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Formation of α,β-Unsaturated Carbonyl Compounds by Palladium-Catalyzed Oxidation of Allylic Alcohols

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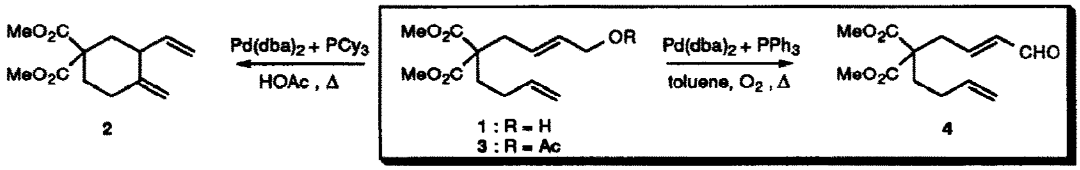
Abstract: Treatment of allylic alcohols with catalytic amounts of palladium catalysts in the presence of oxygen leads to the formation of α,β-unsaturated carbonyl compounds.

Allyl alcohols have been seldom used as substrates for the palladium-catalyzed allylic alkylation.[1,2] Substrates with better leaving groups such as acetates, carbonates, and halides, are preferred for the formation of intermediate η^3-allyl palladium complexes under catalytic conditions.[1] As part of a study on the application of the recently developed intramolecular olefin allylation[3,4] we examined the behaviour of allyl alcohol **1** in the formation of a six-membered ring.[5] Treatment of **1** with Pd(dba)$_2$ (dba = dibenzylindeneacetone) (10 %) and PPh$_3$ (30 %) in acetic acid under reflux gave only traces of the desired cyclohexane **2**. The major product was the acetate **3** (90-100 % yield), formed by esterification of the alcohol. Addition of a catalytic amount of trifluoroacetic acid led to **2** in 10-24 % yield, along with **3** as the major product. A 62 % yield of **2** was achieved with Pd(dba)$_2$-PPh$_3$ in refluxing toluene in the presence of the stronger acid camphorsulfonic acid (1 equiv). A similar yield (65 %) was obtained when **1** was treated with catalyst prepared from Pd(dba)$_2$ and tricyclohexylphosphine (PCy$_3$) in refluxing acetic acid for 20 h.



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1 : R = H
3 : R = Ac

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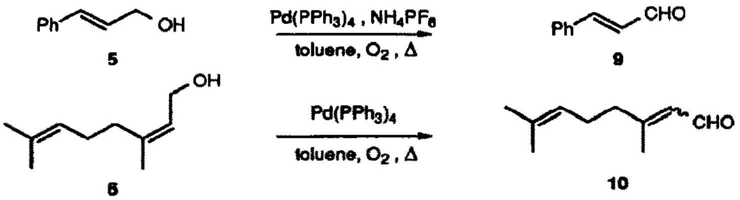
Surprisingly, heating of **1** in toluene (110 °C) with Pd(dba)$_2$ (10%) and PPh$_3$ (30 %) in the absence of acids and in the presence of air led to the α,β-unsaturated aldehyde **4** in 38 % isolated yield (61 % based on unrecovered starting material). Similar results were obtained with Pd(PPh$_3$)$_4$ as the catalyst. Cinnamyl alcohol (**5**), nerol (**6**), and secondary alcohols **7** and **8** furnished the corresponding α,β-unsaturated carbonyl compounds **9** (90 %), **10** (56 % at 63 % conversion, 3:1 *E/Z* mixture), **11** (40 %), and **12** (50 %),[6] respectively.



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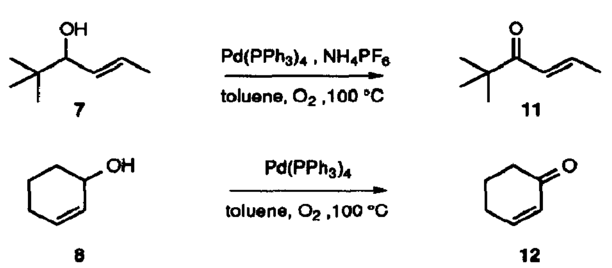
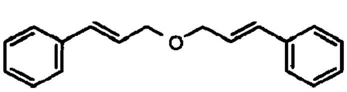


The palladium-catalyzed oxidation of cinnamyl alcohol (**5**) in the presence of air was studied in more detail. Heating of **5** in toluene under reflux for 3 days with $Pd(PPh_3)_4$ as the catalyst (10 %) furnished a mixture of **9** (18 %), 3-phenylpropanal (3%), and regioisomeric diallyl ethers **13** (69 %) and **14** (2 %). The reactions of (*E*)-crotyl alcohol and 3-methyl-2-buten-1-ol (prenol) gave also the corresponding diallyl ethers as the major products. The yield of **9** increased up to 39 % when the reaction was carried out in the presence of K_2CO_3 (0.1 mol). The best result was obtained by NH_4PF_6 (0.1 mol) leading to (**9**) in 90 % yield.[7]



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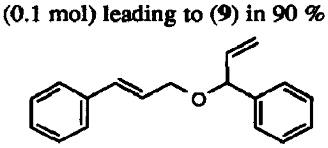

14

The observed oxidation has a precedent in the oxygenation under UV light of (η^3-allyl)palladium complexes in acetonitrile discovered by Muzart.[8,9] This oxygenation could also be performed catalytically from allyl silanes to give allyl alcohols or α,β-unsaturated carbonyl compounds in acetone solutions,[8c] in a process that does not involve the formation of free-radicals.[8e] However, the oxidations described herein proceed from readily available allyl alcohols in a less polar solvent and, more significantly, in the dark. Further work directed towards an understanding of the mechanism of the formation of α,β-unsaturated carbonyl compounds is underway.

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