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# Potassium Allyl- and Crotyltrifluoroborates: Stable and Efficient Agents for Allylation and Crotylation

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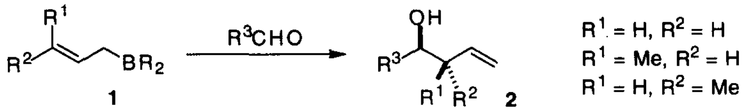
***Abstract:*** Potassium allyl- and crotyltrifluoroborates react rapidly with aldehydes in the presence of $BF_3{\cdot}Et_2O$. These salts are stable to air and moisture, and lead to adducts in high yield and with high diastereoselectivity. The stereochemistry of the crotylated products is consistent with the reaction via allylboron difluoride and a Zimmerman-Traxler like transition state. © 1999 Elsevier Science Ltd. All rights reserved.

Allylation and crotylation reactions of aldehydes are widely employed in organic synthesis, due to the versatility of homoallylic alcohols as synthetic intermediates.[1,2] A variety of different organometallic reagents have been used, including those derived from Li, B, Mg, Al, Si, Ti, Cr, Zn, Zr, In, Sn, etc. Allyl- and crotylboron compounds are particularly useful reagents, leading to adducts in high yield, with excellent levels of stereocontrol (Scheme 1).[3] There are two main classes of these reagents, allyl/crotyl dialkylboranes and allyl/crotyl boronates, but at the present time only one reagent is commercially available, allyl pinacol boronate.[4] Other allyl- and crotylboron compounds are usually prepared immediately prior to use, since subsequent storage and handling of these compounds can be difficult, due to sensitivity to air and/or moisture. As part of our ongoing research in organoboron chemistry,[5] we now report a new class of allyl- and crotylboron compounds, potassium allyl- and crotyltrifluoroborates, and their Lewis acid catalyzed addition to carbonyl compounds.



**Scheme 1**

Organotrifluoroborates ($RBF_3M$, M = alkali metal) have received little attention with regard to their application in organic synthesis.[6] These salts are more readily isolated than the corresponding boronic acids, and are also air and water stable.[7] Recently, Vedejs and co-workers reported the facile preparation of potassium aryltrifluoroborates ($ArBF_3K$) using $KHF_2$ and showed them to be useful precursors for the formation of arylboron difluoride Lewis acids.[6a] Inspired by this work, we reasoned that potassium allyltrifluoroborate should be a convenient precursor for the *in situ* formation of *allylboron difluoride*, and its subsequent addition to aldehydes.[6a,8] This species has been theoretically predicted to have higher reactivity in allylation processes.[9]

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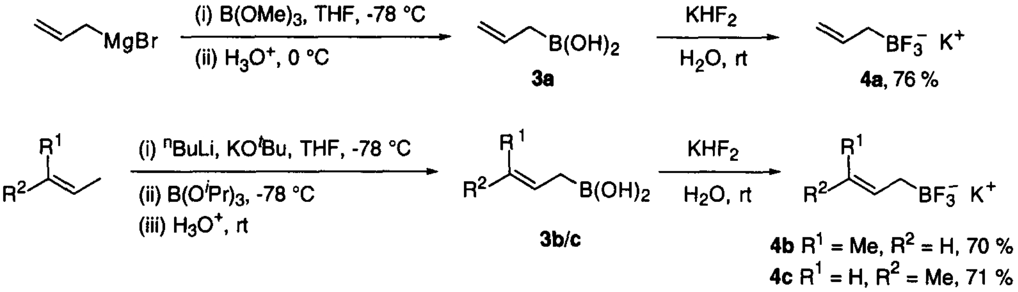
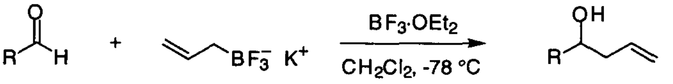
The formation of the potassium allyl- and crotyltrifluoroborates **4** was achieved via the corresponding boronic acids, in an analogous manner to that used for the synthesis of other potassium trifluoroborate salts (Scheme 2). The requisite allyl- and crotylboronic acids **3** were readily synthesized using established literature protocols involving the addition of either allylmagnesium bromide[10] or crotylpotassium[11] to triisopropyl borate followed by acidic hydrolysis. Subsequent conversion to the potassium allyl- or crotyltrifluoroborates **4**[12] was achieved by treatment with aqueous $KHF_2$ followed by recrystallization from acetonitrile.[6a] The salts **4** are crystalline solids, which are air and water stable, and can be stored for extended periods without special precautions.[13]



**Scheme 2**

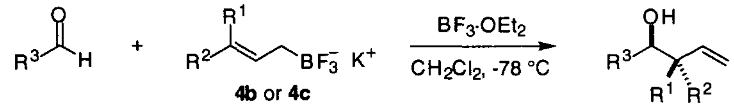
Initial attempts to add potassium allyltrifluoroborate to simple aldehydes using TMSCl as a Lewis acid promoter yielded the desired adducts in moderate yields only after prolonged reaction times. However, with 2 equiv. of $BF_3{\cdot}OEt_2$, allylation proceeded very rapidly at -78 °C in ether or dichloromethane, with full conversion achieved within 15 minutes.[14] Both aryl and alkyl aldehydes were allylated in this manner, giving homoallylic alcohols in high isolated yields (Table 1).



| Entry | R | Yield [%] |
|---|---|---|
| 1 | *n*-$C_7H_{15}$ | 82 |
| 2 | (*E*)-Ph-CH=CH– | 89 |
| 3 | Ph | 93 |
| 4 | 4-$MeOC_6H_4$ | 95 |
| 5 | 4-$MeSC_6H_4$ | 90 |
| 6 | 4-$NCC_6H_4$ | 95 |
| 7 | 4-$O_2NC_6H_4$ | 96 |
| 8 | 3,4-$Cl_2C_6H_3$ | 85 |
| 9 | 3-MeO-4-$HOC_6H_3$ | 84 |

**Table 1. Allylation of Aldehydes with Potassium Allyltrifluoroborate**

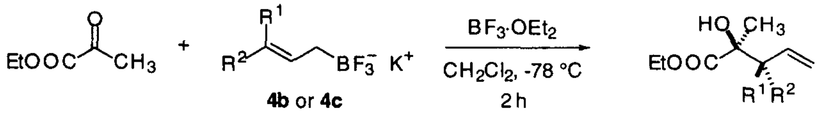
The process can also be achieved in comparable yield using catalytic quantities of $BF_3{\cdot}OEt_2$ (1 mol%). The reaction is not as rapid, with full conversion achieved after 3 hours at room temperature. Reaction of the salts does not occur in the absence of a Lewis acid catalyst even at elevated temperatures. This feature distinguishes the reactivity of **4** from most allylboron compounds, which do not require such activation. Crotylation using potassium (*E*)- and (*Z*)-crotyltrifluoroborate was found to work equally well using either stoichiometric or catalytic $BF_3{\cdot}OEt_2$, and led to products with excellent levels of stereocontrol (Table 2). The (*Z*)-crotyltrifluoroborate **4b** consistently gave rise to the *syn* diastereomer, whereas the (*E*)-crotyltrifluoroborate **4c** gave the *anti* product. Each of these observations is consistent with the intermediacy of allylboron difluoride, formed *in situ* by Lewis acid promoted removal of fluoride from the salts **4**, and addition via a Zimmerman-Traxler like transition state.



| Entry | $R^1$ | $R^2$ | $R^3$ | d.r. | Yield [%] |
|---|---|---|---|---|---|
| 1 | Me | H | $n$-$C_7H_{15}$ | > 98 : 2 | 74 |
| 2 | H | Me | $n$-$C_7H_{15}$ | > 98 : 2 | 84 |
| 3 | Me | H | Ph | > 98 : 2 | 91 |
| 4 | H | Me | Ph | > 98 : 2 | 94 |
| 5 | Me | H | 4-$MeOC_6H_4$ | 96 : 4 | 91 |
| 6 | H | Me | 4-$MeOC_6H_4$ | 97 : 3 | 91 |
| 7 | Me | H | 4-$O_2NC_6H_4$ | > 98 : 2 | 95 |
| 8 | H | Me | 4-$O_2NC_6H_4$ | > 98 : 2 | 96 |

**Table 2. Crotylation of Aldehydes with Potassium Crotyltrifluoroborate**

This methodology can also be applied to the allylation of pyruvates. Earlier studies with (*E*)-crotyl-9-BBN had displayed only moderate diastereoselectivity (d.r. = 73 : 27) in the reaction with methyl pyruvate.[15] By contrast, the use of both the (*Z*)- and (*E*)-potassium crotyltrifluoroborate salts under the standard conditions, resulted in the efficient crotylation of ethyl pyruvate in 90% and 92% isolated yields respectively, and with excellent diastereoselectivity in both cases (d.r. > 98 : 2) (Scheme 3).



$R^1$ = Me, $R^2$ = H, 90 %
$R^1$ = H, $R^2$ = Me, 92%

Scheme 3

The viability of potassium allyl- and crotyltrifluoroborates as air and moisture stable reagents for allylation and crotylation has been demonstrated. These reagents offer several advantages over existing allylboration reagents, including rapid and high yielding additions, and in the case of crotylation reactions, excellent levels of diastereocontrol. Further synthetic and mechanistic studies on these reagents, and related compounds will be reported in due course.

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12. Spectral data for potassium allyltrifluoroborate: $^1$H NMR ($CD_3CN$) $\delta$ 6.08 (1H, m), 4.83 (1H, d, *J* = 17.0 Hz), 4.74 (1H, d, *J* = 10.0 Hz), 1.20 (2H, s); $^{13}$C NMR ($CD_3CN$) $\delta$ 142.82, 111.12, 27.20.
13. The salts can be stored at room temperature in plastic bottles.
14. The allylation of 4-nitrobenzaldehyde with potassium allyltrifluoroborate is representative: To a suspension of the borate (200 mg, 1.35 mmol) and the aldehyde (102 mg, 0.676 mmol) in $CH_2Cl_2$ (15 mL) cooled to -78 °C was added $BF_3{\cdot}OEt_2$ (0.17 mL, 1.35 mmol). The reaction mixture was stirred for 15 min at -78 °C prior to quenching with sat. aqueous. $NaHCO_3$ (7 mL). The reaction mixture was then allowed to warm to room temperature. The layers were separated, and the aqueous layer extracted with $CH_2Cl_2$ (3 x 10 mL). The combined organic extracts were dried ($MgSO_4$), filtered and concentrated *in vacuo* to afford a clear, colorless oil. Column chromatography on a short plug of silica gel (10% EtOAc / 90% hexanes) afforded 1-(4-nitrophenyl)-but-3-en-1-ol as a clear, colorless oil (124 mg, 96% yield).
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