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ORGANOLITHIUM ADDITIONS TO ALLYLIC ALCOHOLS

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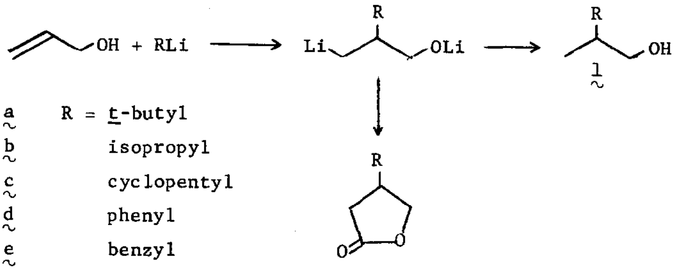
Simple organolithium reagents do not generally add to nonconjugated olefins[1]; although instances of such reactions have been reported in which particularly strained olefins were used,[1,2] a substantially more stable organolithium species was formed,[1,4] or the reaction was intramolecular in nature[5]. In contrast, we now find that the lithium salts of allylic alcohols add these reagents readily in one of two useful manners depending on the structure of the alcohol.

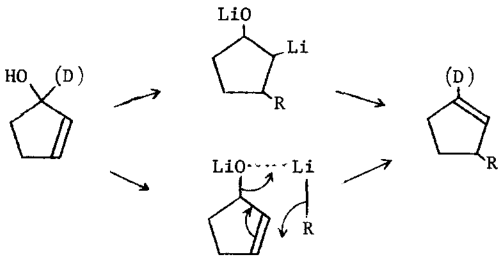
Allyl alcohol combines with a variety of organolithium species upon exposure in hydrocarbon solvents for several hours to produce the corresponding 2-alkyl or aryl-1-propanols (**1**). The isomeric alcohols derived from the alternate mode of addition, or (*vide infra*) the olefinic materials expected from this process, were not found in appreciable amounts. *t*-Butyllithium gave a 22% yield of **1a**; isopropyllithium, 48% of **1b**; cyclopentyllithium, 34% of **1c**; phenyllithium, 40% of **1d**[6]; benzyllithium, 60% of **1e**[6]; and *n*-butyllithium, only 4% of **1f**. Fortunately, a dramatic enhancement of the last product was promoted by the presence of 0.2 equivalents of TMEDA[6] such that a 72% yield of distilled **1f** was obtained in a preparative reaction. On the other hand, the *t*-butyllithium reaction was not materially affected by TMEDA. Deuterium oxide quenching of the *t*-butyllithium reaction and subsequent mass-spectral analysis of the acetate of **1a** demonstrated that the indicated organolithium species was indeed an intermediate[7]. The synthetic potential of this addition reaction when combined with the available myriad of further organometallic transformations of the intermediate is obvious. By way of illustration the *n*-butyllithium adduct was poured onto Dry Ice and then treated with acid to produce β-*n*-butyl-γ-butyrolactone[8].



a R = *t*-butyl
b isopropyl
c cyclopentyl
d phenyl
e benzyl
f *n*-butyl

The lithium alkoxide function of the olefinic substrate is thought to be instrumental in promoting reaction and in controlling the addition to give the more stable primary organometallic. This is in opposition to the suggested mode of addition of isopropyllithium to propylene[3] which is proposed to give oligomeric product by preferential attack at the least hindered olefinic carbon. Since the lithium alkoxides and alkyllithium reagents undoubtedly exist as mixed aggregates in hydrocarbon solutions,[9] it appears that reaction is facilitated by preliminary complexation.

Allylic alcohols substituted at the γ-position cannot generate a primary organolithium adduct in the manner described for the parent compound. Nonetheless ready reaction is observed, but in this instance an unusual and unexpected conversion obtains as illustrated below for 2-cyclopentenol. This compound is transformed to 3-alkylcyclopentenes in a reaction reminiscent of the interaction of allylic halides and organometallics[10]. The same range of alkyllithium reagents is effective in this process and TMEDA again promotes the sluggish *n*-butyllithium addition which produced distilled 3-*n*-butylcyclopentene in 63% yield.



Use of cyclopentenol specifically labelled with deuterium at the carbinol carbon allowed for the demonstration that replacement of the alkoxy function by the alkyl group had proceeded with simultaneous double bond migration. Analysis of the product from n-butyllithium addition was nicely effected by deuterium magnetic resonance spectroscopy[11] which clearly indicated olefinic deuterium (at δ 5.76 relative to TMS-d_3) but none attached to saturated carbon. A control experiment showed that cyclopentene does not add alkyllithium reagents under the reaction conditions either by itself or in the presence of an equivalent amount of cyclopentanol, thereby illustrating the necessity of the intramolecular alcohol function for reaction to occur. Hence, we conclude that reaction again takes place within a mixed lithium alkyl-alkoxide aggregate probably via either a cyclic six-center process or an addition-elimination mechanism involving the opposite addition orientation to that found for allyl alcohol. Both of these mechanistic possibilities derive substantial driving force from the thermodynamically favorable production of lithium oxide[12].

We are currently engaged in exploring the mechanism, stereochemistry, and synthetic potential of these interesting new organometallic reactions.

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6. N,N,N′,N′-Tetramethylethylenediamine. The efficacy of this bidentate complexing agent in increasing the reactivity of organolithium reagents is attested to by a host of recent papers. For example: A. W. Langer, Trans. N.Y. Acad. Sci., **27**, 741 (1965); G. G. Eberhardt and W. A. Butte, J. Org. Chem., **29**, 2928 (1964); H. E. Zieger and E. M. Laski, Tetrahedron Letters, 3801, (1966). See also: technical literature on organometallic-amine complexes, Foote Mineral Company. Compounds **1d** and **1e** were prepared by addition of allyl alcohol to solutions of phenyl and benzyllithium prepared by reaction of *n*-butyllithium - TMEDA with excess benzene and toluene respectively.

7. Owing to a very small parent ion in the mass spectrum of this compound, an estimate of deuterium incorporation was obtained from the M-CH$_3$ peaks assuming that only non-deuterated methyl groups were lost. This treatment gives a minimum value of 83% d_1 which should be corrected upward to compensate for mass-spectral loss of CH$_2$D.

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