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An Exceptional Hydroboration of Substituted Fluoroolefins Providing Tertiary Alcohols

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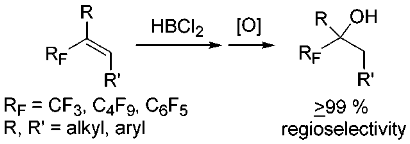
ABSTRACT



$R_F = CF_3, C_4F_9, C_6F_5$
R, R' = alkyl, aryl

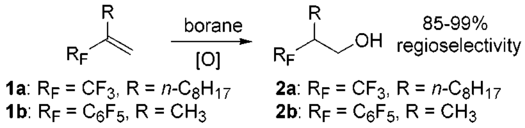
≥99 %
regioselectivity

A rare hydroboration–oxidation providing 3°-alcohols has been achieved in the case of 1,1,2-perfluoroalkyl(aryl)ethylenes. The hydroboration of substituted perfluoroalkyl(aryl)ethylenes with dichloroborane reveals that the regioselectivity does not entirely depend on the electronics of the fluoroolefins.

Organoboranes derived from the hydroboration of olefins are extremely useful intermediates in organic syntheses. However, relatively little of this chemistry has been utilized to prepare fluoroorganic compounds.[1] Recently, we reported the regioselective, stoichiometric, and catalytic hydroborations of perfluoroalkyl(aryl)ethylenes ($R_FCH{=}CH_2$).[2] While the former afforded Markovnikov products, either regioisomer can be obtained via catalytic hydroboration with an appropriate combination of rhodium catalysts and boranes.[2b] Continuing our "organoboranes for fluoroorganic synthesis" program, the hydroboration of a representative series of 1,1-, 1,2-, and 1,2,2-substituted fluorinated olefins was examined. This study revealed a rare hydroboration resulting in the formation of 3°-alcohols.

The required olefins were prepared as reported by us earlier.[3] The hydroboration−oxidation of a representative 1,1-disubstituted fluoroolefin, 2-*n*-octyl-3,3,3-trifluoropropene (**1a**), with $BH_3{\cdot}THF$ and $HBCl_2$ afforded the 1°-alcohol (**2a**) in 82% and 90% isolated yields, respectively, with 85% regioselectivity. Improved regioselectivity was achieved by increasing the steric bulk of the borane reagent. Thus, hydroboration of **1a** with *n*-hexyl-, cyclohexyl-, and *tert*-hexylchloroborane showed gradual increase in regioselectivity; complete regioselectivity was achieved with thexylchloroborane. Similar results were obtained for the hydroboration of 1-methyl-2′,3′,4′,5′,6′-pentafluorostyrene (**1b**), which provided 92% of the 1°-alcohol (**2b**) in 86% yield with $HBCl_2$ and >99% of **2b** with ThxBHCl (Scheme 1). The results from the hydroboration of **1a** and **1b** are compiled in Table 1.

Scheme 1



1a: $R_F = CF_3$, R = n-C_8H_{17}
1b: $R_F = C_6F_5$, R = CH_3
2a: $R_F = CF_3$, R = n-C_8H_{17}
2b: $R_F = C_6F_5$, R = CH_3

On the basis of the >98% regioselectivity obtained for perfluoroalkyl terminal olefins,[2a] absolute regioselectivity was anticipated for the hydroboration of 1,2-disubstituted olefins. Indeed, hydroboration−oxidation of **1c**−**g** with $HBCl_2$

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[1] (a) Ichikawa, J.; Hamada, S.; Sonoda, T.; Kobayashi, H. *Tetrahedron Lett.* **1992**, *33*, 3779 and references therein. (b) Ramachandran, P. V.; Gong, B.; Brown, H. C. *J. Org. Chem.* **1995**, *60*, 61.

[2] (a) Brown, H. C.; Chen, G.-M.; Jennings, M. P.; Ramachandran, P. V. *Angew. Chem., Intl. Ed.* **1999**, *38*, 2052. (b) Ramachandran, P. V.; Jennings, M. P.; Brown, H. C. *Org. Lett.* **1999**, *1*, 1399.

[3] Jennings, M. P.; Cork, E. A.; Ramachandran, P. V. *J. Org. Chem.* **2000**, *65*, 8763.

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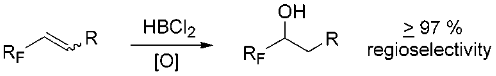
Table 1. Hydroboration of 1,1-Disubstituted Fluorinated Olefins with Boranes of Varying Electronic and Steric Environments

olefin	reagent	solvent	time, h	yield, %	3°/1°-ol[a]
1a	BH_3.THF	THF	5	82	14/86
1a	$HBCl_2$	hexane	inst.	90	15/85
1a	*n*-HexBHCl	hexane	4	72	7/93
1a	ChxBHCl	hexane	6	73	5/95
1a	ThxBHCl	hexane	6	65	1/99
1b	$HBCl_2$	hexane	1	86	8/92
1b	ThxBHCl	hexane	6	78	1/99

[a] Determined by a combination of ^{1}H NMR, ^{19}F NMR, and GC analyses.

provided the α-fluoroalkyl(aryl) alcohols (**2c**−**g**)[4] almost exclusively in 76−89% isolated yields. Even the presence of a phenyl group (**1d**, **1g**) did not alter the regioselectivity (Scheme 2).

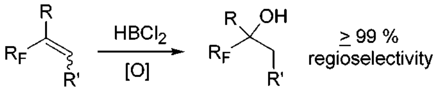
Scheme 2



1c: $R_F = n\text{-}C_4F_9$, $R = n\text{-}C_5H_{11}$ **2c**: $R_F = n\text{-}C_4F_9$, $R = n\text{-}C_5H_{11}$, 83%
1d: $R_F = n\text{-}C_4F_9$, $R = C_6H_5$ **2d**: $R_F = n\text{-}C_4F_9$, $R = C_6H_5$, 89%
1e: $R_F = CF_3$, $R = n\text{-}C_5H_{11}$ **2e**: $R_F = CF_3$, $R = n\text{-}C_5H_{11}$, 79%
1f: $R_F = C_6F_5$, $R = CH_3$ **2f**: $R_F = C_6F_5$, $R = CH_3$, 81%
1g: $R_F = C_6F_5$, $R = C_6H_5$ **2g**: $R_F = C_6F_5$, $R = C_6H_5$, 76%

The hydroboration of 1,1,2-trisubstituted perfluoroalkyl olefins revealed an exceptional reaction! On the basis of the results in Schemes 1 and 2, we expected that a combination of the steric and electronic effects in trisubstituted olefins would direct the boron to reside on both of the carbons. There have been reports that the stereoelectronic requirements of perfluoroalkyl groups are quite large in the various reactions studied.[5] Accordingly, we anticipated a slight preference for the β-carbon with respect to the fluoroalkyl moiety. However, the hydroboration of 6,6,7,7,8,8,9,9,9-nonafluoro-5-*n*-propylnon-4-ene (**1h**) with $HBCl_2$ furnished exclusively, by ^{1}H NMR analysis, the 3°-alcohol (**2h**)[6] in 82% isolated yield (Scheme 3). Such regioselective hydroborations at a tertiary position are rare.[7] The generality of this observation was demonstrated by hydroborating **1i**−**k**. In all of these cases, we obtained >99% of the 3°-alcohol.

Scheme 3



1h: $R_F = n\text{-}C_4F_9$, R, R' = $n\text{-}C_3H_7$ **2h**: $R_F = n\text{-}C_4F_9$, R, R' = $n\text{-}C_3H_7$, 82%
1i: $R_F = n\text{-}C_4F_9$, R, R' = $\text{-}(CH_2)_4\text{-}$ **2i**: $R_F = n\text{-}C_4F_9$, R, R' = $\text{-}(CH_2)_4\text{-}$, 88%
1j: $R_F = C_6F_5$, $R = C_2H_5$, $R' = CH_3$ **2j**: $R_F = C_6F_5$, $R = C_2H_5$, $R' = CH_3$, 84%
1k: $R_F = C_6F_5$, R, R' = $\text{-}(CH_2)_4\text{-}$ **2k**: $R_F = C_6F_5$, R, R' = $\text{-}(CH_2)_4\text{-}$, 76%

Clearly, boron is placed on the carbon with the perfluoroalkyl substituent as long as the difference in the degree of substitution is ≤ 1 as in a 2° vs 1°, 2° vs 2°, or 3° vs 2° carbon. When the selection is between a 3° and a 1° carbon, the sterics surrounding the carbon overtake the electronics of the perfluoroalkyl substituent.

It is known that the difference in sterics between a 3° and a 2° carbon is considerably more than the difference between a 2° and a 1° carbon.[8] Yet, the perfluoroakyl substituent controls the regioselectivity of hydroboration. Brown and Chandrasekharan have reported that haloboranes are very sensitive to minor electronic differences.[9] The hydroboration of fluoroolefins with dichloroborane provides another example of this phenomenon.

In conclusion, we have examined the hydroboration of substituted fluoroolefins and encountered a rare example of the formation of 3°-alcohols by stoichiometric hydroboration−oxidation.

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Supporting Information Available: A typical experimental procedure and spectral data for compounds **1a**−**b**, **1d**−**h**, **1j**−**k**, **2a**−**d**, **2f**−**h**, and **2j**. This material is available free of charge via the Internet at http://pubs.acs.org.

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(10) Contribution no.14 from the Herbert C. Brown Center for Borane Research