

Tetrabutylammonium and Polymer-supported Dihydrogen trifluoride: New Hydrofluorinating Reagents for Electrophilic Alkynes

Patrice Albert and Jack Cousseau*

Groupe de Recherche de Chimie Organique et Bio-organique, Institut de Recherches Scientifiques et Techniques, Université d'Angers, Bd Lavoisier, 49045 Angers Cedex, France

Tetrabutylammonium and polymer-supported dihydrogen trifluoride are readily accessible reagents which allow addition of HF to activated carbon-carbon triple bonds, thus leading to functional fluoroalkenes in good yields.

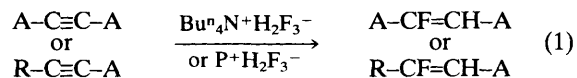
Functionalised fluoroalkenes, which are attractive molecules owing to their biological activity,^{1,2} are generally obtained in multi-step sequences.³⁻⁵ The addition of HF to activated $-C\equiv C-$ bonds should make similar compounds more accessible. However neither anhydrous HF,⁶ except when treated with $CF_3C\equiv CH$,⁷ nor amine-HF complexes investigated by Olah⁸ and Yoneda⁹ bring about this addition.

The $H_2F_3^-$ ion, in which the $H \cdots F$ hydrogen bonds appear to be much weaker than in HF_2^- ,¹⁰ might be expected to provide both the nucleophilic F^- and the electrophilic H^+ species. We report here that $Bu^4N^+H_2F_3^-$ and $P^+H_2F_3^-$ (P^+ = a polymeric cation from a macroreticular anion-exchange resin, e.g. Amberlyst A 26 or Amberlite IRA 900) can be used as efficient hydrofluorinating reagents towards electrophilic alkynes.

These stable and easily handled new dihydrogen trifluoride salts are obtained using a very simple method. The corresponding fluorides, $Bu^4N^+F^-$ dissolved in 1,2-dichloroethane (DCE), or the solid resin P^+F^- , are stirred in the presence of an aqueous saturated solution of HF-KF (2:1 ratio) (or HF-KHF₂). HF phase-transfer occurs and leads to the dihydrogen trifluoride salts which, after separation of the aqueous layer, are isolated from DCE (this solvent being added in the case of $P^+H_2F_3^-$) after distillation of the water-DCE azeotrope.

$Bu^4N^+H_2F_3^-$ and $P^+H_2F_3^-$ react smoothly at moderate temperatures with bis-activated $A-C\equiv C-A$ or mono-activated

$R-C\equiv C-A$ acetylenic bonds, generating the desired addition of HF according to equation (1). In all cases the reaction stops at the alkene stage; generally a mixture of the *Z*- and *E*-isomers of the fluoro-adduct $A-CF=CH-A$ or $R-CF=CH-A$ is obtained in good yields, a bigger proportion of *syn*-adduct being formed from the polymer-supported reagent. The results are summarized in Table 1.



R = alkyl or phenyl; A = nitrile, ester, ketone, aldehyde

The $H_2F_3^-$ ion seems to play a fundamental role in this reaction. We have observed that Olah's reagent does not add HF to $MeO_2CC\equiv CCO_2Me$ and that this ester is not readily transformed into *Z*- $MeO_2CCF=CHCO_2Me$ (max. 10-15%) under the action of $Bu^4N^+HF_2^-$. On the other hand, the dihydrogen trifluoride salts do not induce any addition of HF to simple alkynes which easily produce *gem*-difluoro alkanes by reaction with pyridine-HF, (1:10 mol. ratio).⁸ These results may be explained by the good nucleophilicity of the $H_2F_3^-$ ion, and the relatively weak $H \cdots F$ hydrogen bonds in this species.

In the aliphatic mono-activated series, a side-reaction occurs which is probably due to the slightly basic power of the $H_2F_3^-$ ion. The ester $Bu^4N^+C\equiv CCO_2Me$ leads to the two isomers

Table 1. Formation of fluoro-adducts A-CF=CH-A and R-CF=CH-A from acetylenic compounds A-C≡C-A and R-C≡C-A.

Acetylenic compound	Reaction with Bu ₄ N ⁺ H ₂ F ₃ ^{-a}				Reaction with P ⁺ H ₂ F ₃ ^{-b}			
	Reaction time/h	Overall yield/%	Z-adduct/%	E-adduct/%	Reaction time/h	Overall yield/%	Z-adduct/%	E-adduct/%
MeO ₂ CC≡CCO ₂ Me	9	90	100	0	30	80	81	19
PhC≡CCOPh	50	53	100	0	— ^c	—	—	—
C ₇ H ₁₅ C≡CCN	7	95	70	30	30	95	34	66
Bu ⁿ C≡CCO ₂ Me	24	90 ^d	42	58	16	78 ^d	35	65
PhC≡CCO ₂ Me	21	75	91	5	24	85	88	12
PhC≡CCHO	4.5	75	91	9	4	62	83	17

^a After the preparation of Bu₄N⁺H₂F₃⁻ most of the DCE is evaporated under vacuum, the alkyne is added (onium salt:alkyne 2:1), then this mixture is heated (60 °C for the dimethyl butynedioate, 110–120 °C for the other alkynes). ^b P⁺H₂F₃⁻: alkyne 2:1 molar ratio, CCl₄ as solvent with dimethyl butynedioate (60 °C) and n-octane as solvent with the other alkynes (110–120 °C); the concentration of the alkyne was 1 M. No difference is observed between the Amberlyst A 26 or the Amberlite IRA 900 resins. ^c This ketone does not add HF when P⁺H₂F₃⁻ is used. ^d This yield includes the formation of the ester PrⁿCH=CFCH₂CO₂Me.

BuⁿCF=CHCO₂Me and PrⁿCH=CFCH₂CO₂Me (relative proportions 5:3); this last compound is likely to be formed by addition of HF to the allenic ester PrⁿCH=C=CHCO₂Me¹¹ after isomerization of BuⁿC≡CCO₂Me through a well-known basic prototropy.¹² This product of this process is observed only as a trace amount from the nitrile C₇H₁₅C≡CCN.

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