

A new palladium-catalysed synthesis of 1,1-dialkylbuta-1,3-dienes via organoboron intermediates†

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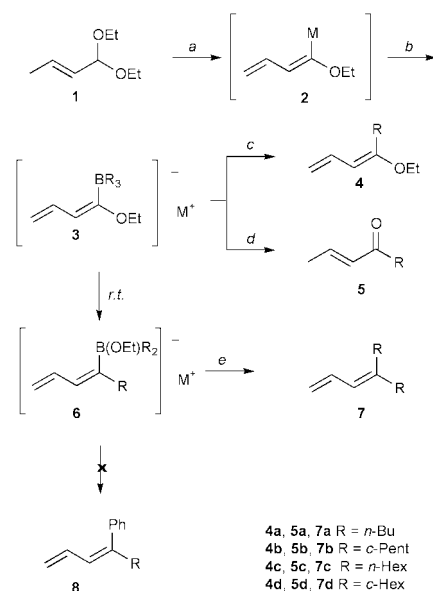
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Iodobenzene and tetrakis(triphenylphosphine)palladium(0) [(C₆H₅)₃P]₄Pd catalyse a new synthesis of 1,1-dialkylbuta-1,3-dienes, starting from 1,1-diethoxybut-2-ene and trialkylboranes, in the presence of Schlosser's superbases LIC-KOR.

The synthesis of polyenic structures has been of great interest to organic chemistry owing not only to their presence in natural products,¹ but also to their importance as useful chemicals in the perfume industry and other fields.² Our interest in the synthesis of stereodefined substituted dienes required the development of diverse organometallic reagents and protocol for the preparation of key building blocks.³ In the course of these studies we have set up a new synthesis of 1,1-dialkyl substituted buta-1,3-dienes, resorting to the reactivity of organoboron compounds.⁴ Treatment of crotonaldehyde diethyl acetal (**1**) at -95 °C with LIC-KOR base (LIC: butyllithium, KOR: potassium *tert*-butoxide)⁵ readily gives α -metalated 1-ethoxybuta-1,3-diene (**2**). Subsequent reaction with trialkylboranes leads to the immediate disappearance of the deeply red colour of the metalated diene. An intermediate 'ate' complex **3**⁶ (Scheme 1) is probably formed that undergoes different reactions according to experimental conditions.

Treatment of complex **3** at -95 °C with H₂O-THF leads to the corresponding 1-alkoxy-1-alkylbuta-1,3-dienes **4**, that can be, like all enol ethers, smoothly converted to the corresponding



Scheme 1 Reagents and conditions: a: LIC-KOR, THF, -95 °C; b: BR₃, THF, -95 °C; c: -95 °C, H₂O; d: BF₃·OEt₂, H₂O₂, -95 °C; e: C₆H₅I, [(C₆H₅)₃P]₄Pd, THF, 25 °C.

† Dedicated to Professor Iacopo Degani on the occasion of his 70th birthday.

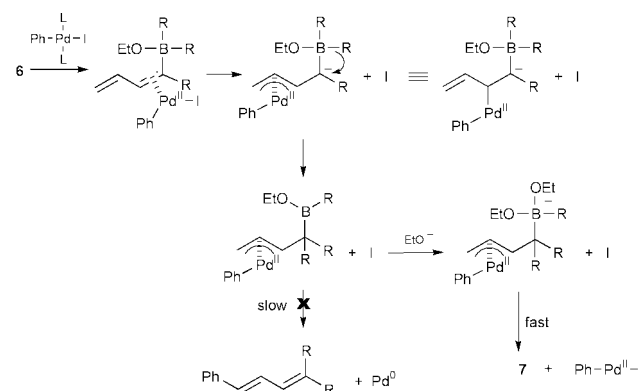
α,β -unsaturated ketones **5** (Scheme 1: path c). Moreover, derivatives **5** can be directly obtained from **3** upon treatment with a Lewis acid (F₃B·OEt₂) in an oxidative milieu (Scheme 1: path d). More interestingly, a new and intriguing result comes from the reaction with iodobenzene in the presence of catalytic amounts of [(C₆H₅)₃P]₄Pd, according to the procedure of the Suzuki-Miyura cross-coupling reaction. Thus, when intermediate **3** was warmed to room temperature and treated with a THF solution of iodobenzene and [(C₆H₅)₃P]₄Pd no coupling product **8** was detected, while the *gem*-dialkyl substituted buta-1,3-diene **7** was isolated in good yield (Scheme 1: path e).^{7,8} In contrast, treatment of **3** with [(C₆H₅)₃P]₄Pd in the absence of iodobenzene afforded only traces of product **7**.⁹ Moreover, also when intermediate **3** undergoes the iodination reaction⁶ or treatment with iodobenzene in the absence of a palladium complex no trace of product **7** was detected and only ketone **5** was recovered. The results obtained with different alkylboranes are reported in Table 1.

Table 1 Synthesis of 1-alkyl-1-ethoxybuta-1,3-dienes and 1,1-dialkylbuta-1,3-dienes^a

1-Alkyl-1-ethoxybuta-1,3-dienes			1,1-Dialkylbuta-1,3-dienes		
R	Product	Yield (%)	R	Product	Yield (%)
<i>n</i> -C ₄ H ₉	4a	86	<i>n</i> -C ₄ H ₉	7a	79
<i>c</i> -C ₅ H ₁₁	4b	87	<i>c</i> -C ₅ H ₁₁	7b	86
<i>n</i> -C ₆ H ₁₃	4c	82	<i>n</i> -C ₆ H ₁₃	7c	68
<i>c</i> -C ₆ H ₁₁	4d	71	<i>c</i> -C ₆ H ₁₁	7d	77

^a For experimental details, see note 7. The spectral data for new compounds **4a–4d** and **7a–7d** are consistent with the structures proposed.

The formation of compound **7** suggests the intermediate formation of the rearranged borate complex **6**, and in Scheme 2 a possible reaction mechanism is reported that may account for the formation of a *gem* substituted diene. According to this hypothesis vinylborate interacts with the Pd catalyst and undergoes transfer of an alkyl group, which promotes the



Scheme 2 Proposed reaction mechanism.

formation of a new π allyl complex. At this stage a new 'ate' complex forms that undergoes the elimination reaction much faster than the phenyl transfer process.

In conclusion, these results indicate that depending on the experimental conditions 1,1-dialkyl substituted buta-1,3-dienes, 1-ethoxy-1-alkylbuta-1,3-dienes and α,β -unsaturated ketones can be selectively prepared. Extension to other organoboron intermediates (asymmetric ones, in particular) and synthetic applications for these functionalized synthons, as well as mechanistic studies to check the role of the palladium complex and iodobenzene, are currently in progress in our group.¹⁰

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- 7 Typical run: to a cooled solution ($-95\text{ }^{\circ}\text{C}$) of *t*-BuOK (1.4 g, 12.5 mmol) in anhydrous THF (10 ml) acetal **1** (0.72 g, 5.0 mmol) and BuLi (7.8 ml, 12.5 mmol) were consecutively added dropwise under stirring. After 2 h the purple–red solution was treated with tributylborane (5.0 mmol, 5 ml, 1.0 M in THF). The solution was allowed to warm to $25\text{ }^{\circ}\text{C}$ and then added to a THF solution of $\text{C}_6\text{H}_5\text{I}$ (4.0 mmol)– $[(\text{C}_6\text{H}_5)_3\text{P}]_4\text{Pd}$ (0.058 g, 1 mol%). The reaction mixture was allowed to react for 8 h. After standard work up the crude product was purified by column chromatography to afford pure **7a**. δ_{H} (400 MHz; CDCl_3) 0.87 (t, *J* 6.5, 3 H), 0.90 (t, *J* 6.5, 3 H), 1.2–1.5 (m, 8 H), 2.05 (t, *J* 6.2, 2 H), 2.15 (t, *J* 6.2, 2 H), 4.95 (dd, *J* 10.0, 1.0, 1 H), 5.10 (dd, *J* 16.0, 10.0, 1 H), 5.85 (d, *J* 10.0, 1 H), 6.60 (dt, *J* 16.0, 10.0, 1 H); δ_{C} (100.4 MHz; CDCl_3) 14.1, 22.7, 22.9, 29.8, 30.4, 30.5, 31.1, 37.0, 114.4, 125.3, 128.3, 133.4, 144.6.
- 8 Organoboron reagents have been used in the preparation of alkylidene-cycloalkanes and *trans* disubstituted alkenes. See, G. Zweifel and R. P. Fisher, *Synthesis*, 1972, 557, and E. Negishi, J.-J. Katz and R. C. Brown, *Synthesis*, 1972, 555, respectively. Moreover, to our knowledge substituted and *gem*-dibutyl substituted buta-1,3-dienes have only been prepared in aqueous medium by the reaction of aldehydes and ketones with 1-chloro-3-iodopropene in the presence of zinc powder. See, T.-H. Chan and C.-J. Li, *Organometallics*, 1990, **9**, 2649.
- 9 We have carried out some control reactions ($\text{R} = n\text{-C}_4\text{H}_9$ and $\text{R} = c\text{-C}_6\text{H}_{11}$) in the presence of catalytic amounts (ranging from 5 to 10% with respect to acetal **1**) of PhI. The reactions proceed in good yields, but longer reaction times are needed.
- 10 In order to assess the role of the catalyst, in accordance with the suggestion of one of the referees, we have carried out a reaction in the presence of a Pd(II) complex. In particular we have repeated the synthesis of compound **7d** ($\text{R} = c\text{-C}_6\text{H}_{11}$) using $\text{Pd}(\text{AcO})_2$ as a catalyst. The reaction takes place, but the product was obtained with a quite lower yield (by GC).