Short communication

Polyfluoroalkylation and polyfluoroalkoxylation of perfluoro-(5,6-dihydro-2H-1,4-oxazine) in the presence of fluoride anion

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Abstract

Polyfluorinated tertiary amines were synthesized by the reactions of primary alkyl triflates ($R_FCH_2OSO_2CF_3$, $R_F = CF_3$, C_2F_5, CHF_2) with the morpholide anion, preformed from perfluoro(5,6-dihydro-2H-1,4-oxazine) on treatment with potassium fluoride (in tetraglyme). In the case of (CF_3)$_2CHOSO_2CF_3$, polyfluoroalkoxylated oxazine was obtained by replacement of the imidoyl fluorine. A similar imidoyl fluorine substitution reaction occurred in the treatment of perfluoro(5,6-dihydro-2H-1,4-oxazine) with polyfluoroalkylsiloxanes regardless of alkyl group variation. © 1998 Elsevier Science S.A. All rights reserved.

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Because of ozone layer depletion, the development of new chlorofluorocarbon (CFC) alternatives is urgently needed [1]. Several nitrogen-containing polyfluoroalkyl compounds have been prepared by the reactions of perfluorodimethylamino anions with dimethyl sulfate and trifluoromethanesulfonate compounds [2,3]. These compounds are possible CFC alternatives; but, the search has been limited only to an aliphatic compound. To investigate new CFC alternatives that have cyclic nitrogen-containing substituents, we prepared a series of perfluorocycloimines by thermal decomposition of their corresponding perfluoro(cycloamino-substituted acetic acid) potassium salts [4], viz., perfluoro(5,6-dihydro-2H-1,4-oxazine) (1), perfluoro-3,4-dihydro-2H-pyrrole, and perfluoro(2,3,4,5-tetrahydropyridine). Earlier reports detailed many perfluoro(2,3,4,5-tetrahydropyridine) reactions, including the substitution reaction of imidoyl fluorine with nucleophiles [5–8] and fluoride anion-induced reactions with chlorine and iodomethane [9–11]. In contrast, only a few dihydrooxazine 1 reactions have been reported; hydrolysis [12], conversion to perfluoromorphorine [13], and reaction with a mercury compound [14]. We here report the reactions of dihydrooxazine 1 with several trifluoromethane-

sulfonates (triflates) (2) and siloxanes (5) in the presence of fluoride anion.

Using previous methods [15,16], triflates 2 were prepared by the reactions of trifluoromethanesulfonyl chloride with the corresponding polyfluoroalcohols. The reactions of dihydrooxazine 1 with triflates 2 took place under anhydrous conditions: the solvent was dried over molecular sieves, and spray-dried KF was dried by heating it in a vacuum before the reaction. Although the reaction proceeded in polyethers and dimethylformamide, for product isolation tetraglyme was the most favorable solvent. The optimum reagent ratio was 1:0.83:1.2 for dihydrooxazine:triflate:KF, and product yields were based on the triflates. A typical procedure for the reactions of dihydrooxazine 1 with triflates 2 is as follows. In a 100-ml reaction vessel, 0.37 g (6.37 mmol) of spray-dried KF placed using a glove box vessel then dried with a hot heat gun using a vacuum line. A 5-ml portion of dried tetraglyme was added under an argon atmosphere, and 1.11 g (5.26 mmol) of 1 was vacuum-transferred to the reaction vessel at $-196°C$. The mixture in the reaction vessel was stirred at room temperature for 5 h, the vessel was cooled to $-196°C$, and 1.02 g (4.39 mmol) of $CF_3CH_2OSO_2CF_3$ (2a) was vacuum-transferred to it. This reaction mixture was heated at 50°C for 20 h. The product, 2,2,3,3,5,5,6,6-octafluoro-4-

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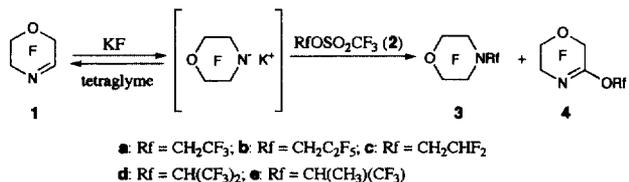
(2,2,2-trifluoroethyl)morpholine (**3a**), collected in traps cooled at $-55°C$ and at $-78°C$ gave an 77% yield as a clear liquid (bp 92.5–93.5°C). Spectral data for **3a** are ^{1}H-NMR (CDCl$_3$) δ: 3.84 (m); ^{13}C-NMR (CDCl$_3$) δ 122.2 (CF$_3$), 41.2 (CH$_2$), 113.0 (2,6-C), 111.0 (3,5-C); ^{19}F-NMR (CDCl$_3$) δ: -72.1 (m, 3F, CH$_2$CF$_3$), -87.4 (br s, 4F, 2,6-F), -96.8 (br s, 4F, 3,5-F); GC-MS (EI, 70 eV, m/z): 294 ([M–F]$^+$, 14.1), 244 ([M–CF$_3$]$^+$, 72.5), 216 (C$_4$H$_2$F$_8$N$^+$, 5.1), 194 (C$_4$H$_2$F$_6$NO$^+$, 6.1), 192 (C$_4$F$_6$NO$^+$, 6.3), 178 (C$_4$H$_2$F$_6$N$^+$, 5.3), 164 (C$_3$F$_6$N$^+$, 14.5), 128 (C$_3$F$_4$O$^+$, 27.1), 119 (C$_2$F$_5$$^+$, 40.2), 100 (C$_2F_4$$^+$, 100), 78 (C$_2F_2O^+$, 52.7), 69 (CF$_3$$^+$, 32.2); IR (cm^{-1}): 1450, 1405, 1361, 1295, 1214, 1175, 1135, 1101, 1013, 963, 870.

Results of the reactions of dihydrooxazine **1** with triflates **2** are given in Table 1. All the analyzed samples were collected with a vacuum line. The products were identified by IR, GC, GC-MS, ^{1}H NMR, ^{13}C NMR, and ^{19}F NMR. In the cases of the primary alkyl triflates (R$_f$CH$_2$OSO$_2$CF$_3$, **2a**–**2c**), the methylene carbon of the R$_f$CH$_2$-group was added to the nitrogen atom (the 4 position) of the morpholino ring giving 4-(polyfluoroalkyl)perfluoromorpholines (**3a–3c**) in high yields (Table 1, entries 1–3). Reactions of **1** with secondary alkyl triflates (R$_f$RCHOSO$_2$CF$_3$, **2d**, **2e**) produced different results. The reaction of **1** with (CF$_3$)$_2$CHOSO$_2$CF$_3$ (**2d**) afforded 3-(2,2,2-trifluoro-1-trifluoromethylethoxy)-2,2,5,5,6,6-hexafluoro(5,6-dihydro-2H-1,4-oxazine) (**4d**), substituting the (CF$_3$)$_2$CHO group for the imidoyl fluorine (the 3 position) (Table 1, entry 4). The reaction of **1** with (CF$_3$)(CH$_3$)CHOSO$_2$CF$_3$ (**2e**) gave a small amount of both 4-(polyfluoroalkyl)perfluoromorpholine (**3e**, 4% yield) and the substituted imine (**4e**, 10% yield). It was difficult, however, to isolate the compounds obtained from the reaction mixture because of the low yield and the presence of unreacted triflate **2e** (Table 1, entry 5). The structural assignment of **3e** and **4e** is therefore based on the GC-MS, ^{1}H NMR, and ^{19}F NMR of the reaction mixture. Spectral data for **4d** (bp 95.5–97.0°C) are ^{1}H-NMR (CDCl$_3$) δ: 6.03 (m); ^{13}C-NMR (CDCl$_3$) δ 119.6 (CF$_3$), 70.6 (CH), 156.6 (C=N), 114.1, 110.9, 109.6; ^{19}F-NMR (CDCl$_3$) δ: -73.4 (m, 6F, CF$_3$), -74.5 (m, 2F, 5-F), -90.8 (br s, 2F, 2-F), -95.3 (br s, 2F, 6-F); GC-MS (EI, 70 eV, m/z): 340 ([M–F]$^+$, 7.2), 320 ([M–HF$_2$]$^+$, 5.0), 312 ([M–COF]$^+$, 1.8), 293 (C$_6$HF$_{10}$NO$^+$, 30.0), 267 (C$_5$HF$_{10}$O$^+$, 3.4), 151 ([CH(CF$_3$)$_2$]$^+$, 6.6), 142 (C$_3$F$_4$NO$^+$, 7.5), 119 (C$_2$F$_5$$^+$, 6.1), 100 (C$_2F_4$$^+$, 21.6), 92 (C$_2F_2NO^+$, 100); IR (cm^{-1}): 2970, 1718 ($\nu_{C=N}$), 1382, 1363, 1350, 1297, 1271, 1230, 1180, 1117, 1099, 1056, 937, 908, 691.

Compound **4d** could be also prepared by the reaction of **1** with (CF$_3$)$_2$CHOSi(CH$_3$)$_3$ (Table 2, entry 2). A 0.15-g (2.58 mmol) portion of spray-dried KF and 5 ml of dried tetraglyme were added to a 100-ml reaction vessel under anhydrous conditions. A 0.51 g (2.39 mmol) of **1** and 0.60 g (2.50 mmol) of (CF$_3$)$_2$CHOSi(CH$_3$)$_3$ (**5d**) [17,18] were added to the reaction vessel at $-196°C$ using a vacuum line. After the reaction vessel was heated at 70°C for 48 h, the mixture inside was trap-to-trap distilled and the clear liquid

Table 1

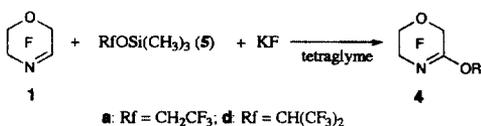Reactions of perfluoro(5,6-dihydro-2H-1,4-oxazine) with polyfluoroalkyl trifluoromethanesulfonates

a: Rf = CH$_2$CF$_3$; b: Rf = CH$_2$C$_2$F$_5$; c: Rf = CH$_2$CHF$_2$
d: Rf = CH(CF$_3$)$_2$; e: Rf = CH(CH$_3$)(CF$_3$)

Entry	Triflate	1 (mmol)	2 (mmol)	KF (mmol)	Product (Yield [a])
1	**2a**	5.26	4.39	6.37	**3a** (77%)
2	**2b**	4.56	3.83	5.51	**3b** (83%)
3	**2c**	4.44	3.72	5.34	**3c** (94%)
4	**2d**	4.95	4.14	6.02	**4d** (37% [b])
5	**2e**	3.26	2.74	3.96	**3e** (4% [b]), **4e** (10% [b])

[a] Isolated yields based on **2** unless otherwise noted.
[b] Determined by GC calculation.

Table 2

Reactions of perfluoro(5,6-dihydro-2H-1,4-oxazine) with (polyfluoroalkoxy)trimethylsilanes

a: Rf = CH$_2$CF$_3$; d: Rf = CH(CF$_3$)$_2$

Entry	Siloxane	1 (mmol)	5 (mmol)	KF (mmol)	Product (Yield [a])
1	**5a**	2.13	2.13	2.58	**4a** (41%)
2	**5d**	2.39	2.50	2.58	**4d** (54% [b])

[a] Isolated yields based on **1** unless otherwise noted.
[b] Determined by GC calculation.

was collected in the trap cooled to $-55°C$ in 54% yield (GC calculation). Spectral data for the product coincided with the data for **4d**. Similarly the reaction of **1** with CF$_3$CH$_2$OSi(CH$_3$)$_3$ (**5a**) gave 3-(2,2,2-trifluoroethoxy)-2,2,5,5,6,6-hexafluoro-(5,6-dihydro-2H-1,4-oxazine) (**4a**, bp 102.5–103.5°C) with no formation of compound **3a**. Spectral data of **4a** are ^{1}H-NMR (CDCl$_3$) δ: 4.79 (q, J_{HF} = 7.8 Hz); ^{13}C-NMR (CDCl$_3$) δ 121.7 (CF$_3$), 65.0 (CH$_2$), 157.2 (C=N), 109.8, 110.9; 114.1; ^{19}F-NMR (CDCl$_3$) δ: -73.9 (m, 3F, CF$_3$), -74.0 (m, 2F, 5-F), -90.6 (br s, 2F, 2-F), -94.2 (br s, 2F, 6-F); GC-MS (EI, 70 eV, m/z): 272 ([M–F]$^+$, 5.9), 225 ([M–COF]$^+$, 43.6), 199 (C$_4$H$_2$F$_7$O$^+$, 5.3), 142 (C$_3$F$_4$NO$^+$, 4.9), 127 (C$_3$H$_2$F$_3$O$_2$$^+$, 17.1), 119 (C$_2F_5$$^+$, 4.1), 100 (C$_2F_4$$^+$, 35.1), 92 (C$_2F_2NO^+$, 100), 83 (CF$_3CH_2$$^+$, 50.8); IR (cm^{-1}): 2987, 2362, 2342, 1705 ($\nu_{C=N}$), 1428, 1351, 1273, 1220, 1181, 1104, 1023, 976, 926, 717.

A mechanism for the reaction of perfluoro(5,6-dihydro-2H-1,4-oxazine) (**1**) with triflates (**2**) is shown in Scheme 1. In the case of (CF$_3$)$_2$CHOSO$_2$CF$_3$ (**2d**), before attack by
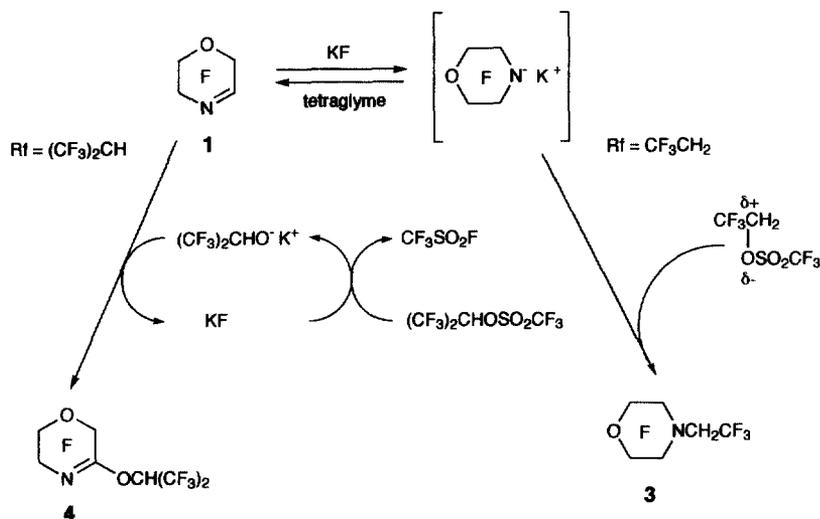
Scheme 1.

the fluorinated morpholido anion, formation of the alkoxide is considered to proceed by reaction of the triflate with KF. Because the morpholido anion is in rapid equilibrium with dihydrooxazine **1** and KF [10], the alkoxide reacts with the imidoyl fluorine via paths similar to those in the reactions of perfluoro(2,3,4,5-tetrahydropyridine) with C_6Cl_5ONa and $(CF_3)_2NONa$ [7]. This alkoxide is also considered to be an intermediate in the reaction of the dihydrooxazine with the polyfluorosiloxane [19].

In conclusion, the reactions of perfluoro(5,6-dihydro-2*H*-1,4-oxazine) with the primary alkyl triflates provide a means of obtaining tertiary amines, carrying the perfluoromorpholine ring and polyfluoroalkyl groups, in high yields, polyfluoroalkoxylated oxazines being obtained in moderate yields in the reactions of the dihydrooxazine with polyfluoroalkylsiloxanes. Further investigation of fluoride anion-induced reactions for various perfluorocycloimino compounds is in progress.

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