A new procedure for the isomerisation of substituted and unsubstituted allyl ethers of carbohydrates

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Treatment of tris(triphenylphosphine)rhodium(I) chloride with butyllithium results in a rhodium catalyst which is able to isomerise a wide range of substituted and unsubstituted allylic ethers.

Since the pioneering work of Gigg *et al.*,[1] the prop-2-enyl (allyl) ether has found general use as a temporary hydroxy protecting group. This blocking group has a broad chemical stability and can be introduced and removed under mild conditions.[2] For example, allyl ethers can be isomerised with tris(triphenylphosphine)rhodium(I) chloride (Wilkinson's catalyst) in a refluxing mixture of ethanol–water to give the corresponding prop-1-enyl ethers (enol ethers)[3] which can be cleaved by different reagents.[2] However, a drawback of this rhodium catalyst is that under the reaction conditions, the allyl ether is partly reduced to the propyl ether.[4] Furthermore, the mild base, diazabicyclo-[2,2,2]octane (dabco), has to be included to avoid hydrolysis of the enol ether since the aldehyde produced poisons the catalyst. Prior to hydrolysis of the enol ether, the dabco has to be removed by basic alumina column chromatography. Other transition metals have been used for this transformation with varying success.[2] Also, strong basic conditions have been applied to isomerise allyl ethers.[2]

Recently, we reported[5] a novel glycosylation strategy which is based on isomerisation of but-3-en-2-yl glycosides to give but-2-en-2-yl glycosides which, in turn, can undergo a Lewis acid-catalysed glycosylation reaction. The latter isomerisation could only be performed by Wilkinson's catalyst. The drawbacks associated with this catalyst led us to search for an alternative isomerisation procedure.

Motherwell *et al.* have shown[6] that in the presence of Wilkinson's catalyst, a wide range of allylic alkoxides in THF can be isomerised to enolates which may undergo *in situ* aldol condensations with ketones. Wilkinson's catalyst in THF, however, is unable to isomerise allylic alcohols.[7] Therefore, we expected that under the applied reaction conditions, the rhodium catalyst was being converted into another more reactive catalytic species.

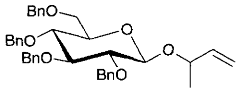
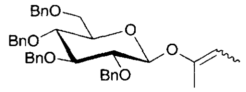
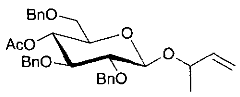
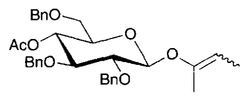
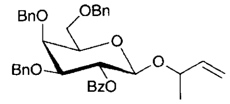
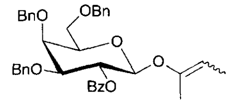
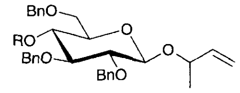
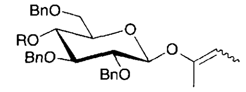
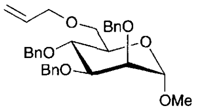
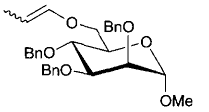
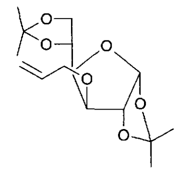
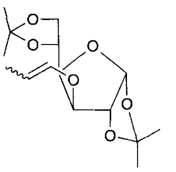
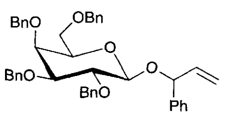
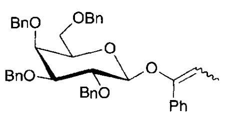
We describe here that the reaction of Wilkinson catalyst with butyl lithium (BuLi) results in a rhodium catalyst which can isomerise a wide range of unsubstituted and substituted allyl ethers without the drawbacks mentioned above.

Thus, treatment of (but-3-en-2-yl)-2,3,4,6-tetra-*O*-benzyl-β-D-glucoside in THF with the catalyst, followed by workup and purification, gave pure enol ether† in an excellent yield of 92%.‡ The unpurified enol ether could also be cleaved by treatment with $HgCl_2$–HgO in acetone to give the corresponding lactol in high yield (93%). It is important to note that BuLi alone failed to promote a reaction proving that the isomerisation is not catalysed by the base. In order to find out whether reduction of the allyl ether to a propyl ether can occur, the allyl glycoside was subjected to the reaction conditions [$Rh(PPh_3)_3Cl$–BuLi in refluxing THF] for a prolonged period of time (16 h). ^1H NMR spectroscopy and FAB-MS of this product did not reveal the presence of any reduced material and the isomerised compound was isolated in high yield.

It was found that the new method is also applicable to derivatives which contain base sensitive acetyl and benzoyl protecting groups (entries 2 and 3). The procedure also gave satisfactory results for anomeric allyl glycosides of disaccharides (entry 4). Furthermore, unsubstituted allyl ethers can smoothly be converted into the corresponding prop-1-enyl ethers (entry 5 and 6). In these cases, the isomerisation reaction was completed within 5 min. Finally, it was shown that a phenyl substituted allyl moiety can be smoothly converted into the analogous vinyl species (entry 7).

We believe that under the applied reaction conditions, the chloride of the Wilkinson's catalyst is substituted by a butyl group which undergoes a β-hydride shift to give hydrido tris(triphenylphosphine)rhodium(I). This rhodium species has been described[8,9] and we have prepared $Rh(PPh_3)_3$ (H) by a known procedure.[9] The catalyst thus obtained was also able to isomerise allyl ethers and glycosides at similar reaction rates as

Table 1 Isomerisation of allyl ethers and glycosides with modified Wilkinson catalyst

Entry	Starting material	Product	Yield (%)
1			92
2			87
3			91
4	 R = 2,3,4,6-tetra-*O*-benzylglucosyl	 R = 2,3,4,6-tetra-*O*-benzylglucosyl	90
5			91
6			93
7			83

for the procedure described above and furthermore the products were isolated in similar yields.

The data reported here show that treatment of tris(triphenylphosphine)rhodium(I) chloride with BuLi results in a rhodium catalyst which can isomerise a wide range of allyl ethers and does not have the drawbacks associated with the use of Wilkinson's catalyst. Preliminary results have shown that this new catalyst allows a one-pot procedure for isomerisation and glycosylation of substituted anomeric allyl glycosides. Studies to prove the proposed identity of the catalyst are underway.

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Footnotes

† All new compounds gave satisfactory elemental analyses and mass spectroscopic and ^{1}H and ^{13}C NMR spectroscopic data.

‡ *General procedure*: tris(triphenylphosphine)rhodium(I) chloride (5–10 mol%) was dissolved in freshly distilled THF. The solution was thoroughly degassed and placed under an atmosphere of argon. Butyllithium [1.6 mol dm^{-3} in hexanes, 1.5 equiv. to Rh(PPh$_3$)$_3$Cl] was added to the solution and stirring was continued for 10 min. The catalyst was added by cannula to a degassed solution of the allyl glycoside in THF and the resulting reaction mixture was heated under reflux for 10 min. The mixture was concentrated under reduced pressure and the residue was filtered through a path of neutral silica gel (flash silica gel ES70X from Crosfield Catalysts, Warrington, UK) or used immediately in the next reaction step.

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