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Pd(0)-Mediated Couplings of Aryl Nonaflates and Triflates with Diphenylphosphine-Borane. Preparation of BH_3-Stabilized, Unsymmetrical Triarylphosphines

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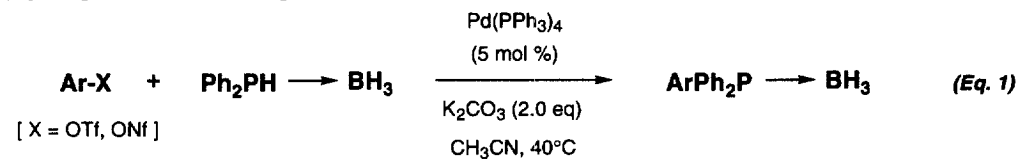
Abstract. *Exposure of an aryl nonaflate or triflate to diphenylphosphine-borane in the presence of catalytic $Pd(PPh_3)_4$ in CH_3CN at 40° leads to good isolated yields of triarylphosphines uncomplicated by autoxidation.* © 1998 Elsevier Science Ltd. All rights reserved.

The importance of phosphines as ligands in organometallic chemistry cannot be overstated. Hardly an issue of a journal on organic chemistry appears wherein such a species is not found associated with some aspect of metal chemistry, be it asymmetric synthesis in general, asymmetric catalysis in particular, or in some other pivotal role.[1] Further testimony can be found in the continuing appearance of new procedures aimed at preparing phosphines of both chiral[2] and achiral[3] varieties. Curiously, there are relatively few reports specifically addressing the preparation of unsymmetrical triarylphosphines,[3b,4,5] arrived at by way of diarylphosphines as nucleophiles in group 10 metal-based couplings. The majority of these methods is characterized by long reaction times, high reaction temperatures, and the use of expensive and pyrophoric phosphine reagents. And for those methods that do afford triaryl derivatives, significant concommitant oxidation to the phosphine oxide is virtually unavoidable, perhaps even innate to the coupling itself,[5] making product isolation very difficult or requiring an additional reductive step. The possibility that Imamoto's phosphine-boranes,[6,7] although known to undergo cross-couplings with aryl iodides,[6] might also be applicable to direct replacement of triflates and the recently described nonaflates[8] led us to investigate this approach. Most notably, if successful, products are stable materials not susceptible to autoxidation. We now report that such triarylphosphines can indeed be realized under very mild conditions *via* Pd(0)-mediated couplings of aryl triflates and nonaflates in most cases using *stoichiometric* quantities of a diarylphosphine- borane (Equation 1).



Diphenylphosphine-borane,[7] an air stable, white solid, is readily prepared from the commercially available ingredients Ph_2PCl and BH_3•THF in the presence of LAH. When dissolved in CH_3CN, as described by Imamoto,[6] followed by addition of an aryl triflate/nonaflate, K_2CO_3 (2 equiv), and 5 mol % $Pd(PPh_3)_4$, a heterogeneous yellow mixture is obtained. Heating to

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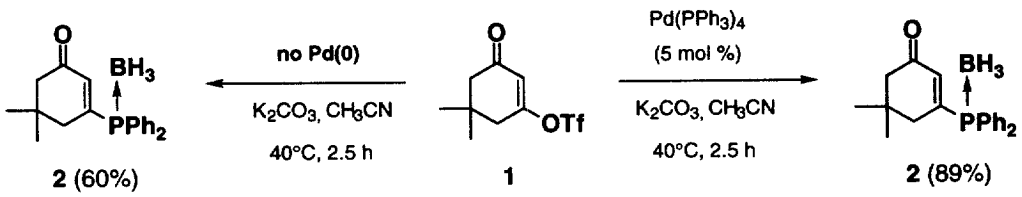
40° for a few hours causes a slight intensification to yellow-orange upon completion of the reaction. An acidic work-up affords the crude but essentially pure triarylphosphine-borane, which can be further purified by column chromatography over silica gel. Eventual removal of the borane 'protecting group' under standard literature conditions[9] using an amine (*e.g.*, Et_2NH, DABCO, etc.) would ultimately give the uncomplexed phosphine. Several representative examples are illustrated in Table 1, concerning which the following salient features emerge: (1) in most cases (entries 1-7), a strictly 1:1 stoichiometry can be used while reaction efficiencies remain high; (2) substituted naphthalenes are especially prone toward coupling, both at the 1- and 2-positions; (3) both electron-rich, as well as electron-poor naphthalene triflates/nonaflates readily participate; (4) substituted phenyl rings bearing electron-withdrawing substituents undergo conversion, although in modest yields (entries 8, 9); (5) a regiochemical concern due to the presence of bromine in a substrate[10] (*e.g.*, entry 5) is a non-issue, as reaction occurs exclusively at the sulfonate-bearing site.

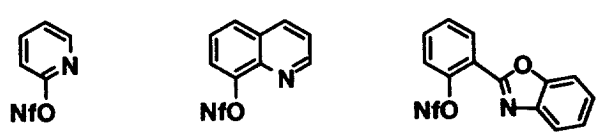
Preference was given, in general, to nonaflates over triflates as educts. The former derivatives are easily prepared, involve a less costly precursor, and are reported to be somewhat more reactive.[7] A striking example of reactivity differences was noted in the case of the nonaflate of 2-naphthol (Table 1, entry 1). The corresponding triflate was completely inert to our standard coupling conditions, while the nonaflate behaved 'normally' to afford the triarylphosphine-borane in virtually quantitative yield.

An activated vinyl triflate **1** was found to also smoothly form the corresponding phosphine-borane **2** (Scheme 1). By contrast, an attempt to effect this net displacement in the *absence* of Pd(0) did afford product **2**; however, after 2.5 hours only a 60% yield was realized along with several by-products.

Scheme 1

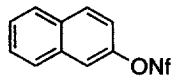
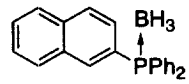
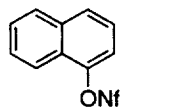
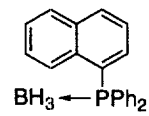
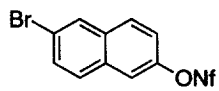
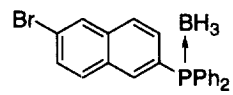
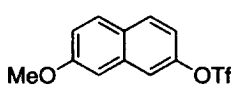
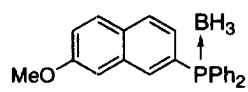
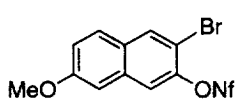
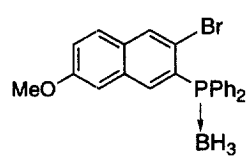
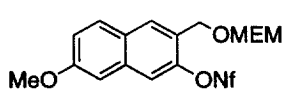
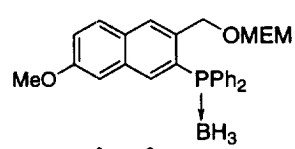
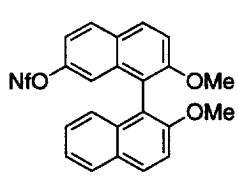
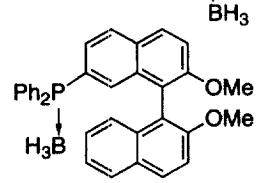
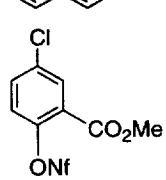
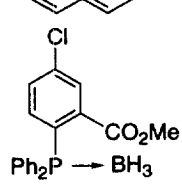
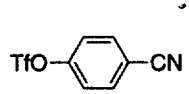
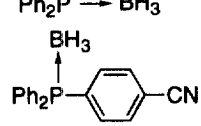


Limitations noted thus far with this protocol are mainly due to the sensitivity of phosphine-boranes to amines (*i.e.*, the species used to de-complex the phosphine; *vide supra*).[9] Thus, several attempts to introduce the diphenylphosphine moiety into substrates **3-5** below were totally unproductive, the major pathway being removal of the borane from phosphorus. Use of the corresponding amine-boranes of **3-5** as electrophiles, while not attempted,[11] should serve to both activate such substrates and eliminate competing decomplexation of Ph_2PH-BH_3.



In summary, it has been found that unsymmetrical triarylphosphine boranes, stable precursors to the corresponding free phosphines, can be readily formed *via* an especially mild

Table 1. Coupling reactions of aryl triflates/nonaflates[12] with Ph_2PH-BH_3 in CH_3CN.

entry	nonaflate / triflate	phosphine borane[a]	time (h)	yield (%)[b]
1			3.0	quant
2			8.0	81
3			4.0	93
4			5.0	95
5			5.0	87
6			3.0	90
7			6.0	68
8			6.0	71[c,d]
9			4.0	67[e]

[a]Fully characterized by spectral and HRMS data.[13] [b]Isolated, chromatographically purified material. [c]2.0 equiv of nonaflate were used relative to phosphine-borane. [d]By GC. [e]$Pd(dba)_2$ and dppf were used instead of $Pd(PPh_3)_4$.

Pd(0)-mediated coupling using aryl nonaflates or triflates as substrates.[12] The method described should expand access to increasingly important mixed triarylphosphine ligands, which are vital components of many asymmetric C-C bond-forming processes.[1]

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12. Typical procedure (Table 1, entry 4); Diphenylphosphine-borane (40 mg, 0.20 mmol), arylsulfonate (61.2 mg, 0.20 mmol) and $Pd(PPh_3)_4$ (11.5 mg, 0.01 mmol, 5 mol %) were weighed into an oven dried 10 mL round bottomed flask equipped with stir bar and septa and purged with argon. Acetonitrile (1.0 mL, distilled from CaH_2) was added and the solution was allowed to stir at rt for 5 min. K_2CO_3 (55.3 mg, 0.40 mmol) was added under a stream of argon and the solution was warmed to 40 °C. The reaction was monitored by TLC and was judged complete after 5.0 h. The solution was cooled to rt and 2.0 mL of diethyl ether and 2.0 mL of 3 M HCl were added. After brief stirring the organics were separated and the aqueous layer extracted two additional times with 2.0 mL of diethyl ether. The crude organics were adsorbed onto silica gel and purified by column chromatography on silica gel (5% diethyl ether in pet ether) to give 68 mg (95%) of an off white solid: mp 118-120 °C; ^{1}H NMR (400 MHz, $CDCl_3$) δ 1.0-2.0 (br m, 3H), 3.89 (s, 3H), 7.12 (d, 2.4 Hz, 1H), 7.23 (dd, 8.8, 2.4 Hz, 1H), 7.38-7.53 (m, 7H), 7.58-7.63 (m, 4H), 7.75 (d, 8.8 Hz, 1H), 7.79 (dd, 8.4, 2.4 Hz, 1H), 8.08 (d, 12.8 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 55.35, 106.26, 121.11, 125.90, 125.98, 128.12, 128.22, 128.69, 128.79, 129.18, 131.18, 131.20, 133.13, 133.22, 133.45, 133.56, 158.27; IR 2387 cm^{-1}; LRFABMS m/z (rel int) 355 (59), 342 (100), 265 (72), 233 (44), 202 (16), 183 (52), 135 (27), 123 (47); HREIMS calcd for $C_{23}H_{19}OP$ 342.1173, found 342.1169.
13. HRMS data was observed for the corresponding triarylphosphines, $ArPPh_2$ (*i.e.*, M^+-BH_3).