction mixture was irradiated at 100 W and 100 °C for 40 min. Then, the mixture was cooled to RT and extracted twice with EtOAc. The organic layers were combined, dried over $MgSO_4$, and concentrated under reduced pressure to yield the crude product, which was further purified by flash chromatography on silica gel (*n*-hexane/EtOAc) to give the desired 2-arylindole (**3**).

*2-Phenyl-1H-indole (**3a**)*[7]

White solid (39.6 mg, 82% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.29 (br s, 1H), 7.65–7.62 (m, 3H), 7.43 (t, J = 7.5 Hz, 2H), 7.38 (d, J = 7.5 Hz, 1H), 7.31 (t, J = 7.5 Hz, 1H), 7.19 (t, J = 7.5 Hz, 1H), 7.12 (t, J = 7.5 Hz, 1H), 6.82 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.9, 136.8, 132.4, 129.3, 129.0, 127.7, 125.1, 122.3, 120.7, 120.3, 110.9, 100.0 ppm.

*5-Methyl-2-phenyl-1H-indole (**3b**)*[8]

White solid (36.3 mg, 70% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.25 (br s, 1H), 7.67 (d, J = 7.4 Hz, 2H), 7.48–7.44 (m, 2H), 7.36–7.30 (m, 2H), 7.05 (d, J = 8.0 Hz, 1H), 6.78 (d, J = 1.3 Hz, 1H), 2.49 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.9, 135.2, 132.5, 129.5, 129.4, 128.9, 127.5, 125.0, 124.0, 120.3, 110.5, 99.5, 21.4 ppm.

*7-Methyl-2-phenyl-1H-indole (**3c**)*[8]

White solid (41.4 mg, 80% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.16 (br s, 1H), 7.67 (d, J = 7.4 Hz, 2H), 7.47 (d, J = 7.1 Hz, 1H), 7.43 (t, J = 7.4 Hz, 2H), 7.31 (t, J = 7.4 Hz, 1H), 7.04–6.98 (m, 2H), 6.82 (s, 1H), 2.52 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.6, 136.4, 132.6, 129.0, 128.8, 127.6, 125.2, 122.9, 120.5, 120.0, 118.4, 110.6, 16.7 ppm.

*5-Methoxy-2-phenyl-1H-indole (**3d**)*[7]

White solid (41.8 mg, 75% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.22 (br s, 1H), 7.63 (d, J = 7.6 Hz, 2H), 7.42 (t, J = 7.6 Hz, 2H), 7.32–7.25 (m, 2H), 7.08 (d, J = 1.9 Hz, 1H), 6.85 (dd, J = 8.7, 2.3 Hz, 1H), 6.75 (d, J = 1.1 Hz, 1H), 3.86 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.6, 132.5, 132.1, 129.8, 129.0, 127.6, 125.1, 112.6, 111.6, 102.4, 99.9, 55.9 ppm.

*6-Fluoro-2-phenyl-1H-indole (**3e**)*[16]

White solid (43.8 mg, 83% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.31 (br s, 1H), 7.61 (d, J = 7.6 Hz, 2H), 7.54–7.50 (m, 1H), 7.43 (t, J = 7.6 Hz, 2H), 7.32 (t, J = 7.6 Hz, 1H), 7.07 (dd, J = 9.5, 1.7 Hz, 1H), 6.88 (dt, J = 9.2, 1.7 Hz, 1H), 6.78 ppm (d, J = 1.0 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 160.1 (d, J = 236.7 Hz), 138.4 (d, J = 3.8 Hz), 136.8 (d, J = 12.4 Hz), 132.1, 129.1, 127.7, 125.8 (d, J = 8.7 Hz), 125.0, 121.3 (d, J = 9.9 Hz), 109.0 (d, J = 24.3 Hz), 99.9 (d, J = 1.0 Hz), 97.3 ppm (d, J = 26.0 Hz).

*5-Chloro-2-phenyl-1H-indole (**3f**)*[7]

White solid (40.3 mg, 71% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.33 (br s, 1H), 7.63 (d, J = 7.5 Hz, 2H), 7.58 (s, 1H), 7.44 (t, J = 7.5 Hz, 2H), 7.34 (t, J = 7.5 Hz, 1H), 7.29 (d, J = 8.6 Hz, 1H), 7.13 (dd, J = 8.6, 1.5 Hz, 1H), 6.75 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 139.3, 135.1, 131.9, 130.3, 129.1, 128.1, 125.9, 125.2, 122.6, 120.0, 111.9, 99.6 ppm.

*5-Bromo-2-phenyl-1H-indole (**3g**)*[17]

White solid (44.7 mg, 66% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.37 (br s, 1H), 7.74 (s, 1H), 7.64 (d, J = 7.5 Hz, 2H), 7.44 (t, J = 7.5 Hz, 2H), 7.34 (t, J = 7.5 Hz, 1H), 7.26 (s, 2H), 6.74 ppm (d, J = 1.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 139.1, 135.4, 131.8, 131.0, 129.1, 128.1, 125.2, 125.1, 123.1, 113.4, 112.3, 99.4 ppm.

*2-Phenyl-1H-indole-5-carbonitrile (**3h**)*[8]

White solid: (27.3 mg, 50% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.78 (br s, 1H), 7.96 (s, 1H), 7.68 (d, J = 7.3 Hz, 2H), 7.48–7.38 (m, 5H), 6.87 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 140.3, 138.4, 131.3, 129.2, 129.0, 128.6, 126.0, 125.4, 125.2, 120.7, 111.7, 103.4, 100.2 ppm.

*Methyl 2-phenyl-1H-indole-4-carboxylate (**3i**)*[8]

White solid (25.7 mg, 41% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.60 (br s, 1H), 7.91 (d, J = 7.8 Hz, 1H), 7.73 (d, J = 7.5 Hz, 2H), 7.60 (d, J = 7.8 Hz, 1H), 7.49 (s, 1H), 7.47 (t, J = 7.5 Hz, 2H), 7.36 (t, J = 7.5 Hz, 1H), 7.23 (t, J = 7.8 Hz, 1H), 4.01 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 168.1, 140.0, 137.6, 131.9, 129.1, 128.9, 128.3, 125.5, 123.8, 121.4, 115.6, 101.3, 51.8 ppm.

*2-(p-Tolyl)-1H-indole (**3j**)*[7]

White solid (41.9 mg, 81% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.28 (br s, 1H), 7.61 (d, J = 7.5 Hz, 1H), 7.55 (d, J = 7.9 Hz, 2H), 7.38 (d, J = 7.5 Hz, 1H), 7.24 (d, J = 7.9 Hz, 2H), 7.17 (t, J = 7.5 Hz, 1H), 7.11 (t, J = 7.5 Hz, 1H), 6.78 (s, 1H), 2.39 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.1, 137.6, 136.7, 129.7, 129.6, 129.4, 125.1, 122.1, 120.5, 120.2, 110.8, 99.4, 21.2 ppm.

*2-(m-Tolyl)-1H-indole (**3k**)*[7]

White solid (39.9 mg, 77% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.32 (br s, 1H), 7.62 (d, J = 7.7 Hz, 1H), 7.48 (s, 1H), 7.46 (d, J = 7.8 Hz, 1H), 7.39 (d, J = 7.7 Hz, 2H), 7.33 (t, J = 7.8 Hz, 1H), 7.19 (t, J = 7.7 Hz, 1H), 7.15–7.09 (m, 2H), 6.81 (d, J = 1.1 Hz, 1H), 2.42 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 138.7, 138.0, 136.8, 132.3, 129.3, 128.9, 128.5, 125.9, 122.3, 122.2, 120.6, 120.2, 110.8, 99.9, 21.5 ppm.

*2-(o-Tolyl)-1H-indole (**3l**)*[7]

White solid (31.1 mg, 60% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.11 (br s, 1H), 7.65 (d, J = 7.6 Hz, 1H), 7.47–7.45 (m, 1H), 7.31 (d, J = 7.6 Hz, 1H), 7.31–7.26 (m, 3H), 7.20 (t, J = 7.6 Hz, 1H), 7.14 (t, J = 7.6 Hz, 1H), 6.61(s, 1H), 2.50 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.4, 136.1, 132.6, 131.1, 129.0, 128.9, 128.0, 126.1, 122.0, 120.5, 120.0, 110.7, 103.0, 21.1 ppm.

*2-(4-(tert-Butyl)phenyl)-1H-indole (**3m**)*[18]

White solid (46.1 mg, 74% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.30 (br s, 1H), 7.61 (d, J = 7.8 Hz, 1H), 7.59 (d, J = 8.4 Hz, 2H), 7.46 (d, J = 8.4 Hz, 2H), 7.39 (d, J = 7.8 Hz, 1H), 7.18 (t, J = 7.8 Hz, 1H), 7.11 (t, J = 7.8 Hz, 1H), 6.80 (s, 1H), 1.36 ppm (s, 9H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 150.9, 138.0, 136.7, 129.6, 129.3, 126.0, 124.9, 122.1, 120.5, 120.2, 110.8, 99.5, 34.7, 31.3 ppm.

*2-(4-Methoxyphenyl)-1H-indole (**3n**)*[7]

White solid (35.1 mg, 63% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.24 (br s, 1H), 7.60–7.58 (m, 3H), 7.38 (d, J = 7.4 Hz, 1H), 7.17 (t, J = 7.4 Hz, 1H), 7.11 (t, J = 7.4 Hz, 1H), 6.99 (d, J = 8.2 Hz, 2H), 6.72 (s, 1H),

3.86 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 159.4, 138.0, 136.7, 129.5, 126.5, 125.3, 121.9, 120.4, 120.2, 114.5, 110.7, 98.9, 55.4 ppm.

*2-(4-Fluorophenyl)-1H-indole (**3o**)*[7]

White solid (36.9 mg, 70% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.24 (br s, 1H), 7.63–7.58 (m, 3H), 7.38 (d, J = 7.7 Hz, 1H), 7.19 (t, J = 7.7 Hz, 1H), 7.15–7.10 (m, 3H), 6.74 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 162.4 (d, J = 245.1 Hz), 136.9 (d, J = 18.7 Hz), 129.2, 128.7 (d, J = 3.3 Hz), 126.9 (d, J = 18.0 Hz), 122.4, 120.5 (d, J = 25.0 Hz), 116.0 (d, J = 20.7 Hz), 110.9, 99.9 ppm (d, J = 1.2 Hz).

*2-(4-Chlorophenyl)-1H-indole (**3p**)*[7]

White solid (55.4 mg, 80% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.24 (br s, 1H), 7.62 (d, J = 7.5 Hz, 1H), 7.56 (d, J = 8.3 Hz, 2H), 7.39 (d, J = 8.3 Hz, 2H), 7.38 (d, J = 7.5 Hz, 1H), 7.20 (t, J = 7.5 Hz, 1H), 7.12 (t, J = 7.5 Hz, 1H), 6.80 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.9, 136.7, 133.4, 130.9, 129.2, 126.3, 122.7, 120.8, 120.5, 110.9, 100.5 ppm.

*2-(2-Chlorophenyl)-1H-indole (**3q**)*[17]

White solid (31.8 mg, 56% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.76 (br s, 1H), 7.66 (d, J = 7.4 Hz, 2H), 7.48 (d, J = 7.7 Hz, 1H), 7.42 (d, J = 7.7 Hz, 1H), 7.33 (t, J = 7.4 Hz, 1H), 7.29–7.20 (m, 2H), 7.14 (t, J = 7.7 Hz, 1H), 6.87 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.4, 135.1, 131.3, 131.2, 130.8, 130.7, 128.8, 128.2, 127.2, 122.7, 120.8, 120.2, 111.0, 103.6 ppm.

*2-(4-Bromophenyl)-1H-indole (**3r**)*[17]

White solid (48.6 mg, 72% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.24 (br s, 1H), 7.62 (d, J = 7.4 Hz, 1H), 7.55 (d, J = 8.2 Hz, 2H), 7.49 (d, J = 8.2 Hz, 2H), 7.37 (d, J = 7.4 Hz, 1H), 7.20 (t, J = 7.4 Hz, 1H), 7.12 (t, J = 7.4 Hz, 1H), 6.80 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.9, 136.6, 132.1, 131.3, 129.1, 126.6, 122.7, 121.5, 120.8, 120.5, 110.9, 100.5 ppm.

*2-(Naphthalen-1-yl)-1H-indole (**3s**)*[17]

White solid (36.5 mg, 60% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.29 (d, J = 8.0 Hz, 1H), 8.23 (s, 1H), 7.91–7.85 (m, 2H), 7.70 (d, J = 7.4 Hz, 1H), 7.59 (d, J = 7.0 Hz, 1H), 7.52–7.46 (m, 3H), 7.40 (d, J = 7.4 Hz, 1H), 7.23 (t, J = 7.4 Hz, 1H), 7.17 (t, J = 7.4 Hz, 1H), 6.78 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 136.7, 136.4, 133.9, 131.5, 131.1, 128.9, 128.6, 128.5, 127.2, 126.7, 126.1, 125.7, 125.3, 122.2, 120.6, 120.2, 110.8, 103.7 ppm.

*2-(Naphthalen-2-yl)-1H-indole (**3t**)*[8]

White solid (37.7 mg, 62%); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 8.47 (s, 1H), 8.04 (s, 1H), 7.90–7.80 (m, 4H), 7.60 (d, J = 7.7 Hz, 1H), 7.53–7.45 (m, 2H), 7.42 (d, J = 7.7 Hz, 1H), 7.22 (t, J = 7.7 Hz, 1H), 7.14 (t, J = 7.7 Hz, 1H), 6.95 ppm (s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 137.8, 137.0, 133.6, 132.9, 129.7, 129.3, 128.8, 128.0, 127.8, 126.7, 126.1, 123.8, 123.0, 122.5, 120.7, 120.3, 110.9, 100.7 ppm.

*1-Methyl-2-phenyl-1H-indole (**3u**)*[7]

White solid (43.0 mg, 83% yield); ^{1}H NMR (400 MHz, $CDCl_3$): δ = 7.64 (d, J = 7.5 Hz, 1H), 7.51 (d, J = 7.4 Hz, 2H), 7.46 (t, J = 7.4 Hz, 2H), 7.41–7.35 (m, 2H), 7.25 (t, J = 7.5 Hz, 1H), 7.14 (t, J = 7.5 Hz, 1H), 6.56 (s, 1H), 3.74 ppm (s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ = 141.5, 138.3, 132.9, 129.4, 128.5, 127.9, 127.8, 121.6, 120.5, 119.8, 109.6, 101.6, 31.1 ppm.

Acknowledgements

This work was financially supported by the National Science Foundation of China (21172092).

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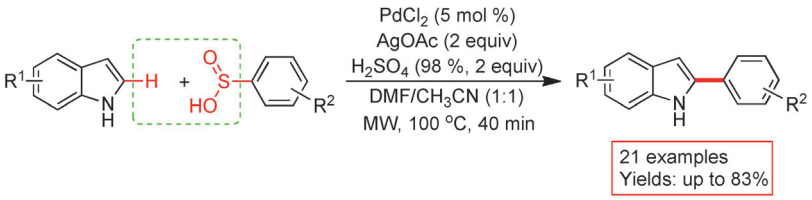
Received: July 10, 2013
Published online: ■■ ▮▮, 0000



From C2 shining sea: The direct C2-arylation of free (NH)-indoles with arylsulfinic acids proceeded through a Pd-catalyzed desulfitation reaction. In the presence of an oxidant and an additive, 2-arylindoles were selectively afforded in good yields.

Microwave Chemistry

*Tao Miao, Pinhua Li, Guan-Wu Wang, Lei Wang** ——— ■■■■–■■■■

Microwave-Accelerated Pd-Catalyzed Desulfitative Direct C2-Arylation of Free (NH)-Indoles with Arylsulfinic Acids