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LETTERS

A preparation of benzylic and allylic boronates: cross-coupling of aryl- and alkenylstannanes with bromomethylboronates

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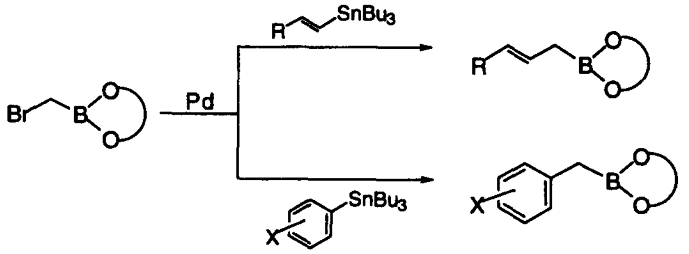
Abstract

Palladium catalyzed cross-coupling of aryl- or alkenylstannanes with pinacol and pinanediol bromomethylboronates affords the corresponding homologated benzylic or allylic boronates in moderate to good yields. © 1999 Elsevier Science Ltd. All rights reserved.

Keywords: boronates; Stille; coupling reactions; palladium.

Organoboronates have emerged as popular and versatile synthetic intermediates.[1] Their unique reactivity, comparative stability, and low toxicity make them especially useful for cross-couplings with a variety of organic electrophilies.[2] Their utility, however, is sometimes restricted because the most common methods for boronate preparation, i.e. anionic processes[3] or hydroboration,[4] are not always compatible with sensitive, multifunctional molecules.[5] Herein, we report the facile Pd catalyzed, cross-coupling of bromomethylboronates with aryl- and alkenylstannanes[6] to give benzylic and allylic boronate esters (Eq. 1).



(1)

The scope and limitation of the cross-coupling were evaluated using the readily available[7,8] pinanediol and pinacol bromomethylboronates, PD and PC, respectively, and a panel of representative aryl- and alkenylstannanes as summarized in Table 1. Under typical Stille conditions,[9] i.e. $Pd_2(dba)_3$ catalyst[10] in

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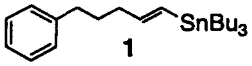
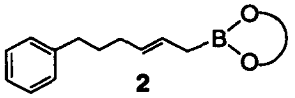
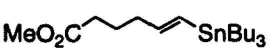
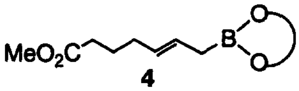
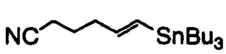
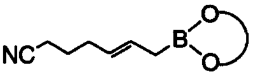
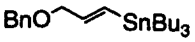
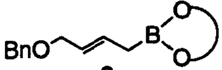
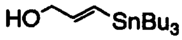
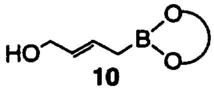
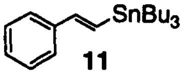
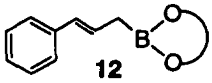
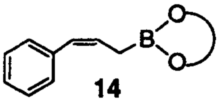
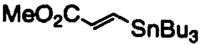
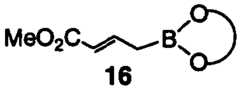
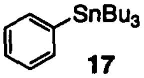
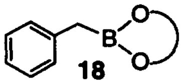
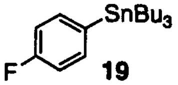
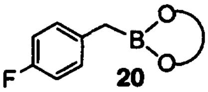
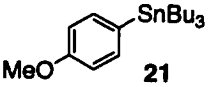
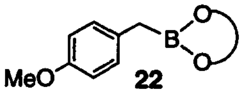
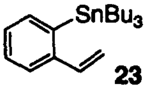
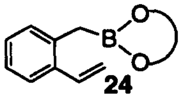
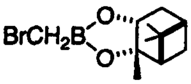
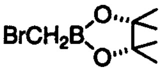
Table 1
Cross-coupling of aryl/vinylstannanes with bromomethylboronates

Entry	Stannane	Bromide	Time (h)/ Temp (°C)	Adduct	Yield (%)
1	 1	PD	10/50[a]	 2	80
2	 3	PD	10/50[a]	 4	78
3	 5	PD	10/50[a]	 6	76
4	 7	PD	12/50[b]	 8	60
5	 9	PD	12/50[b]	 10	63
6	 11	PD	8/23[a]	 12	60
7	 13	PD	8/23[a]	 14	60
8	 15	PD	10/50[a]	 16	0
9	 17	PD PC	6/23[a] 14/80[c]	 18	86 78
10	 19	PD PC	6/23[a] 10/50[c]	 20	83 76
11	 21	PD PC	4/23[a] 7/50[c]	 22	63 56
12	 23	PD	6/60[a]	 24	80

[a]Reagents: $Pd_2(dba)_3 \cdot CHCl_3$, HMPA. [b]$Pd_2(dba)_3$, Ph_3P, HMPA. [c]$Pd(Ph_3P)_4$, HMPA.

PD = 

PC = 

HMPA, vinylstannane **1** gave rise to pinanediol boronate **2**[11] as the sole product (entry 1) in good yield. The yield of **2** was significantly reduced in other solvents,[12] e.g. DMF, CH_2Cl_2, THF, C_6H_6, and DMSO, and there was no reaction in the absence of catalyst. Importantly, the cross-coupling proved compatible with a wide variety of functionality, inter alia, methyl ester (entry 2), nitrile (entry 3), benzyl ether (entry 4), and even an unprotected hydroxyl (entry 5). For the latter two examples, satisfactory results were only obtained in the presence of triphenylphosphine.[9] Cross-coupling of *trans*-styrene **11** (entry 6) and *cis*-styrene **13** (entry 7) proceeded at room temperature with complete retention of configuration to give *trans*-cinnamylboronate **12** and *cis*-cinnamylboronate **14**, respectively, albeit in more modest yields than the preceding vinylstannanes. In sharp contrast, acrylate **15** remained unchanged (entry 8); forcing conditions led to decomposition.

Arylstannanes, likewise, provided facile access to benzylic boronates. Couplings were generally productive for unactivated aromatics (entry 9) and for those with electronegative substituents (entry 10), but somewhat blunted by electron donating substituents (entry 11). Notably, the conversion of **23** to **24** (entry 12) did not compromise the adjacent olefin.

General procedure, Method A: Stannane (1 equiv.) and bromomethylboronate (1.1 equiv.) were added to a solution of $Pd_2(dba)_3 \cdot CHCl_3$ (3 mol%) in anhydrous HMPA under an argon atmosphere and stirred at the indicated temperature (Table 1) until TLC monitoring indicated all of the starting material was consumed. For pinanediol esters, the reaction mixture was partitioned between water and ether. The ethereal fraction was washed with brine, dried, concentrated in vacuo, and the residue purified by SiO_2 column chromatography to yield the corresponding homologated boronate. For pinacol esters, the solvent was removed in vacuo and the residue was purified by SiO_2 column chromatography without water washing.

Method B: Stannane (1 equiv.) and bromomethylboronate (1.1 equiv.) were added to a solution of $Pd_2(dba)_3$ (3 mol%) and Ph_3P (12 mol%) in anhydrous HMPA under an argon atmosphere. The mixture was stirred at the indicated temperature (Table 1) until TLC monitoring indicated all of the starting material was consumed. The homologated boronate was isolated and purified as described above.

Acknowledgements

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6. Under these conditions, alkyl- and alkynylstannanes react sluggishly to give little, if any, homologated boronate.
7. These esters were selected for their hydrolytic stability.
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10. Mainly decomposition and/or stannane dimerization were observed with Pd(dppf)Cl_2, Pd(dppe)Cl_2, Pd$(Ph_3P)_2Cl_2$, and Pt$(Ph_3P)_4$.
11. ^{1}H NMR ($CDCl_3$, 400 MHz) of pinanediol boronate **2**: δ 7.12–7.32 (m, 5H), 5.38–5.60 (m, 2H), 4.26 (dd, J=1.9, 8.8 Hz, 1H), 2.57–2.63 (m, 2H), 2.29–2.36 (m, 1H), 2.18–2.22 (m, 1H), 2.00–2.12 (m, 3H), 1.80–1.92 (m, 2H), 1.62–1.76 (m, 4H), 1.36–1.40 (m, 3H), 1.27 (s, 3H), 1.16 (d, J=10.7, 1H), 0.83 (s, 3H). Pinanediol boronate **14**: δ 7.17–7.37 (m, 5H), 6.43 (d, J=11.5 Hz, 1H), 5.80–5.90 (m, 1H), 4.28 (dd, J=1.9, 8.8 Hz, 1H), 2.16–2.40 (m, 2H), 1.98–2.09 (m, 3H), 1.82–1.96 (m, 2H), 1.38 (s, 3H), 1.28 (s, 3H), 1.10 (d, J=10.7 Hz, 1H), 0.84 (s, 3H). Pinanediol boronate **22**: δ 7.11 (d, J=8.5 Hz, 2H), 6.80 (d, J=8.5 Hz, 2H), 4.27 (dd, J=1.8, 8.8 Hz, 1H), 3.77 (s, 3H), 2.24–2.36 (m, 3H), 2.14–2.22 (m, 1H), 2.01–2.06 (m, 1H), 1.78–1.92 (m, 2H), 1.37 (s, 3H), 1.27 (s, 3H), 1.06 (d, J=10.6 Hz, 1H), 0.82 (s, 3H).
12. Stannane dimerization was the main reaction in these solvents.