

# Nickel-catalyzed generation of 2-methylhex-5-enyl ethers from allyl ethers with trimethylaluminum

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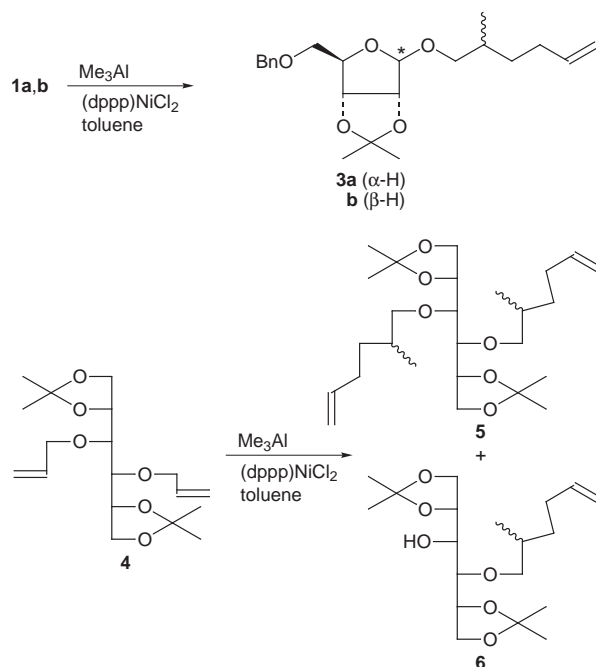
Allyl ethers have been converted into the corresponding 2-methylhex-5-enyl ethers in one step on treatment with trimethylaluminum in the presence of a catalytic amount of (dppp)NiCl<sub>2</sub>.

We recently found that allyl ethers **1** are cleaved facilely and selectively to give the alcohols **2** with expulsion of propene on treatment with DIBAL-H in the presence of a catalytic amount of dichloro[bis(diphenylphosphino)propane] nickel [(dppp)NiCl<sub>2</sub>] in an aprotic solvent<sup>1</sup> (Scheme 1). The reaction may be applied to allyl acetals, such as **1a,b**, using triethylaluminum in place of DIBAL-H to give the same hemiacetal mixture **2a/b**, in good yield, without causing reduction of the hemiacetal functionality, although the fate of the allyl functionality was uncertain<sup>1</sup> (Scheme 2). We report here an unprecedented type of C–C bond formation reaction which was observed during the examination of the reaction of the allyl acetals **1a,b** with trimethylaluminum in place of triethylaluminum in the presence of the same nickel catalyst.

Thus, when the α-H allyl acetal **1a** was treated with trimethylaluminum (1.3 equiv.) in the presence of (dppp)NiCl<sub>2</sub> (2 mol%) in toluene at 0 °C to room temperature for 0.5 h, an inseparable mixture of **3a**‡ consisting of two diastereomers was generated in a substantial yield as well as the expected hemiacetal mixture **2a/b**. On the same treatment, the β-H epimer **1b** gave the diastereoisomeric mixture **3b** consisting of two diastereomers and the same hemiacetal mixture **2a/b** above. The sugar moiety, including the hemiacetal stereochemistry, of the products was recognized to be unchanged during the reaction by examination of <sup>1</sup>H NMR and mass spectra which indicated that the change occurred in the allyl moiety of **1** with an increment of 56 mass numbers attributed to one Me on a tertiary stereogenic center and one allyl unit. It was also concluded that the reaction that occurred was essentially a dimerization and, therefore, the yields of **3a,b** were calculated as 61 and 60%, respectively. The same reaction occurred with another sugar derivative **4** having a bis-allyl ether moiety in the molecule to give the bis(2-methylhex-5-enyl) ether **5** and the mono-2-methylhex-5-enyl ether **6** both as diastereomeric mixtures in yields of 10 and 40% as well as 34% of the double

deallylated diol in the presence of 2.6 equiv. of trimethylaluminum (Scheme 3).

The other simple allyl ethers **1c–l**, those that gave the corresponding alcohols **2c–l** with DIBAL-H and (dppp)NiCl<sub>2</sub>, were, therefore, subjected to the same reaction with trimethylaluminum in the presence of (dppp)NiCl<sub>2</sub> and it was found that all but the aryl ether gave the corresponding products having the same ether moiety in addition to the corresponding deallylated products. The aryl ether gave the phenol quantitatively as the sole product. Most importantly, neither the coupling reaction nor the cleavage reaction occurred at all in the absence of

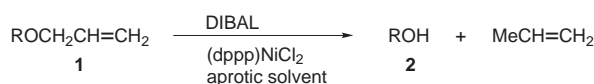


Scheme 3

Table 1 Reaction of allyl ethers **1** with Me<sub>3</sub>Al and (dppp)NiCl<sub>2</sub>

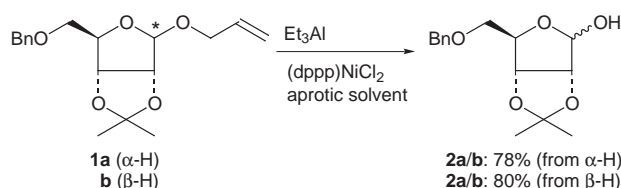
Entry	Substrate <b>1</b>	Product <b>3</b>	R	Yield <sup>a</sup>
1	<b>a</b>	<b>a</b> <sup>b</sup>	Scheme 3	61 <sup>c</sup>
2	<b>b</b>	<b>b</b> <sup>b</sup>	Scheme 3	60 <sup>c</sup>
3	<b>c</b>	<b>c</b>	HO(CH <sub>2</sub> ) <sub>2</sub> O	27
4	<b>d</b>	<b>d</b>	HO(CH <sub>2</sub> ) <sub>3</sub> O	27
5	<b>e</b>	<b>e</b>	4-MeOPh	0
6	<b>f</b>	<b>f</b>	PhCH <sub>2</sub>	45 <sup>c</sup>
7	<b>g</b>	<b>g</b>	PhCH <sub>2</sub> CH <sub>2</sub>	42 <sup>c</sup>
8	<b>h</b>	<b>h</b>	AcO(CH <sub>2</sub> ) <sub>4</sub>	44 <sup>c</sup>
9	<b>i</b>	<b>i</b>	Ph <sub>2</sub> CH	30 <sup>c</sup>
10	<b>j</b>	<b>j</b>	Me <sub>2</sub> C=CHCH <sub>2</sub> O(CH <sub>2</sub> ) <sub>4</sub>	39 <sup>c</sup>
11	<b>k</b>	<b>k</b>	(S)-PhCHMe	42 <sup>c</sup>
12	<b>l</b>	<b>l</b>	THP	48 <sup>c</sup>

<sup>a</sup> Isolated yield after SiO<sub>2</sub> column chromatography. <sup>b</sup> Obtained as a diastereomeric mixture. <sup>c</sup> Yield was calculated based on consumption of 2 equiv. of the substrate per product.

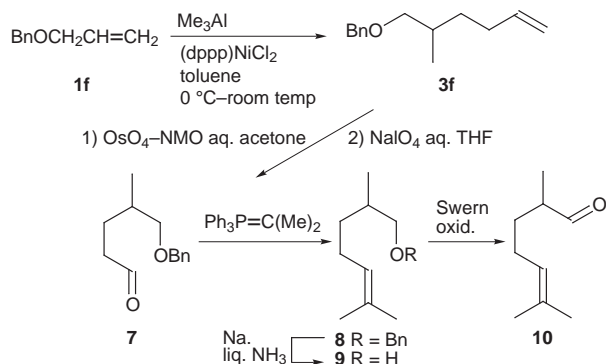


R = alkyl, allyl, aryl

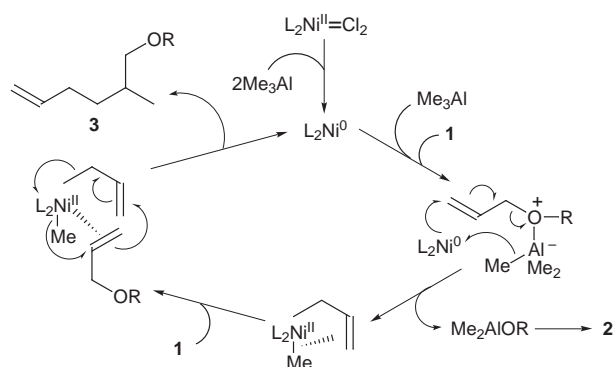
Scheme 1



Scheme 2



Scheme 4



Scheme 5

(dppp)NiCl<sub>2</sub> and only the cleavage reaction occurred when triethylaluminium in place of trimethylaluminium was used under the same catalytic conditions (Table 1).

To confirm the structure of the products **3a–l**, the benzyl ether **3f** generated from allyl benzyl ether **1f** was transformed into the known compound ( $\pm$ )-norcitronellal<sup>2</sup> **10** in 69% overall yield *via* sequential olefin cleavage, Wittig condensation, reductive debenzoylation and oxidation through the aldehyde **7**, the ether **8** and the alcohol **9**. This confirmed unambiguously the structure of the common ether half as a 2-methylhex-5-enyl functionality (Scheme 4).

Formation of the 2-methylhex-5-enyl functionality indicated that a concurrent regioselective addition of a methyl moiety from trimethylaluminium and of the allyl moiety from the substrate allyl ether to the allyl double bond of another molecule of the substrate occurred under the conditions used. It is plausible that the reaction was initiated by generation of a Ni<sup>0</sup> complex<sup>3</sup> which led to formation of an allyl–methyl–Ni<sup>II</sup> complex by reaction with trimethylaluminium and an allyl ether to induce the ether cleavage at the first stage. The complex then interacted with another molecule of allyl ether to allow the regioselective addition<sup>4</sup> of the methyl and allyl functionalities from Ni<sup>II</sup> to the allyl ether double bond *via* a reductive elimination pathway that reformed the Ni<sup>0</sup> complex (Scheme 5).

## Notes and References

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‡ All new compounds had spectroscopic [IR, <sup>1</sup>H NMR, mass] and analytical (HRMS) data consistent with the assigned structure.

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