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Preliminary Communication

Stereoselective synthesis of allylic boronates via palladium-catalyzed cross-coupling reaction of Knochel's (dialkoxyboryl)methylzinc reagents with 1-halo-1-alkenes

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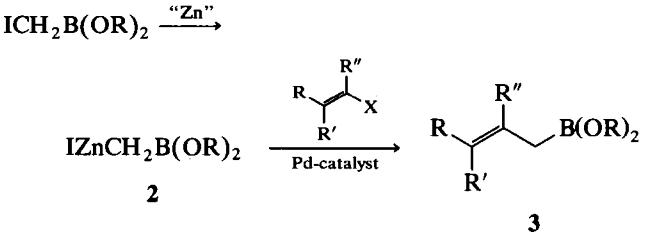
Abstract

The cross-coupling reaction of (dialkoxyboryl)methylzinc reagents $IZnCH_2B(OR)_2$ with 1-halo-1-alkenes was catalyzed by triphenylphosphine- or triphenylarsine-based palladium complexes to provide esters of stereodefined allylboronic acids with stereoselectivity. The reaction was applied to provide a cyclic alcohol *via* the first intramolecular allylboration of carbonyl.

In view of synthetic promise, the synthesis and reaction of allylic boronates have been the focal point of several groups in recent publications [1]. A variety of allylic boronates were made by the reaction of allylic lithium or magnesium compounds with halo- or alkoxyboron compounds [2], or by alkylation of (halomethyl)boronates with stereodefined 1-alkenyllithium reagents [3]. As a part of our program on the synthetic use of the palladium-catalyzed reaction [4], we became interested in developing a new method for obtaining such stereodefined allylic boronates *via* the coupling reaction between (dialkoxyboryl)methylmetal reagents with 1-halo-1-alkenes. Although the (dialkoxy) methyllithium compounds reported by Matteson [5] resulted in very low yields of coupling products owing to thermal instability of these reagents under the coupling conditions, the borylmethylzinc reagent **2a**, recently reported by Knochel [6], performed a clean cross-coupling reaction with 1-bromo- or 1-iodo-1-alkenes to provide allylic boronates stereoselectively [7] (eqn. (1)).



1a: $(RO)_2 = -OCMe_2CMe_2O-$
1b: $(RO)_2 = -OCH_2CMe_2CH_2O-$ (1)
1c: $(RO)_2 = -OCHMeCHMeO-$

We found that not only the pinacol derivative **2a** but also the derivatives of 2,2-dimethyl-1,3-propanediol (**2b**) and 2,3-butanediol (**2c**) can be synthesized in quantitative yields under the conditions similar to those used for the preparation of **2a** from (iodomethyl)boronates **1** and excess of zinc activated by 1,2-dibromoethane in THF at room temperature. The solutions of the zinc reagents **2a** and **2b** are sufficiently stable to be stored in a cold place. However, **2c** is more labile upon storage.

In Table 1, the results of the reaction of **2a** with a variety of 1-halo-1-alkenes in the presence of palladium catalyst are summarized. The coupling reaction of (*E*)-*β*-iodostyrene with a 50% excess of zinc reagent of the pinacol derivative **2a** to give the (*E*)-cinnamylboronate was carried out at 50°C in the presence of several catalysts. A rather fast reaction under mild conditions was desired for this coupling owing to the instability of zinc reagents and allylic boronate products under the coupling conditions. Recently, tris-2-furylphosphine and triphenylarsine ligands were recommended as new ligands in the palladium-catalyzed tin coupling reaction at extremely fast coupling rates [8]. Although a reasonable yield was obtained for *β*-iodostyrene with the triphenylphosphine based palladium catalyst, the superiority of the triphenylarsine ligand was observed in the reactions with 1-iodo-1-hexene and 1-iodocyclohexene (entries 7, 8 and 10).

The reaction proceeded through a complete retention of configuration of haloalkenes to provide stereodefined allylic boronates. Thus, (*E*)-*β*-iodostyrene and (*Z*)-*β*-bromostyrene gave (*E*)- and (*Z*)-cinnamylboronic acid esters stereoselectively. The formation of only a single isomer of allylic boronate was confirmed by GC-massspectrometry analysis (a fused silica capillary column, OV-17) and the magnitude of the cou-

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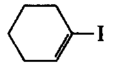
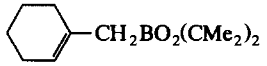
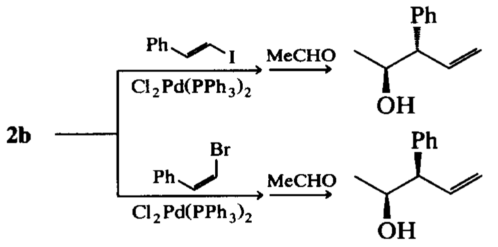
TABLE 1. Synthesis of allylic boronates (eqn. (1)) [a]

Entry	1-Halo-1-alkene	Catalyst	Product **3a**	Yield (%) [b]
1	(E)-PhCH=CHI	$Cl_2Pd(PPh_3)_2$	(E)-$PhCH{=}CHCH_2BO_2(CMe_2)_2$	(62)
2		$Pd(PPh_3)_4$		54 (76)
3		$Pd(DBA)_2 \cdot 4AsPh_3$		(74)
4		$Ni(PPh_3)_4$ [c]		(15)
5	(Z)-PhCH=CHBr	$Pd(PPh_3)_4$	(Z)-$PhCH{=}CHCH_2BO_2(CMe_2)_2$	68
6	(E)-$C_4H_9CH{=}CHI$	$Pd(PPh_3)_4$	(E)-$C_4H_9CH{=}CHCH_2BO_2(CMe_2)_2$	(45)
7		$Pd(DBA)_2 \cdot 4AsPh_3$		(63)
8	(Z)-$C_4H_9CH{=}CHI$	$Pd(DBA)_2 \cdot 4AsPh_3$	(Z)-$C_4H_9CH{=}CHCH_2BO_2(CMe_2)_2$	55
9	(Z)-PhSCH=CHBr	$Pd(PPh_3)_4$	(Z)-$PhSCH{=}CHCH_2BO_2(CMe_2)_2$	54
10		$Pd(DBA)_2 \cdot 4AsPh_3$		61

[a] All reactions were carried out in THF at 50°C for 3 h by using 1-halo-1-alkenes (1 equiv), **2a** (*ca.* 0.5 M in THF, 1.5 equiv. for entries 1–7 and 2 equiv. for entries 8–10), and a palladium-catalyst (0.03 equiv.). ^1H NMR and GC-MS analyses showed that all the allylic boronates were isomerically pure (> 99%). [b] Isolated yields by Kugelrohr distillation and GC yields were shown in the parentheses. [c] The catalyst was prepared by treatment of a mixture of $Ni(acac)_2$ and PPh_3 (4 equivs) with HAl^iBu_2 (1 equiv.) at room temperature.

pling constant of the vinylic protons in the ^1H NMR spectrum ($J = 11.6$ and 16.1 Hz for *cis* and *trans* isomers). The reaction with (E)- and (Z)-1-iodo-1-hexene, and (Z)-1-bromo-2-phenylthioethene also provided the corresponding allylic boronates stereoselectively (entries 6–9).

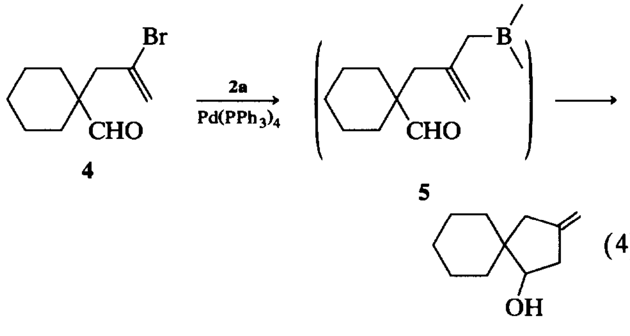
Although the zinc reagent of the pinacol ester derivative **2a** was used in most of the present work described here, the reagent **2b** also gave allylic boronates **3b** which are more susceptible to hydrolysis on treatment with water at work-up. Since the 2,2-dimethyl-1,3-propanediol esters of allylic boronates are less sterically hindered than the pinacol derivatives, much faster allyl transposition can be expected in the reaction with carbonyl compounds. The reaction of **2b** with (E)-β-iodostyrene or (Z)-β-bromostyrene in THF at 50°C for 3 h in the presence of 3 mol% of $Cl_2Pd(PPh_3)_2$, followed by *in situ* treatment with an excess of acetaldehyde at room temperature for 16 h provided *threo* and *erythro* homoallylic alcohols in 61 and 57% yield (eqns. (2) and (3)). High diastereoselectivities over 99% in both reactions indicate the stereoselective formations of (E)- and (Z)-allylic boronates **3b**. However, all attempts to synthesis 2,3-butanediol derivatives **3c** were unsuccessful, presumably due to thermal instability of the zinc reagent **2c**.



(2)

(3)

The potential versatility of the present coupling reaction was demonstrated by a new intramolecular allylboration reaction, as shown in eqn. (4). The cross-coupling of the borylmethylzinc reagent **2a** with bromoalkene **4** in dioxane/THF (3/1) at 70°C for 3 h in the presence of 3 mol% of $Pd(PPh_3)_4$ provided directly the spirocyclic compound **6** in 67% yield.



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(4)

The following procedure for preparation of a pinacol ester of (Z)-cinnamylboronic acid is representative. To the flask flushed with nitrogen was added $Pd(PPh_3)_4$ (0.06 mmol), (Z)-β-bromostyrene (2 mmol), THF (12 ml), and finally a solution of the zinc reagent **2a** in THF (3 mmol). After stirring for 3 h at 50°C, the reaction mixture was diluted with benzene (50 ml), washed quickly with brine, and dried over $MgSO_4$. Distillation by Kugelrohr gave the desired allylboronate as viscous oil in a 68% yield. B.p. 70–75°C/0.05 mmHg (oven temperature of Kugelrohr).

References

1 R. W. Hoffmann, *Angew. Chem., Int. Ed. Engl., 21* (1982) 555; W. R. Roush and R. L. Halterman, *J. Am. Chem. Soc., 108* (1986) 294; H. C. Brown and K. S. Bhat, *J. Am. Chem. Soc., 108* (1986)

293; H. C. Brown and M. V. Rangaishenvi, *Tetrahedron Lett.*, *31* (1990) 7113.

2 M. Schlosser and G. Rauchschwalb, *J. Am. Chem. Soc.*, *100* (1978) 3258 and reference 1.

3 P. G. Wuts, P. A. Tompson and G. R. Callen, *J. Org. Chem.*, *48* (1983) 5398; H. C. Brown, N. R. DeLue, Y. Yamamoto, K. Maruyama, T. Kasahara, S.-I. Murahashi and A. Sonoda, *J. Org. Chem.*, *42* (1977) 4088.

4 The synthesis of (Z)-allylic boronates *via* the catalytic 1,4-hydroboration of 1,3-dienes: M. Sato, Y. Nomoto, N. Miyaura and A. Suzuki, *Tetrahedron Lett.*, *30* (1989) 3789; the cross-coupling reaction of organoboron compounds: A. Suzuki, *Pure Appl. Chem.*, *57* (1985) 1749.

5 D. S. Matteson, *Synthesis*, (1975) 147.

6 P. Knochel, *J. Am. Chem. Soc.*, *112* (1990) 7431; M. J. Rozema, A. R. Sidduri and P. Knochel, *J. Org. Chem.*, *57* (1992) 1956.

7 The cross-coupling reaction of alkylzinc reagents: E. Negishi, *Acc. Chem. Res.*, *15* (1982) 340.

8 V. Farina and B. Krishnan, *J. Am. Chem. Soc.*, *113* (1991) 9585.