ELSEVIER

Journal of Fluorine Chemistry 93 (1999) 159–164

JOURNAL OF FLUORINE CHEMISTRY

Electrolytic partial fluorination of organic compounds. Part 29[1]. Anodic mono- and difluorination of 2-benzoxazolyl sulfides

Kamal M. Dawood[2], Seiichiro Higashiya, Yankun Hou, Toshio Fuchigami*

Department of Electronic Chemistry, Tokyo Institute of Technology, 4259, Nagatsuta, Midori-ku, Yokohama 226-8502, Japan

Received 28 May 1998; received in revised form 17 August 1998; accepted 28 September 1998

Abstract

Anodic fluorination of 2-benzoxazolyl sulfides using various fluoride salts and dimethoxyethane as a supporting electrolyte and a solvent, respectively, resulted in the formation of the corresponding mono- and difluorinated products in reasonable yields. The monofluorination took place selectively at the position α to the sulfur atom while the difluorination resulted at both the α-position and the benzene ring while the expected α,α-difluorination did not take place at all. Moreover, anodic fluorination of the electrolytic solvent, DME, which has never been reported so far, was also observed as a side-reaction and this fluorination was further confirmed by carrying out anodic fluorination of DME itself in the absence of a substrate sulfide. © 1999 Elsevier Science S.A. All rights reserved.

Keywords: Selective anodic fluorination; Benzoxazolyl sulfides; Fluoride salt; Dimethoxyethane

1. Introduction

Benzoxazole derivatives are well-known to exhibit antibacterial [2], antimicrobial [3], antifungal [4], antiinflammatory and analgesic [5,6] activities. On the other hand, fluoroorganic compounds have attracted a great deal of interest due to their considerable importance as medicines and agrochemicals [7–10]. Therefore, introduction of fluorine atom into the benzoxazoles **2a–d** or their side chains may enhance their biological activities. However, direct fluorination is not always straightforward and very often requires hazardous or costly fluorinating agents. Recently, anodic fluorination proved to be more convenient because of its selectivity and safety [11–22]. For example, anodic fluorination of some heterocyclic sulfides bearing electron-withdrawing groups at their α-position was firstly explored by our research group and the fluorine atom has been introduced selectively to the α-position but the heterocyclic ring fluorination did not take place at all [23–29].

In our continuous studies on the anodic fluorination of a variety of heterocyclic sulfides [23–29], we disclose herein the anodic behavior of 2-mercaptobenzoxazoles **2a–d** toward various fluoride salts and electrolytic solvents. Anodic monofluorination at α-position to the sulfur atom took place preferentially and by-products difluorinated at both a side-chain and a benzene ring were also formed. Interestingly, anodic fluorination of 1,2-dimethoxyethane (DME), solvent used for the electrolysis, was also observed.

2. Results and discussion

2.1. Preparation of 2-benzoxazolyl sulfides 2a–c

Treatment of 2-mercaptobenzoxazole (**1**) with α-chloroacetone, ethyl α-chloroacetate, and α-chloroacetonitrile in refluxing THF, in the presence of K_2CO_3, afforded the corresponding 2-benzoxazolyl sulfides **2a–c**, respectively, in good yields, as shown in Scheme 1.

2.2. Oxidation potentials of 2-benzoxazolyl sulfides

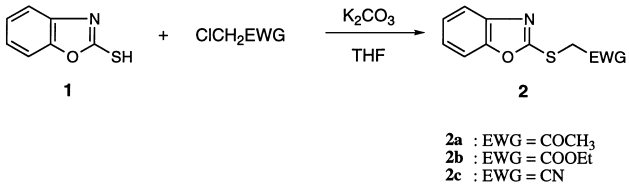
The oxidation potentials of 2-benzoxazolyl sulfides **2a–d** and the benzoxazole (**6**) were measured by cyclic voltammetry in an anhydrous acetonitrile solution containing $Bu_4Nm{\cdot}BF_4$ (0.1 M) using a divided cell and platinum electrodes. All benzoxazoles **2a–d** and **6** displayed irreversible oxidation peaks. Among all compounds under study, the benzoxazole (**6**) has the highest oxidation potential (2.32 V) and 2-methylthiobenzoxazole (**2d**) has the lowest

*Corresponding author. Fax: +81-45-924-5406; e-mail: fuchi@echem.titech.ac.jp

[1] For Part 28, see [1].

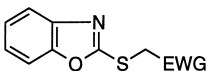
[2] UNESCO Research Fellow (1997–1998), on leave from Department of Chemistry, Faculty of Science, Cairo University, Cairo, Egypt.

0022-1139/99/$ – see front matter © 1999 Elsevier Science S.A. All rights reserved.
PII: S0022-1139(98)00292-9



Scheme 1.

Table 1
Oxidation potentials of 2-benzoxazolyl sulfides



Sulfide		E_p^{ox} (V vs. SSCE)[a]
No	EWG	
2a	$COCH_3$	2.08
2b	COOEt	1.96
2c	CN	2.22
2d	H	1.90
Benzoxazole		2.32

[a]In 0.1 M $Bu_4N{\cdot}BF_4$/MeCN. Anode: Pt plate. Sweep rate: 100 mVs^{-1}.

one (1.90 V). Substitution of an electron-withdrawing group at the position α to the sulfur atom increases the oxidation potentials in the order COOEt<$COCH_3$<CN as shown in Table 1.

2.3. Current–potential curves

Before carrying out the anodic fluorination, the current–potential curves for acetonitrile and DME in the presence and absence of **2a** in 0.3 M $Et_4NF{\cdot}4HF$ were measured in order to select the proper electrolytic solvent. As shown in Fig. 1(B), addition of 2-acetonylmercaptobenzoxazole (**2a**) to the DME electrolytic solution led to an anodic shift. This indicated that both **2a** and DME should be oxidized simultaneously. Therefore, this electrolytic system does not seem to be preferable for anodic fluorination. On the other hand, a large cathodic shift was observed after addition of **2a** to the electrolytic acetonitrile solution as shown in Fig. 1(A). Compared with the former case, the latter electrolytic solution gave a much larger faradaic current due to the discharge of **2a**. Therefore, acetonitrile seemed to be suitable for anodic fluorination. Experimental results showed however, the reverse trend: DME was found to be a suitable electrolytic solvent.

2.4. Anodic fluorination of 2-S-substituted mercaptobenzoxazoles 2a–d

Anodic fluorination of 2-acetonylmercaptobenzoxazole (**2a**), as a model example, was studied in details under various conditions and the results are summarized in Table 2.

Instead of selective fluorination at the α-position to the electron-withdrawing group as reported, previously by us for the cases of 2-pyridyl [24,27] and 2-benzothiazolyl sulfides [26], the 2-benzoxazolyl sulfide (**2a**) differed to some extent and the fluorination took place at the position α to the sulfur atom as well as at the benzene ring as depicted in Scheme 2.

When the reaction was monitored by GC–MS during the electrolysis, it was found that fluorination took place firstly at the α-position till 5 F mol^{-1}, then difluorination started to take place at the benzene ring. However, the expected α,α-difluorinated product **5a**, like the case of the corresponding phenyl sulfides [21], was not formed at all during the electrolysis. Among the fluoride salts used, $Et_4NF{\cdot}4HF$ was the best fluorinating agent in DME and the α-fluorinated product **3a** was obtained in reasonable yield as a major product. Regardless of supporting electrolytes, a small amount of difluorinated product **4a** was obtained as a by-product when DME was used as a solvent (Scheme 2). The position of the additional fluorination could not be deter-

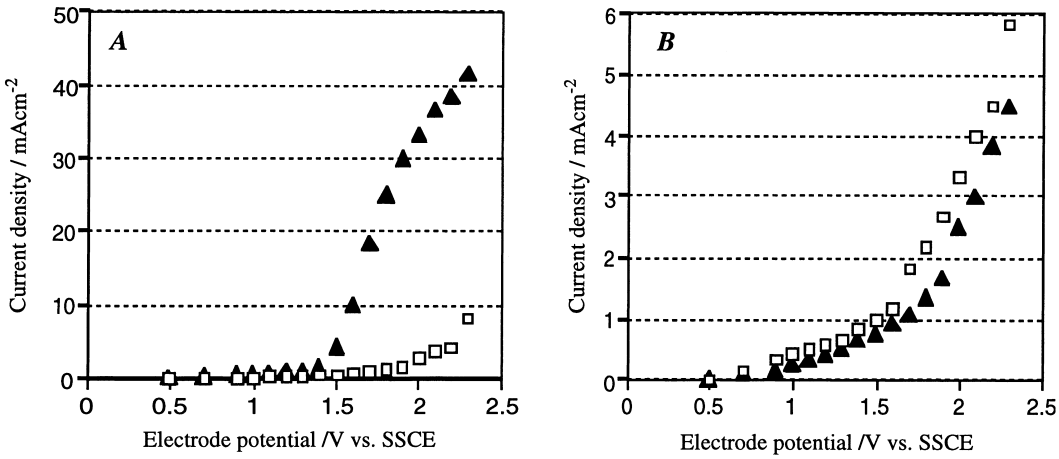
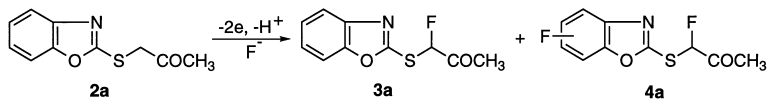


Fig. 1. Current–potential curves of the electrolytic solutions: (A) 0.3 M $Et_4NF{\cdot}4HF$/MeCN (20 ml) and (B) 0.3 M $Et_4NF{\cdot}4HF$/DME (20 ml), in the presence (▲) and the absence (□) of substrate **2a** (1 mmol).

Table 2
Anodic fluorination of 2-acetonylmercaptobenzoxazole (**2a**)

Run	Supporting electrolyte	Solvent	Charge passed (F/mol)[a]	Yield (%)[b]		
				3a	**4a**	Others
1	$Et_4NF{\cdot}4HF$	DME	9.5	17	3	+[c,e]
2	$Et_4NF{\cdot}4HF$	DME	18	39	8	+[c]
3	$Et_4NF{\cdot}3HF$	DME	7	10	2	+[c,e]
4	$Et_4NF{\cdot}3HF$	DME	18	34	7	+[c]
5	$Et_3N{\cdot}3HF$	DME	18	35	7	+[c]
6	$Et_4NF{\cdot}4HF$	MeCN	7	0	0	+[d]
7	$Et_3NF{\cdot}3HF$	MeCN	7	2	0	+[d]
8	$Et_4NF{\cdot}4HF$	CH_2Cl_2	8	2	0	+[e]
9	$Et_4NF{\cdot}4HF$	(Neat)	8	<1	0	+[e]

[a]Constant current electrolysis (6 mA cm^{-2}). Anode and cathode were Pt plates (3×2 cm^2).
[b]Determined by ^{19}F-NMR spectra.
[c]$CH_3OCH_2CH_2OCH_2F$ was formed.
[d]Unidentified solid product was obtained.
[e]Starting material was recovered.



Scheme 2.

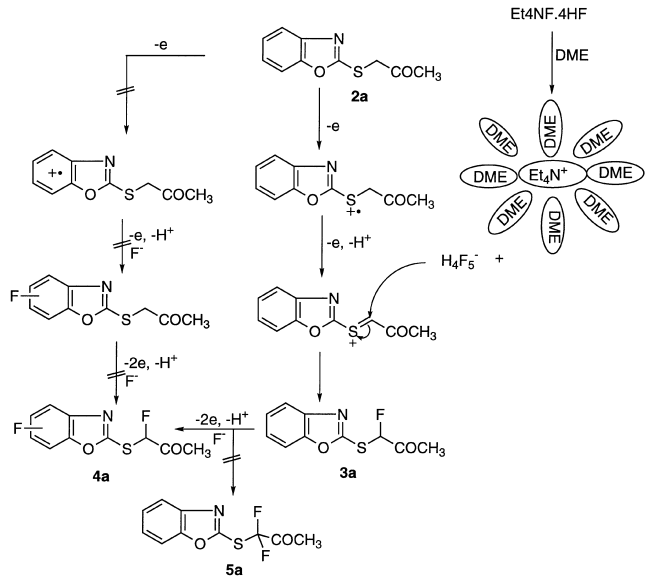
mined due to its extremely low yield, however, it seems to be the 5- or 6-position of the benzoxazole ring like the case of benzoxazole (**6**) (Scheme 7).

On the other hand, acetonitrile and dichloromethane were not suitable as a solvent even when $Et_4NF{\cdot}4HF$ was used as a supporting electrolyte. Thus, DME gave much better results than acetonitrile, which cannot be explained from *I–E* curves of **2a** and the solvents, DME and acetonitrile. This can be explained in terms of the ability of DME to solvate the cationic part of the fluoride salts, due to its higher donor number (23.9) than acetonitrile (14), leaving a naked fluoride anion which can consequently attack easily the anodically generated cationic intermediate of the substrate. A plausible mechanism is outlined in Scheme 3.

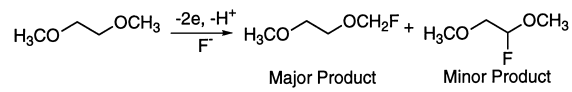
Although $Et_4NF{\cdot}4HF$/DME was effective for the anodic fluorination, $Et_4NF{\cdot}4HF$ without any solvent was not effective at all (run 9). This is quite different from the anodic fluorination of arenes using neat $Et_4NF{\cdot}4HF$ [30].

It is notable that anodic fluorination of DME (Scheme 4) was observed as a side reaction, in all cases using DME as an electrolytic solvent, which may reflect the poor current efficiency in runs 1–5.

Fluorinated DME was established based on ^{19}F NMR and mass spectrum of the reaction product. A triplet signal (J_{HF}=56 Hz) was observed at δ −74.61 ppm in the ^{19}F NMR and molecular ion peak of monofluorinated DME, *m/e* 108 was also detected by the mass spectrum although the molecular ion peak was rather weak. The formation of monofluorinated DME was further confirmed by carrying out the anodic fluorination of DME itself without substrate **2a** and the same results were obtained. A possible mechanism is depicted in Scheme 5.

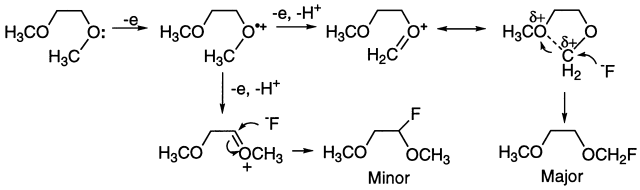


Scheme 3.



Scheme 4.

Next, we extended the anodic fluorination to other 2-substituted mercaptobenzoxazoles **2b–d** using DME as an electrolytic solvent (Scheme 6). As shown in Table 3, mono- and difluorinated products **3b**,**c** and **4b**,**c** were obtained in reasonable yields, respectively, regardless of

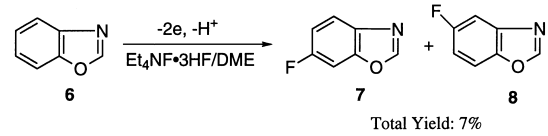


Scheme 5.

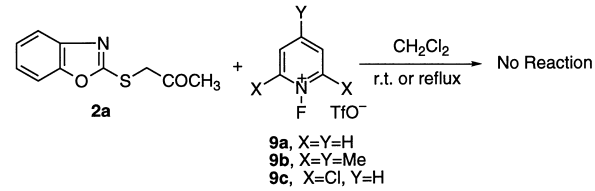
the electron-withdrawing groups. In contrast to these cases, 2-methylthiobenzoxazole (**2d**) devoid of an electron-withdrawing group gave an extremely low yield of fluorinated products **3d** and **4d**. The fluorination of DME was observed in all cases and particularly in the case of **2d**, the difluorination of DME took place considerably. However the α,α-difluorinated products were not detected at all regardless of sulfides.

Anodic fluorination of benzoxazole (**6**) was also performed. The formation of two monofluorinated products **7** and **8** were detected and confirmed by ^{19}F NMR [δ −38.02 (ddd, J=8.27, 4.60, 3.67 Hz) and −48.18 (dd, J=8.25, 4.60 Hz)] and GC–MS spectra [*m/z* 137 (M^+), 110 (M^+–HCN)], respectively, although their yields were extremely low. In this case, fluorination took place at the benzene ring but the oxazole ring was not fluorinated at all (Scheme 7). This trend is quite similar to the anodic fluorination of benzothiazole [26] and oxindole [25].

N-Fluoropyridinium salts are known to be a good fluorinating reagents [31,32]. Therefore, the chemical fluorination of compound **2a**, as a model compound, was also attempted. However, treatment of **2a** with various *N*-fluoropyridinium triflates **9a–c** in dichloromethane at either room temperature or under refluxing resulted in no formation of any desired fluorinated products as shown in Scheme 8. Therefore, the electrochemical fluorination proved to be superior to the conventional chemical method.



Scheme 7.



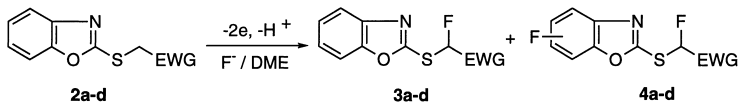
Scheme 8.

3. Experimental

3.1. General

Caution. $Et_3N{\cdot}3HF$ and $Et_4NF{\cdot}nHF$ (n=3,4) are toxic and if in contact with skin cause a serious burn, so proper safety precautions should be taken at all times. It is therefore recommended to protect the hands with rubber gloves.

^{1}H NMR, ^{19}F NMR and ^{13}C NMR spectra were recorded at 270, 254 and 68 MHz, respectively, in $CDCl_3$ as a solvent using a JEOL EX-270 spectrometer. The chemical shifts for ^{1}H and ^{13}C NMR are given in δ ppm downfield from internal TMS and ^{19}F NMR are given in δ ppm downfield from external perfluorobenzene. Mass spectra were obtained with Shimadzu GCMS-QP2000A and JEOL JMS-700 mass spectrometers. Cyclic voltammetry was performed using a Hokuto Denko Potentiostat/Galvanostat HA 6-151 at a scan speed of 100 mV s^{-1} in 0.1 M $Bu_4N{\cdot}BF_4/CH_3CN$. Preparative electrolysis experiments were carried out using a Metronix Corp. (Tokyo) constant-current power supply.



Scheme 6.

Table 3
Anodic fluorination of 2-benzoxazolyl sulfides **2a–d**.

Sulfide	EWG	Supporting electrolyte	Charge passed (F/mol)[a]	Yield (%)[b]		
				3	**4**	Others[c]
2a	$COCH_3$	$Et_4NF{\cdot}4HF$	18	**3a**(39)	**4a**(8)	+
2b	COOEt	$Et_4NF{\cdot}4HF$	10	**3b**(35)	**4b**(13)	+
2b	COOEt	$Et_3N{\cdot}3HF$	10	**3b**(29)	**4b**(8)	+
2c	CN	$Et_4NF{\cdot}4HF$	18	**3c**(17)	**4c**(6)	+
2c	CN	$Et_3N{\cdot}3HF$	18	**3c**(12)	**4c**(8)	+
2d	H	$Et_4NF{\cdot}4HF$	18	**3d**(2.2)	**4d**(2)	++

[a]Constant current electrolysis (6 mA cm^{-2}). Anode and cathode were Pt plates (3×2 cm^2).
[b]Determined by ^{19}F-NMR spectra.
[c]$CH_3OCH_2CH_2OCH_2F$ was formed.

3.2. Preparation of 2-S-substituted mercaptobenzoxazoles **2a–c**: general procedure

To a stirred solution of 2-mercaptobenzoxazole (**1**) (3.02 g, 20 mmol) in THF (40 ml), in the presence of potassium carbonate (3.4 g, 25 mmol), was added the appropriate α-chloro compound (20 mmol). The reaction mixture was heated under reflux for 1 h, then left to cool. The inorganic salts were filtered off and the filtrate was evaporated under vacuum. The remaining product was crystallized from hexane/isopropanol (5:1) or methanol to give the desired products **2a–c**.

1-(2-Benzoxazolylthio)-2-propanone (**2a**) [33]: 78% yield, m.p. 68–69°C; ^{1}H NMR δ 2.40 (s, 3H), 4.23 (s, 2H), 7.27 (m, 2H), 7.44 (dt, J=7.26, 1.65 Hz, 1H), 7.57 (dt, J=6.93, 1.65 Hz, 1H); MS *m/e* 207 (M^+), 164 (M^+–$COCH_3$); Anal. Calcd. for $C_{10}H_9NO_2S$: C, 57.96%; H, 4.38%; N, 6.76%. Found C, 58.14%; H, 4.22%; N, 6.53%.

Ethyl α-(2-benzoxazolylthio)acetate (**2b**) [34]: 78% yield, m.p. 46°C; ^{1}H NMR δ 1.29 (t, J=7.26 Hz, 3H), 4.12 (s, 2H), 4.24 (q, J=7.26 Hz, 2H), 7.28 (m, 2H), 7.44 (dt, J=5.94, 1.65 Hz, 1H), 7.60 (dt, J=5.94, 1.65 Hz, 1H); MS *m/e* 237 (M^+), 164 (M^+–COOEt); Anal. Calcd. for $C_{11}H_{11}NO_3S$: C, 55.68%; H, 4.67%; N, 5.90%. Found C, 55.78%; H, 4.59%; N, 5.78%.

α-(2-Benzoxazolylthio)acetonitrile (**2c**) [35]: 84% yield, m.p. 95°C; ^{1}H NMR δ 4.11 (s, 2H), 7.34 (m, 2H), 7.48 (m, 1H), 7.66 (m, 1H); MS *m/e* 190 (M^+), 164 (M^+–HCN), 150 (M^+–CH_2CN); Anal. Calcd. for $C_9H_6N_2OS$: C, 56.83%; H, 3.18%; N, 14.73%. Found C, 56.84%; H, 2.99%; N, 14.81%.

3.3. Anodic fluorination of 1-(2-benzoxazolylthio)-2-propanone (**2a**)

Electrolysis was carried out with platinum electrodes (3×2 cm^2) in 0.3 M $Et_4NF{\cdot}4HF$/DME (15 ml) to which the substrate **2a** (1 mmol) was added, using an undivided cell under nitrogen atmosphere at ambient temperature. Constant current (6 mA cm^{-2}) was applied until the starting material **2a** was almost consumed. The course of the reaction was monitored by TLC and GC–MS. After complete electrolysis, the electrolytic solution was neutralized with 10% $NaHCO_3$ solution followed by extraction with ether several times. The combined extracts were dried over anhydrous $MgSO_4$, then evaporated under vacuo and the product yields were estimated by ^{19}F NMR spectroscopy. The solvent was removed by evaporation and the oily residue was purified by passing through column chromatography on silica gel using hexane/ethyl acetate (5:1) as an eluent.

This typical electrolysis procedure was also carried out for the other benzoxazoles **2b–d** and **6** as well as DME.

1-(2-Benzoxazolylthio)-1-fluoro-2-propanone (**3a**): ^{1}H NMR δ 2.50 (d, J=3.63 Hz, 3H), 6.81 (d, J=50.48 Hz, 1H), 7.33 (m, 2H), 7.49 (m, 1H), 7.65 (m, 1H); ^{19}F NMR δ −85.89 (dq, J=50.55, 3.68 Hz); MS *m/e* 225 (M^+), 183 (M^+–CH_2=C=O), 163 (M^+–CH_3COF), 150 (M^+–$CHFCOCH_3$); HRMS: Calcd. for $C_{10}H_8FNO_2S$: *m/e* 225.0260; Found 225.0263.

Ethyl α-(2-benzoxazolylthio)-α-fluoroacetate (**3b**): ^{1}H NMR δ 1.35 (t, J=7.26 Hz, 3H), 4.37 (q, J=7.26 Hz, 2H), 6.94 (d, J=50.56 Hz, 1H), 7.33 (m, 2H), 7.50 (m, 1H), 7.67 (m, 1H); ^{13}C NMR δ 13.90, 63.31, 91.66 (dd, J=238, 6.1 Hz), 110.29, 119.30, 124.88 (d, J=9.5 Hz), 141.33, 152.16, 159.15 (d, J=2.4 Hz), 164.48 (d, J=25.7 Hz); ^{19}F NMR δ −85.52 (d, J=50.56 Hz); MS *m/e* 255 (M^+), 182 (M^+–COOEt), 150 (M^+–CHFCOOEt); HRMS: Calcd. for $C_{11}H_{10}FNO_3S$: *m/e* 255.0365; Found 255.0364. Anal. Calcd. for $C_{11}H_{10}FNO_3S$: C, 51.76%; H, 3.95%; N, 5.49%. Found C, 51.75%; H, 3.82%; N, 5.30%.

α-(2-Benzoxazolylthio)-α-fluoroacetonitrile (**3c**): ^{1}H NMR δ 7.22 (d, J=49.16 Hz, 1H), 7.37 (m, 2H), 7.53(m, 1H), 7.71 (m, 1H); ^{19}F NMR δ −81.13 (d, J=48.72 Hz); MS *m/e* 208 (M^+), 191 (M^+–HCN), 150 (M^+–CHFCN); HRMS Calcd. for $C_9H_5FN_2OS$: *m/e* 208.0106; Found 208.0114.

1-[5(6)-Fluoro-2-benzoxazolylthio]-1-fluoro-2-propanone (**4a**): ^{1}H NMR δ 2.51 (d, J=3.62 Hz, 3H), 6.76 (d, J=50.48 Hz, 1H), 7.10 (m, 1H), 7.22 (dd, J=7.91, 2.64 Hz, 1H), 7.58 (dd, J=8.91, 4.95 Hz, 1H); ^{19}F NMR δ −38.29 (m, 1F), −85.89 (dq, J=50.55, 3.68 Hz, 1F); MS *m/e* 243 (M^+), 201 (M^+–CH_2=C=O), 168 (M^+–$CHFCOCH_3$); HRMS: Calcd. for $C_{10}H_7F_2NO_2S$, *m/e* 243.0165; Found 243.0165.

Ethyl α-[5(6)-Fluoro-2-Benzoxazolylthio]-α-fluoroacetate (**4b**): ^{1}H NMR δ 1.35 (t, J=7.26 Hz, 3H), 4.37 (q, J=7.26 Hz, 2H), 6.88 (d, J=50.48 Hz, 1H), 7.09 (m, 1H), 7.24 (dd, J=7.91, 2.31 Hz, 1H), 7.61 (dd, J=8.91, 4.95 Hz, 1H); ^{19}F NMR δ −38.23 (m, 1F), −85.50 (d, J=50.56 Hz, 1F); MS *m/e* 273 (M^+), 200 (M^+–COOEt), 168 (M^+–CHFCOOEt); HRMS Calcd. for $C_{11}H_9F_2NO_3S$: *m/e* 273.0271; Found 273.0269.

α-[5(6)-Fluoro-2-Benzoxazolylthio]-α-fluoroacetonitrile (**4c**): ^{1}H NMR δ 7.15 (d, J=49.15 Hz, 1H), 7.15 (m, 1H), 7.30 (dd, J=7.92, 2.64 Hz, 1H), 7.65 (dd, J=8.91, 4.95 Hz, 1H); ^{19}F NMR δ −37.55 (m, 1F), −81.11 (d, J=48.72 Hz, 1F); MS *m/e* 226 (M^+), 199 (M^+–HCN), 168 (M^+–CHFCN); HRMS Calcd. for $C_9H_4F_2N_2OS$: *m/e* 226.0012; Found 226.0022.

Acknowledgements

We are grateful to Morita Chemical Industries Co., Ltd. and Chichibu–Onoda Cement Co. for their kind gifts of $Et_4NF{\cdot}3HF$ and *N*-fluoropyridinium salts, respectively.

References

[1] Y. Hou, S. Higashiya, T. Fuchigami, Synlett (1998), 973.
[2] I. Yalcin, I. Oren, E. Sener, A. Akin, N. Ucarturk, Eur. J. Med. Chem. 27 (1992) 401.

[3] I. Yalcin, E. Sener, Int. J. Pharm. 98 (1993) 1.
[4] E. Sener, I. Yalcin, E. Sungur, Quant. Struct.-Act. Relatsh. 10 (1991) 223.
[5] F. Russo, G. Romeo, N.A. Santagati, A. Caruso, V. Cutuli, D. Amore, Eur. J. Med. Chem. 29 (1994) 569.
[6] C. Safak, R. Simsek, K. Erol, K. Vural, Pharmazie 51 (1996) 180.
[7] R. Filler, Y. Kobayashi (Eds.), Biomedicinal Aspects of Fluorine Chemistry, Kodansha and Elsevier Biomedical, Tokyo, 1982.
[8] J.T. Welch, Tetrahedron 43 (1987) 3123.
[9] T. Welch, S. Eswarakrishnan (Eds.), Fluorine in Bioorganic Chemistry, Wiley, New York, 1991.
[10] H. Yoshioka, C. Nakayama, N. Matsuo, J. Synth. Org. Chem. Jpn. 42 (1984) 809.
[11] T. Fuchigami, Rev. Heteroatom. Chem. 10 (1994) 155.
[12] S. Narizuka, H. Koshiyama, A. Konno, T. Fuchigami, J. Fluorine Chem. 73 (1995) 121.
[13] T. Fuchigami, T. Fujita, A. Konno, Tetrahedron Lett. 35 (1994) 4153.
[14] T. Fuchigami, M. Sano, J. Electroanal. Chem. 369 (1994) 255.
[15] T. Fuchigami, T. Fujita, J. Org. Chem. 59 (1994) 7190.
[16] T. Fuchigami, A. Konno, K. Nakagawa, M. Shimojo, J. Org. Chem. 59 (1994) 5937.
[17] T. Fuchigami, M. Shimojo, A. Konno, J. Org. Chem. 60 (1995) 3459.
[18] S. Narizuka, T. Fuchigami, Bioorg. Med. Chem. Lett. 5 (1995) 1293.
[19] A. Konno, T. Fuchigami, J. Appl. Electrochem. 25 (1995) 173.
[20] T. Fuchigami, M. Sano, J. Electroanal. Chem. 414 (1996) 81.
[21] A. Konno, T. Fuchigami, J. Org. Chem. 62 (1997) 8579.
[22] A. Konno, M. Shimojo, T. Fuchigami, J. Fluorine Chem. 87 (1998) 137.
[23] S. Narizuka, T. Fuchigami, J. Org. Chem. 58 (1993) 4200.
[24] A.W. Erian, A. Konno, T. Fuchigami, J. Org. Chem. 60 (1995) 7654.
[25] Y. Hou, S. Higashiya, T. Fuchigami, J. Org. Chem. 61 (1996) 8773.
[26] Y. Hou, S. Higashiya, T. Fuchigami, J. Org. Chem. 62 (1997) 9173.
[27] S. Higashiya, T. Sato, T. Fuchigami, J. Fluorine Chem. 87 (1998) 203.
[28] T. Fuchigami, S. Narizuka, A. Konno, K. Momota, Electrochim. Acta 43 (1998) 1985.
[29] W.V. Childs, T. Fuchigami (Eds.), in: The Electrochemical Society, Electrochemistry in the Preparation of Fluorine and Its Compounds, Pennington, NJ, 1997, pp. 65–73.
[30] K. Momota, T. Yonezawa, K. Mukai, M. Morita, J. Fluorine Chem. 87 (1998) 173.
[31] T. Umemoto, G. Tomizawa, Bull. Chem. Soc. Jpn. 59 (1986) 3625.
[32] T. Umemoto, G. Tomizawa, J. Org. Chem. 60 (1995) 8563.
[33] V. Kalcheva, M. Tosheva, P. Hadjieva, Lieb. Ann. Chem. (1993) 1319.
[34] V.A. Petrosyan, M.E. Niyazymbetov, L.D. Konyushkin, V.P. Litvinov, Synthesis. (1990) 841.
[35] V.P. Ahluwalia, M. Alauddin, C.H. Khanduri, V.D. Mehta, Heterocycles 29 (1989) 1729.