Journal of Fluorine Chemistry, *49* (1990) 183–195

Received: December 15, 1989; accepted: March 14, 1990

STEREOSPECIFIC 1,2 MIGRATION REACTIONS DURING FLUORINATION OF 2-METHOXY-2-METHOXYCARBONYL-3-HYDROXYTETRAHYDROPYRANS AND THE CORRESPONDING TRIFLATES

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SUMMARY

Treatment of the titled compounds by fluorinating reagents lead either to rearranged fluoro tetrahydrofuran derivatives, fluoro tetrahydropyrans and/or to an elimination product depending on the conditions. The fluorinated compounds result from a stereospecific migration of a C-O bond but the process is weakly stereoselective furnishing a mixture of two diastereoisomers in both cases.

INTRODUCTION

Pursuing our studies devoted to the synthesis of selective inhibitors of enzymes implicated in various pathologies [1], we recently initiated a program directed toward the preparation of inhibitors of viral neuraminidase. As part of this program, we became interested in obtaining compounds of type **3**. Despite the fact that the vicinal position of the anomeric carbon in glycosides is notoriously resistant to nucleophilic displacement, in particular with fluoride ions, several examples of successful introduction of fluorine atom in this position have been reported from alcohols or their trifluoromethanesulfonate derivatives [2]. Therefore we first developed a stereospecific synthesis of alcohols **1** [3] in the hope that they would be suitable starting materials for our purpose (Scheme 1). We report here the behaviour of alcohols **1** or their triflates **2** under several fluorinating conditions.

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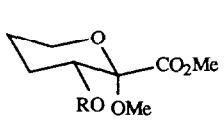
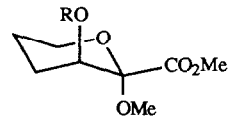


1a R = H

2a R = SO_2CF_3



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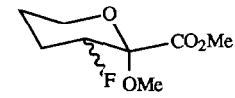
2b R = SO_2CF_3



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Scheme 1.

RESULTS

We first attempted the direct transformation of the alcohols **1** into **3** using diethylamino sulfur trifluoride (Et_2N-SF_3 : DAST). When **1a** was allowed to react with 5 mol equ. of DAST for 4 h in refluxing CCl_4 solution , it did not lead to the desired displacement product **3** but to a mixture of methyl 2-fluoro-2-methoxy-2-(2'-tetrahydrofuranyl)ethanoates **4a** and **4b** in a diastereoisomeric ratio of 65/35 (GPC 25 m capillary column) in an excellent yield (92% after chromatographic purification on silica gel). Similar treatment of the isomeric alcohol **1b** furnished 2-fluoro-2-methoxycarbonyl-3-methoxytetrahydropyrans **5a** and **5b** (85%; ratio 63/37) besides compound **6** (15%) in a combined yield of 71% (Scheme 2).

In order to verify if the above 1,2 migrations resulted from the use of DAST or were an inherent feature of our substrates, we decided to examine the behaviour of sulfonate derivatives of the alcohols **1**. Thus the triflates **2a** and **2b** were prepared from **1**, in the usual manner, and submitted to the action of two fluorinating reagents :

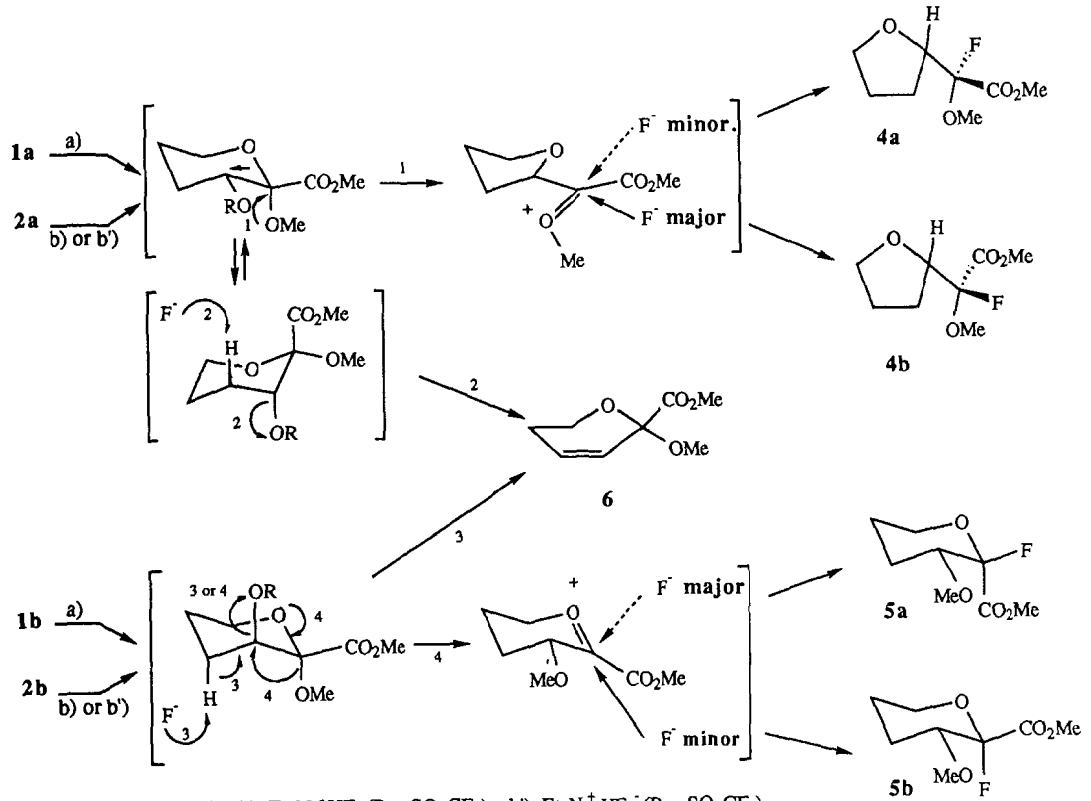
- with triethylamine tris-hydrofluoride (Et_3N-3HF, 5 mol equ.; refluxing CH_3CN,3 h) they gave similar results to those previously observed from alcohols. Thus **2a** led to the above-mentioned products **4a** and **4b** in comparable yield (89% after column chromatography) and ratio (70/30). The triflate **2b** furnished a mixture of compounds **5a** and **5b** (86%; ratio 60/40) and compound **6** (14%) in a combined yield of 72%.

- with tetraethylammonium hydrogendifluoride [4] ($Et_4N^+HF_2^-$; 3 mol equ. refluxing CH_3CN, 4 h) only elimination product **6** was formed in very good yield (88% from **2a**; 90% from **2b**) regardless of the starting triflate used.

STRUCTURAL ASSIGNMENTS

- Dihydropyran **6**. This compound was purified by column chromatography on silica gel and its structure established after comparison with an authentic sample [5].

- Fluorinated compounds. Pure analytical samples of **4a**, **4b**, **5a** and **5b** were available by H.P.L.C. (see experimental section). Brief inspection of their ^1H and ^{19}F NMR



a) DAST ($R = SF_2NEt_2$) b) $Et_3N,3HF$ ($R = SO_2CF_3$) b') $Et_4N^+ HF_2^-$ ($R = SO_2CF_3$)
Compounds **4a**, **4b**, **5a** , **5b** and **6** are racemic mixtures.

Scheme 2.

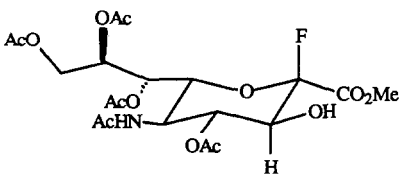
spectra showed that the spectral characteristics of these products were not consistent with the anticipated structure **3**. The absence of a vicinal ^2J H-F coupling constant (50 Hz) ruled out the possibility that they would arise from simple fluorine displacement of the hydroxy function in the alcohols **1**. Thus they might be formed after a rearrangement leading either to tetrahydrofurans or to tetrahydropyrans depending on the migrating adjacent C-O bond. The question was to ascertain the corresponding structure of **4** and **5**.

- Tetrahydropyrans **5a** and **5b**. Even if their ^1H NMR spectra (Table 1) contained overlapping signals and second order effects which precluded complete analysis, their major characteristics led us to propose a tetrahydropyranic structure for these compounds. The configuration and conformation depicted in Table 1 were based mainly on the signal for H_3 which is reasonably resolved in each diastereoisomer.

On the basis of the large J H_3-F value (21,5 Hz) corresponding to a $^3J\ H_3^{ax}$-F^{ax} coupling constant, we assigned the structure **5b** to the minor diastereoisomer in the energetically favoured conformation depicted. This value is very close to that recently reported (22,6 Hz) for the compound **7** [6].

Thus the major isomer must be **5a**. In this compound, the signal of H_3 is a pseudo-quartet which results from close values for ^3J H_3-F, ^3J H_3-H_4^{ax} and ^3J H_3-H_4^{eq} corresponding to an equatorial position for this proton. Thus the fluorine atom is axial, the ^3J H_3-F coupling constant of 2.6 Hz being in good agreement with literature ($J < 3$ Hz) [7]. A gauche disposition with the equatorial fluorine atom and the axial H_3 would lead to a larger value ($J > 12$ Hz) [7] as in compound **8** for which a ^3J H_3-F coupling constant of 15.0 Hz has been recently reported [6]. The conformational preference of **5a** may result from two stabilizing effects : the anomeric effect of the axial fluorine atom and the "anti" anomeric effect of the methoxycarbonyl group in the equatorial position [8].

In addition, the relatively small values of ^3J C_4-F and ^3J C_6-F coupling constants for **5a** and **5b** (1,2 and 2,2; 1,0 and 2,9 respectively) are in good agreement with a skew



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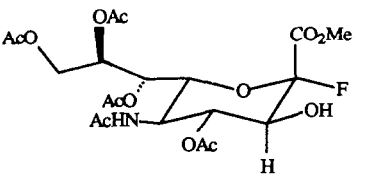

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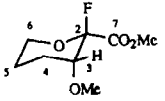
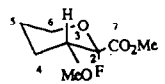
TABLE 1

N.M.R. data for tetrahydropyrans **5**

		H_3	H_4^{ax}	H_4^{eq}	H_5^{ax}	H_5^{eq}	H_6^{ax}	H_6^{eq}	$COOCH_3$	OCH_3
 **5a**	^1H	3.65 q* J=**2.6**	1.85 t*m J=14.0	1.95-2.15 m		1.40 d m J=12.0	3.95 t*d J=11.4 = 2.5	3.98 m	3.84 s	3.27 s
 **5b**		3.69 ddd J=**21.5** = 11.4 = 5.2	1.6-1.9 m	2.17 dm J=10.9	1.6-1.9 m		3.8-4.0 m		3.86 s	3.37 s

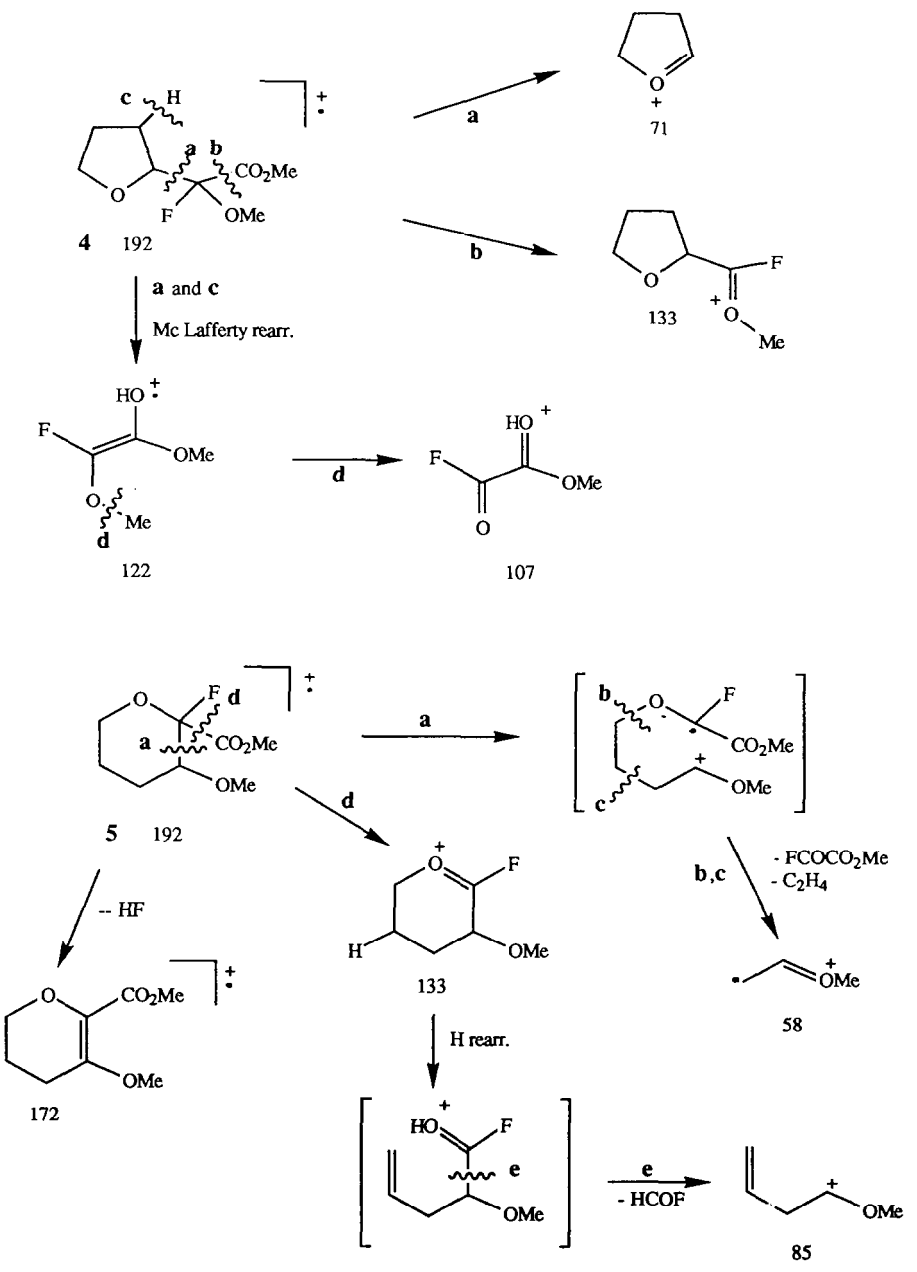
		C_2 (s)**	C_3 (d)	C_4 (t)	C_5 (t)	C_6 (t)	C_7 (s)	$COOCH_3$ (q)	OCH_3 (q)
5a	^{13}C (C_6D_6)	106.31 d*** J=226.1	73.62 d J=39.6	21.45 d **J=1.2**	18.35 s	63.31 d **J=2.2**	166.36 d J=28.3	56.96 s	52.10 s
5b		107.98 d J=245.1	77.04 d J=25.6	23.16 d **J=1.0**	23.74 s	62.80 d **J=2.9**	166.84 d J=31.7	56.70 s	52.29 s
5a	^{19}F	118.68 broad s $l_{1/2}$ = 4.5							
5b		142.95 broad d J=21.5 $l_{1/2}$ = 3							

* Pseudo triplet or quartet ; ** Multiplicity (C-H) DEPT ; *** J_{F-C} values.

arrangement of the $C_4C_3C_2F$ and C_6OC_2F bonds in both isomers. An anti-disposition (F equatorial) would have led to a greater value (12-14 Hz) according to several reports in the literature [9].

-Tetrahydrofurans **4a** and **4b**. The assignment of a tetrahydrofuranic structure to these compounds was initially based on their MS spectra. The two products gave identical spectra showing a peak at m/z = 71 (100%-C_4H_7O) interpreted on the basis of the fragmentation depicted in Scheme 3, a classical feature of 2-substituted tetrahydrofuranic compounds [10]. (The main features of the MS spectra of compounds **5** are given for comparison). In addition, the small differences between the chemical shifts of shielded protons ($H_{3'}$ and $H_{4'}$ -Table 2) and the absence of large ^3J ax-ax coupling constants, ruled out a tetrahydropyranic structure for these compounds. The ^{19}F and ^{13}C NMR data of both **4a** and **4b** supported their overall structure. As regards the stereochemistry of these two diastereoisomers, we were not able to determine the relative configurations of C_2 and $C_{2'}$ and the stereochemistry proposed in Scheme 2 results from the following consideration. The stereoselectivity observed during the migration of either the ring oxygen or the methoxy group seems to be related to the preferred conformation of the starting alcohols or triflates revealed by the coupling constants between H_3 and the vicinal protons (see [2] for alcohols and experimental section for triflates). Thus **1a** (or **2a**) led to tetrahydrofurans **4** whereas **1b** (or **2b**) led to tetrahydropyrans **5** the migrating C-O bond being in each case antiperiplanar to the leaving group (-OSF_2NEt_2 or -OSO_2CF_3). However the rearrangment is not fully concerted and a mixture of diastereoisomers was formed in both cases. Nevertheless starting from **1b** (or **2b**) the major isomer is **5a** resulting from a formal concerted process. A similar stereoselectivity in the case of compound **1a** (or **2a**) would lead preferentially to the isomer **4b** during the ring contraction. Thus we assigned to this compound the stereochemistry depicted in Scheme 2.

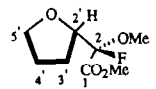
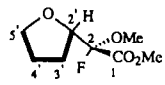
If our configurational attribution is correct, recently reported ^1H-NMR data for compounds **9** [11] allow us to deduce the preferred conformations of **4a** and **4b**. Thus the major diastereoisomer **4b** would adopt preferentially the conformation depicted in Table 2 with an anti relationship between the $C_{2'}$-H and C-F bonds leading to a ^3J H-F coupling constant of 21,3 Hz close to the value of 25 Hz observed for the favoured rotamer of compound **9a** (Scheme 4). In the case of **4a** (^3J H-F = 13,2 Hz), the favoured rotamer conformation may lie somewhere between those adopted by **9a** and **9b** which showed a ^3J H-F value of 8 Hz [11]. However, the coupling constants being largely dependent on the electronegativity of the atoms attached to the coupled nuclei [7] the comparison between compounds **4** and **9** remains somewhat uncertain.


c H
a b
CO2Me
O
F
OMe
4 192
a
71
b
133
a and c
Mc Lafferty rearr.
HO
F
OMe
O
Me
d
122
d
107
F d
a
CO2Me
OMe
5 192
a
b
c
d
-- HF
CO2Me
OMe
172
133
H rearr.
HO
e
- HCOF
85
b,c
- FCOCO2Me
- C2H4
58

Scheme 3.

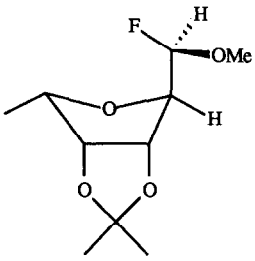
TABLE 2

N.M.R. data for tetrahydrofurans 4

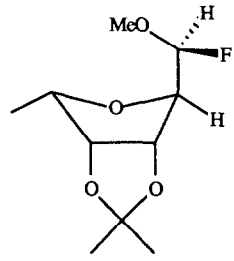
		$H_{2'}$	$H_{3'}$; $H_{4'}$	$H_{5'}$	$H_{5'}$	$COOCH_3$	OCH_3
 **4a**	^1H	4.23 ddd J=**13.2** = 7.2 = 6.3	1.80 - 2.15 m	3.80 - 3.95 m		3.86 s	3.47 d J=1.0
 **4b**		4.25 ddd J=**21.3** = 7.4 = 5.1	1.75 - 2.15 m	3.87 q* J=7.8	3.76 q* J=7.8	3.88 s	3.40 d J=0.9

		$C_{2'}$ (d)*	$C_{3'}$ (t)	$C_{4'}$ (t)	$C_{5'}$ (t)	C_2 (s)	C_1 (s)	$COOCH_3$ (q)	OCH_3 (q)
4a	^{13}C	80.20 d** J=26.5	26.22 d J=1.7	25.71 s	69.77 s	111.5 d J=234.2	166.85 d J=42.5	52.95 s	53.22 d J=4.7
4b		79.81 d J=23.8	25.33 d J=2.7	25.77 d J=0.8	69.56 s	112.04 d J=238.5	167.13 d J=42.3	52.95 s	53.02 d J=4.0
4a	^{19}F	132.6 broad d J=13.2 I 1/2 = 4.5							
4b		143.4 broad d J=21.3 I 1/2 = 4.0							

* Multiplicity (C-H) DEPT ; ** J_{F-C} values



9a



9b

Scheme 4.

DISCUSSION

The 1,2 migration of the aglycone part of pyranosides during attempts to substitute a leaving group on C_2 is well documented in the chemistry of carbohydrates and several examples of such migrations have been observed during fluorination, particularly when DAST was the fluorinating agent [12]. Participation of the ring oxygen has been mentioned although less often [13], and only recently a ring contraction of this type leading to fluorinated compounds has been reported [11]. To our knowledge, we are the first to describe these two kinds of rearrangements for compounds bearing a methoxycarbonyl group on the "anomeric" carbon.

These migrations seem to be related to the resistance of the C_2 position to nucleophilic displacement for which steric and electronic explanations have been proposed [14]. However, as already mentioned in the introduction, such substitutions have been carried out in many instances especially those when the highly reactive triflates were the starting material [2]. In our case it appears that the presence of both methoxy and methoxycarbonyl groups on the "anomeric" carbon precludes any direct nucleophilic displacement by fluoride ions on the neighbouring position.

Unsaturated compounds resulting from an elimination are side products which are also frequently observed in this type of substitution. Thus the competitive formation of **6** during the treatment of **1b** (or **2b**) could be anticipated due to the well disposed axial H_4 for an anti β-elimination. The unique formation of **6** with $Et_4N^+HF_2^-$, regardless of the starting triflate **2a** or **2b**, confirms that this reagent is, probably, one of the most basic fluorinating agents [15].

In conclusion, regardless of the explanations for the migrations or elimination that we report here, they convinced us that alcohols **1** are not suitable precursors for compound **3**, in spite of the fact that other leaving groups [16] or fluorinating agents [17] could be envisaged. Thus we are presently trying to prepare these compounds following a different approach.

EXPERIMENTAL

Dichloromethane and acetonitrile were distilled from calcium hydride and carbon tetrachloride from phosphoric anhydride. Pyridine was distilled from barium oxide and stored over potassium hydroxide.

All reactions were performed under a constant flow of dry nitrogen and reagents introduced through rubber septa using syringes.

The term ' standard work-up ' means that the organic layer was washed with water, dried over sodium sulfate, filtered and the solvent removed under reduced pressure (rotary evaporator).

Column flash-chromatographies [18] were carried out on SiO_2 (Amicon 35-70 μ). HPLC was realized with a Waters model 510 with a differential refractometer detector 410 equipped with a column C_{18} Bondapack 9 μ 30 cm x 3,9 mm (eluent : MeOH/H_2O, 1/1).

Infrared spectra (IR) were recorded (thin-film) on a Perkin-Elmer 1310 spectrometer. NMR spectra were recorded in $CDCl_3$ (unless otherwise specified) on a Varian EM 360 (60 MHz), on Brüker CW 80 (80 MHz), on Brüker AM 300 (300 MHz) for ^1H, Brüker AM 300 (75,47 MHz) for ^{13}C and Brüker CW 80 (75.27 MHz) for ^{19}F spectrometers. Chemical shifts were expressed in parts per million downfield from TMS for ^1H and ^{13}C and upfield from $CFCl_3$ for ^{19}F. Coupling constants are in hertz (Hz) and splitting pattern abbreviations are : s, singulet; d, doublet; q, quartet; m, multiplet.

Elemental analysis were performed by ' Service Central de Microanalyses du CNRS ' 69 Solaize (France). MS (MS-GPC : OV 1701 25 m; m/z : %) were recorded on a Nermag R1010S (70 eV) spectrometer.

Alcohols **1**

They have been prepared according to [3].

Triflates **2**

Alcohols **1** (0,190 g, 1 mmol) and pyridine (2 ml, 2.5 mmol) were dissolved in 5 ml of dichloromethane. Triflic anhydride (0.42 ml, 2.5 mmol) was added to the reaction mixture which has been cooled to 0°C. This mixture was stirred and allowed to warm to room temperature over a period of 2 h. The reaction mixture was then poured into 50 ml of cold saturated $NaHCO_3$ in a separatory funnel and shaken. The aqueous layer was extracted with three 15 ml portions of dichloromethane. After standard work up the crude triflates were chromatographed (eluent : diethylether/hexane, 4/1).

2a : 0.296 g (92 %). IR : 2960, 1760, 1410, 1210, 930; ^{1}H NMR (80 MHz) : 1.7-2.4 (m, 4H), 3.5-3.8 (m, 2H), 3.37 (s, 3H), 3.78 (s, 3H), 4.9 (dd, J=11 ,J=6, **H3**).

2b : 0.283 g (88 %). IR : 2980, 1760, 1420, 1210, 920; ^{1}H NMR (80 MHz) : 1.7-2.4 (m, 4H), 3.2 (s, 3H), 3.8 (s, 3H), 3.5-4.2 (m, 2H), 5.1 (broad s, $l_{1/2}$=6.5, **H3**).

Fluorination of alcohols **1** with DAST

- Alcohol 1a

A mixture of alcohols **1a** (0.380 g, 2 mmol) in 15 ml of carbon tetrachloride and 1.20 ml (10 mmol) of DAST was refluxed for 4 h, then cooled to room temperature and poured into 10 ml of cold saturated $NaHCO_3$. The aqueous layer was extracted with two 15 ml portions of dichloromethane. After standard work up the crude oil was purified by chromatography (eluent hexane/diethylether, 3/2), to give a mixture of **4a** + **4b** (0.353 g, 92 %).

4a . IR : 2950, 1770, 1450, 1090, 1040; MS : 192 (M^+, 1), 133 (7), 122 (4), 107 (3), 71 (100), 43 (47), 41 (16).

4b . IR : 2950, 1770, 1450, 1090, 1040; MS : 192 (M^+, 1), 133 (10), 122 (4), 107 (3), 71 (100), 43 (52), 41 (18).

Anal. (**4a** + **4b**) : Calcd. for $C_8H_{13}F0_3$: C 50.00 , H 6.77, F 9.89; Found C 49.73, H 6.89, F 9.60.

- Alcohol 1b

Alcohol **1b** was treated in a similar manner as **1a** and led after chromatography (eluent : hexane/diethylether ,3/2) to a mixture of **5a** + **5b** (0.230 g, 60 %) and **6** (0.037 g, 11 %).

5a. IR : 2980, 1770, 1450, 1060; MS : 172 (7), 133 (14), 85 (29), 84 (9), 71 (9), 63 (11), 59 (10), 58 (100), 55 (10), 43 (19).

5b. IR : 2980, 1770, 1450, 1060; MS : 172 (7), 133 (9), 85 (24), 84 (8), 71 (9),, 63 (9), 59 (8), 58 (100), 55 (9), 43 (19).

Anal. (5a + 5b)*: Calcd. for $C_8H_{13}FO_3$: C 50.00 , H 6.77, F 9.89; Found C 49.96, H 6.95, F 9.15

Fluorination of triflates **2**

- With triethylamine tris hydrofluoride

Triflate **2a**

A mixture of **2a** (0.162 g, 0.5 mmol) in 10 ml of acetonitrile and triethylamine tris-hydrofluoride (0.41 ml, 2.5 mmol) was refluxed for 3 h. After cooling to room temperature and pouring into 5 ml of saturated $NaHCO_3$, the aqueous layer was extracted by two 10 ml portions

* Samples of **4** and **5** for elemental analysis were micro-distillated. In the case of **5**, a very small amount of a new compound was detected by HPLC after distillation. This compound may result from a β-elimination of HF during the distillation.

of diethylether. After standard work-up of the organic layer, the crude oil was purified by chromatography and led to a mixture of **4a** + **4b** (0.077 g, 89%).

Triflate **2b**

Under the same conditions **2b** (0.243 g, 0.75 mmol) led to a mixture of **5a** + **5b** (0.090 g, 62 %) and **6** (0.013 g, 10 %).

- With tetraethylammonium hydrogendifluoride

To a solution of **2a** (or **2b**) (0.230 g, 0.7 mmol) in 10 ml of dry acetonitrile was added a solution of tetraethyl ammonium hydrogendifluoride [4b] (0.447 g, 2.1 mmol) in 10 ml of acetonitrile. The mixture was then refluxed for 2 h. After evaporating the solvent under reduced pressure, the oil thus obtained was chromatographed (eluent : diethylether/hexane, 1/1) to give **6** (0.107 g, 89 % from **2a**) (0.108 g, 90 %, from **2b**) as sole product.

ACKNOWLEDGEMENTS

The authors wish to thank Dr. D. ANKER and Dr. D. PICQ (Laboratoire de Chimie Organique III - Lyon) for a gift of triethylamine tris-hydrofluoride and for valuable discussions during the course of this work and the ' Rhône Alpes-Region ' for financial support.

REFERENCES

1 a) G. Quash, H. Rippol, L. Gazzolo, A. Saba, A. Doutheau and J. Goré, Biochimie, 69 (1987) 101.
b) G. Ogier, J. Chantepie, G. Quash, A. Doutheau, J. Goré and C. Marion, Biochem. Pharmacol., 38 (1989) 1335.
c) D. Bernard, A. Doutheau, J. Goré, J. Moulinoux, V. Quemener, J. Chantepie and G. Quash, Tetrahedron, 45 (1989) 1429.
2 P.J. Card, J. Carbohydr. Chem., 4 (1985) 451.
3 A. Saroli and A. Doutheau, Tetrahedron Lett., 28 (1987) 5501.
4 a) R.K. Sharma and J.L. Fry, J. Org.Chem., 48 (1983), 2112.
b) D. Picq, I.Drivas, G. Carret and D. Anker, Tetrahedron, 41 (1985), 2681.
5 V. Faivre, C. Lila, A. Saroli and A. Doutheau, Tetrahedron, in press.
6 K. Okamoto, T. Kondo and T. Goto, Bull. Chem. Soc. Jpn, 60 (1987) 631.
7 L. Phillips and V. Wray, J. Chem Soc. (B) (1971) 1618.
8 C.B. Anderson and D.T. Sepp, J. Org. Chem., 33 (1968) 3272.
9 G. Alvernhe, D. Anker, A. Laurent, G. Haufe and C. Beguin, Tetrahedron, 44 (1988) 3551 and references wherein.
10 S.R. Heller and G.W.A. Milne, EPA/NIH Mass Spectral Data Base, U.S. Department of Commerce, U.S. Government Printing Office Washington, Vol. 1 (1978) p. 43,96, 100, 144.
11 H.H. Baer, F.H. Mato and L. Siemsen, Carbohyd. Res., 187 (1989) 67.
12 a) A. Hasegawa, M. Goto and M. Kiso, J. Carbohydr. Chem., 4 (1985) 627.
b) K.C. Nicolaou, T. Ladduwahetty, J.L. Randall and A. Chucholowski, J. Am. Chem. Soc., 108 (1986) 2466.
c) P. Kovac, H.J.C. Yeh, G.L. Jung and C.P.J. Glaudemans, J. Carbohydr.Chem., 5 (1986) 497.
d) C. Bliard, F.C. Escribano, G. Lukacs, A. Olesker and P. Sarda , J. Chem. Soc. Chem.Commun. (1987) 368.
e) J.P. Street and G. Withers, Can. J. Chem., 64 (1986) 1400.

13 a) A. Grouiller, H. Bazin and C. Gagnieu, Tetrahedron Lett., 23 (1982) 2559.
b) F.M. El Sayed Ahmed, S. David and J.M. Vatèle, Carbohydr. Res., 155 (1986) 19 and references wherein.
14 a) A.C. Richardson, Carbohydr. Res., 10 (1969) 395.
b) S. Nadkarni and N.R. Williams, J.Chem. Soc. (1965) 3496.
c) J.M. Sigihara, W.J. Teerlink, J. Org. Chem., 29 (1964) 550.
d) M. Miljkovic, M. Gligorijevic and D. Glisin, J. Org. Chem., 39 (1974) 3223.
15 D. Picq *et al.*, unpublished results.
16 S. Hanessian and J.M. Vatèle, Tetrahedron Lett, 22 (1981) 3579.
17 a) B. Doboszewski, G.W. Hay and W.A. Szarek, Can. J. Chem., 65 (1987) 412.
b) P. Bosch, F. Campo, E. Chamono, V. Gasol and G. Gueriero, Tetrahedron Lett., 28 (1987) 4733.
18 W.C. Still, M. Kahn and A. Mitra, J. Org. Chem., 43 (1978) 2923.