THE FACILE PREPARATION OF HF FREE POLYFLUORINATED ACYL FLUORIDES [1]

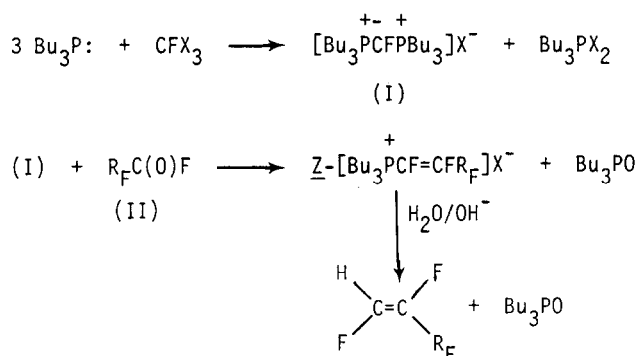DARYL G. COX, LEE G. SPRAGUE and DONALD J. BURTON*

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SUMMARY

The reaction of polyfluorinated acids with the Ishikawa Reagent (FAR) in the presence of NaF gives 59-91% isolated yields of HF free polyfluorinated acyl fluorides. The reaction is rapid, safe, easily scaled up, and amenable to a one-pot procedure.

INTRODUCTION

Recent work in our laboratory has resulted in a rapid, convenient preparation of fluorinated phosphoranium salts (I) via reaction of tertiary phosphines and trihalofluoromethanes [2]. In contrast to the usual acylation reaction observed in the reaction of ylides with acyl halides, (I) readily undergoes a Wittig reaction with polyfluorinated acyl fluorides (II) to stereospecifically give a Z-phosphonium salt. Subsequent base hydrolysis gives the E-1-hydro-F-olefin (Scheme I).

$$3 \; Bu_3P: \; + \; CFX_3 \longrightarrow [Bu_3\overset{+}{P}CF\overset{-}{P}Bu_3]X^- \; + \; Bu_3\overset{+}{P}X_2$$
$$(I)$$

$$(I) \; + \; R_FC(O)F \longrightarrow \underline{Z}\text{-}[Bu_3\overset{+}{P}CF=CFR_F]X^- \; + \; Bu_3PO$$
$$(II) \qquad\qquad\qquad \downarrow H_2O/OH^-$$

$$\begin{array}{c} H \diagdown \qquad \diagup F \\ C=C \qquad + \; Bu_3PO \\ F \diagup \qquad \diagdown R_F \end{array}$$

Scheme I

The success of this novel approach to fluoroolefin synthesis depends upon: (a) the use of dry solvents and reagents - to prevent protonation of any reaction intermediates in the formation of (I); and (b) a facile route to (II) from the parent acid which is HF free - to suppress quenching of the reaction via protonation of (I).

$$(I) \ + \ HF \ \longrightarrow \ [Bu_3\overset{+}{P}CFHP\overset{+}{B}u_3]F^- \ X^-$$
$$(III)$$
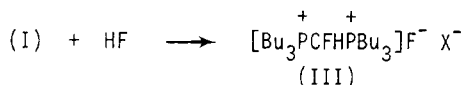
This report addresses the problem of the preparation of HF free acyl fluorides from polyfluorinated acids via a simple one-pot procedure.

RESULTS AND DISCUSSION

Our requirements in the selection of a reagent to accomplish this simple functional group transformation were that the reagent be: (a) general; (b) rapid in its reaction with acids; (c) amenable to a one-pot procedure; (d) safe; and (e) be either commercially available or easily prepared from commerically available materials.

When we began this work there were several available fluorinating agents which could be potentially employed to convert carboxylic acids to acyl fluorides. None, however, had been systematically applied to a series of polyfluorinated carboxylic acids. We eliminated from consideration SF_4 [3] and diethylamino sulfurtrifluoride (DAST) [4] on the basis of toxicity, safety, and cost. The Yarovenko Reagent [5] was discarded on the basis of limited storage stability, and perfluoro-2-methyl-2-pentene (PMP) [6] was rejected because of its cost relative to the Ishikawa Reagent (see below). Two reagents which met our requirements were fluorosulfonic acid and the Ishikawa Reagent, FAR (F-propene-dialkylamine reagent) [7].

Preliminary experiments involving F-acetic acid and F-propionic acid with these two reagents indicated that both met our criteria cited above. However, FAR was much more rapid and gave higher yields of (II) relative to FSO_3H. Thus, all subsequent work focused on FAR and we examined its generality with illustrative examples of polyfluorinated carboxylic acids (cf. Table I).

TABLE I

Data of the acyl fluorides prepared by:

$$R_FCOOH \ + \ FAR \ \xrightarrow[\Delta]{NaF} \ R_FC(O)F$$
$$(II)$$
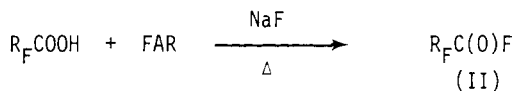
Acyl Fluoride	% Yield (isolated)	^{19}F NMR(ppm)[a]	IR(cm^{-1})[b]
CF$_3$COF	91	+14.3	1880
C$_2$F$_5$COF	82	+23.2	1880
C$_3$F$_7$COF	84	+24.9	1880
CF$_2$ClCOF	84	+9.7	1880
CF$_2$HCOF	(87)[c]	—	—
C$_7$F$_{15}$COF	59	+24.6	1890
(CF$_2$)$_3$(COF)$_2$	72	+24.7	1 ?0

a) Chemical shift of C(O)$\underline{F}$ relative to CFCl$_3$.
b) C(O)F absorption
c) Isolated as the ethyl ester _via_ reaction of the acyl fluoride with
   NaOEt in triglyme (TG). The other gaseous acyl fluorides (entries
   1-4 above) were also quantitatively converted to their ethyl esters
   by reaction with NaOEt in TG.

FAR is readily prepared from commercially available materials as a 1:1
mixture of (IV) and (V); (V) is the active fluorinating agent. As noted
in the elegant work of Ishikawa [7], FAR can be stored for several weeks to
months in a refrigerator without excessive decomposition.

$$Et_2NH \ + \ CF_2=CFCF_3 \ \longrightarrow \ Et_2NCF=CFCF_3 \ + \ Et_2NCF_2CFHCF_3$$
$$(IV) \qquad\qquad\qquad (V)$$
$$\underline{FAR}$$
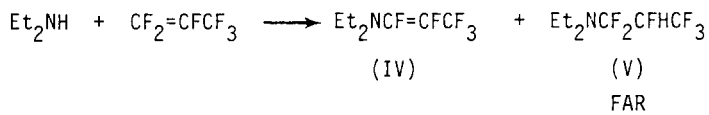
Although the enamine present in FAR can serve as a scavenger for HF produced in any subsequent reactions of FAR [7], we found that best results with carboxylic acids were obtained when NaF was added as the

$$R_FCOOH \ + \ FAR \ \xrightarrow[\Delta]{NaF} \ R_FC(O)F$$

$$(II)$$
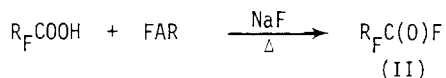
scavenger for HF. Indeed, the efficient uptake of HF allows the acyl fluoride reaction to be readily accomplished in all glass apparatus without any apparent HF damage to the apparatus. The apparatus utilized for the preparation of gaseous acyl fluorides is shown in Fig. I. Similar apparatus (see Experimental) is employed for the preparation of liquid acyl fluorides. Table I details the ^{19}F NMR, IR, and yield data of the acyl fluorides prepared by this procedure.

The success of this procedure was determined by distillation of the gaseous acyl fluorides (entries 1-4 in Table I) directly into a solution of (I) in benzonitrile. Less than 2% of (III) was detected via ^{19}F NMR and the Wittig reaction occurred in good yield [8].

In conclusion, FAR is an excellent reagent (with added NaF) for the conversion of polyfluorinated carboxylic acids to acyl fluorides. It is easy (a) to prepare; (b) to store; (c) to handle and is useful as a general reagent for the preparation of HF free products. We recommend this reagent to researchers in need of acyl fluorides.

EXPERIMENTAL

Preparation of FAR

A solution of diethylamine (105 g, 1.44 moles) in dry diethyl ether (200 ml) is placed in a three-necked flask which is fitted with a Dry-Ice/-isopropanol reflux condenser connected to a bubbler and a source of dry nitrogen. The amine solution is cooled to 0-5°C with an ice bath and then hexafluoropropene (HFP) (240 g, 1.60 moles) is added via the Dry-Ice condenser at a sufficient rate to keep the solution temperature below 10°C. After the HFP addition is completed, the resulting solution is stirred overnight at room temperature, followed by concentration via simple distillation. The remaining oil is vacuum distilled at 51°C/40 mm Hg to afford a clear colorless liquid (209 g, 0.94 moles, 65%) consisting of a 50:50 mixture of (IV) and (V).

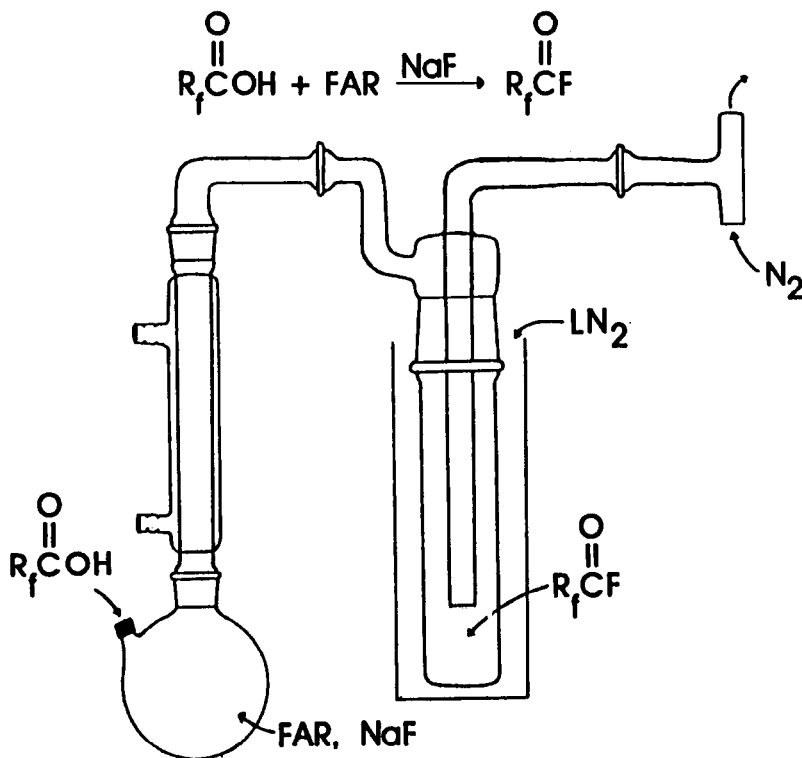$$R_fCOH + FAR \xrightarrow{NaF} R_fCF$$

Fig. 1 Apparatus utilized for the preparation of gaseous acyl fluorides

General procedure for gaseous acyl fluorides

Apparatus is detailed in Fig. I. To the 50 ml flask, equipped with a stir bar, is charged 22.3 g (0.1 mole) FAR and 4.2 g (0.1 mole) NaF. The resultant slurry under dry nitrogen is cooled to -78°C, and then 6.3 g (0.055 mole) of F-acetic acid is syringed dropwise into the cold slurry. After the addition of the acid is completed, the reaction mixture is stirred for 15 minutes at -78°C, the cold bath removed, and the reaction mixture allowed to warm to room temperature. As the mixture warms, F-acetyl fluoride distills and is collected in the trap at -196°C. To ensure that all of the F-acetyl fluoride has been removed, the reaction mixture is heated at 70°C for 20 minutes with an oil bath. A total of 5.8 g (0.05 mole), 91%, of F-acetyl fluoride is obtained. It can be utilized directly via distillation into a reaction mixture [8] or trans-ferred to a storage cylinder. Table I summarizes the preparation of other gaseous acyl fluorides via this procedure.

General procedure for liquid acyl fluorides

A 50 ml round bottom three-neck flask, equipped with a stir bar, is set up for simple distillation. The apparatus is connected to a bubbler and a source of dry nitrogen. The flask is charged with 22.3 g (0.1 mole) FAR and 4.2 g (0.1 mole) NaF. The resultant slurry is cooled to -78°C and then 20.7 g (0.051 mole) of dry F-octanoic acid [9] is added slowly via a solids addition tube. After the addition of the acid is completed, the reaction mixture is stirred for 15 minutes at -78°C, the cold bath removed, and the reaction mixture is allowed to warm to room temperature. The re- action mixture is stirred for one hour at room temperature and then flash distilled to give ~20 ml of distillate. Two subsequent fractional distilla tions (to remove all traces of FAR) from 1 g NaF gives 12.5 g (0.03 mole), 59%, of F-octanoyl fluoride, bp 98°C, lit bp 104°C [10].

Similar treatment of F-glutaric acid gave 72% of the acyl fluoride, bp 46°C.

NOTES AND REFERENCES

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2 10th International Symposium On Fluorine Chemistry, Vancouver, Canada, August 1982, Abstract 0-5.
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