JOC Article

Electrochemical Partial Fluorination of Organic Compounds. 74. Efficient Anodic Synthesis of 2-Fluoro- and 2,3-Difluoro-2,3-dihydrobenzofuran Derivatives[1]

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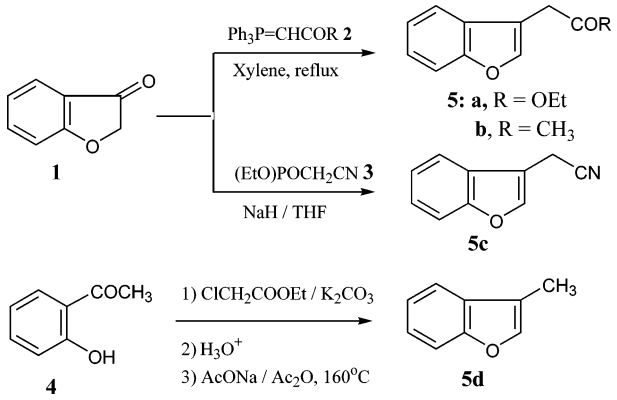
Received December 25, 2003

Anodic fluorination of 3-substituted benzofuran derivatives in a variety of fluoride salts resulted in the formation of three fluorinated products; two stereoisomers of 2,3-difluoro-2,3-dihydrobenzofuran (cis and trans) and *cis*-2-fluoro-3-hydroxy-2,3-dihydrobenzofuran derivatives. Dehydrofluorination of the main products, *cis*-difluoro derivatives, furnished the nonaromatic 2-fluoro-3-benzofuranyledene derivatives instead of the aromatic 2-fluorobenzofuran derivatives.

Introduction

The benzofuran moiety is incorporated in various natural products[2] and pharmaceuticals.[3] Fluorinated heterocycles have also proved to be highly biologically active compounds.[4] Recently, copious literature concerning electrochemical fluorination of sulfur-containing heterocycles has been reported;[5] however, limited examples of selective anodic fluorination of oxygen-containing heterocycles were studied.[6] More than 10 years ago, anodic fluorination of furan and benzofuran was attempted; however, their fluorinated products were unstable and not isolable.[7] These facts prompted us to perform, for the first time, anodic mono- and difluorination of 3-substituted benzofurans.[8]

SCHEME 1



Results and Discussion

Synthesis of 3-Substituted Benzofuran Derivatives 5a−d. Compounds **5a**,**b** were prepared by the reaction of 3-coumaranone (**1**) with ethoxycarbonyl methylenetriphenylphosphorane (**2a**)[9] and acetylmethylenetriphenylphosphorane (**2b**),[10] in refluxing xylene, while compound **5c** was obtained by the reaction of **1** with diethyl (cyanomethyl)phosphonate (**3**)[11] under refluxing tetrahydrofuran in the presence of sodium hydride (Scheme 1). Furthermore, the synthesis of 3-methylbenzofuran (**5d**) was achieved through a multistep procedure

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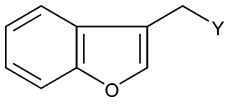
10.1021/jo035871g CCC: $27.50
Published on Web 07/03/2004

TABLE 1. First Oxidation Potentials (E_p^{ox}) of Starting Substrates 5a−d



compd	Y	E_p^{ox} (V vs SCE)
5a	COOEt	1.80
5b	$COCH_3$	1.71
5c	CN	1.94
5d	H	1.64

[a] In 0.1 M $Bu_4NF{\cdot}BF_4$/MeCN. Sweep rate 100 mV s^{-1}.

utilizing 2-hydroxyacetophenone (**4**) with ethyl chloroacetate followed by basic hydrolysis and then thermal cyclization in acetic anhydride in the presence of sodium acetate[12] (Scheme 1).

Oxidation Potentials of 3-Substituted Benzofuran Derivatives 5a−d. The oxidation potentials (E_p^{ox}) of benzofuran derivatives **5a−d** were measured by cyclic voltammetry in 0.1 M anhydrous acetonitrile solution containing $Bu_4N{\cdot}BF_4$ using platinum electrodes versus saturated calomel electrode (SCE) as a reference electrode. All compounds **5a−d** showed irreversible oxidation waves in cyclic voltammograms, and their E_p^{ox} values are listed in Table 1. The oxidation potentials of the starting substrates are markedly affected by the type of the substituent functionality and are in the following order: CN > COOEt > $COCH_3$ > H. The electron transfer seems to take place from the furan moiety of the benzofuran ring. Therefore, as the electron-withdrawing ability of the substituents at the furan ring increases, the oxidation potential increases.

Anodic Fluorination of 3-Substituted Benzofuran Derivatives 5a−d. First, anodic fluorination of ethyl (3-benzofuranyl)acetate (**5a**), as a model example, was extensively studied under various conditions. In all cases, three fluorinated products were obtained. ^1H, ^{19}F, and ^{13}C NMR spectra of the electrolysis products showed that there are two isolable isomers of 2,3-difluoro-2,3-dihydrobenzofuran derivative **6a** (cis/trans isomers) and *cis*-2-fluoro-3-hydroxy-2,3-dihydrobenzofuran derivative **7a** as shown in Table 2. The overall fluorination yield and the product selectivity were greatly affected by the electrolysis conditions. Acetonitrile was found to be a more convenient electrolytic solvent (runs 3−5) than dimethoxyethane (DME) (run 1). When constant-potential electrolysis was applied (runs 3−5), the overall fluorination yield was almost quantitative; however, the overall yield was reduced to its half value when constant-current electrolysis was applied (run 2). $Et_4NF{\cdot}4HF$ proved to be a powerful fluorinating agent under optimum conditions (run 3). Among the three fluorination products, *cis*-2,3-difluoro-2,3-dihydrobenzofuran derivative **6a** was the major one regardless of the electrolysis conditions as shown in Table 2. This can be accounted for by the occurrence of the fluorination process at the anode surface. Constant-potential electrolysis under a nitrogen atmosphere resulted in the formation of the cis isomer of **6a** predominantly (run 4). However, similar electrolysis under a normal atmosphere furnished a low yield of the cis isomer of **6a** and the yield of 2-fluoro-3-hydroxy-2,3-dihydrobenzofuran derivative **7a** increased sharply (run 3). This finding can be attributed to the air moisture, which suppresses the fluorination process and facilitates the attack of hydroxide ions. This result was confirmed by conducting similar electrolysis in the presence of a few drops of water where difluorinated products could not be detected at all and the only obtained product was *cis*-2-fluoro-3-hydroxy-2,3-dihydrobenzofuran derivative **7a** as shown in Scheme 2.

Next, anodic fluorination of the other benzofuran derivatives **5b−d** was conducted under similar electrolytic conditions, and the results are listed in Tables 2 and 3. As shown in Table 2 (runs 7−10), anodic fluorination of 1-(3-benzofuranyl)-2-propanone (**5b**) proceeds in a manner similar to that for the ester **5a**, where three isolable fluorinated products **6b** (cis/trans) and **7b** (cis) were obtained in overall good yields. The best results were recorded with the application of $Et_4NF{\cdot}4HF$ inacetonitrile

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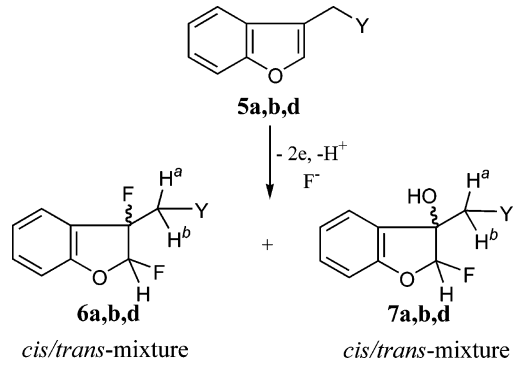
TABLE 2. Anodic Fluorination of Compounds 5a,b,d



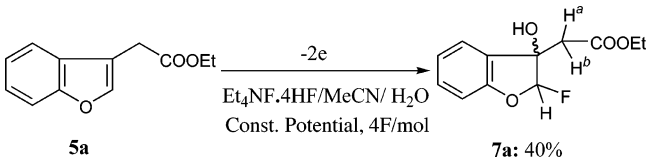
cis/trans-mixture *cis/trans*-mixture

5~7: Y; **a** : COOEt; **b**: $COCH_3$; **d**: H

run	substrate	supporting electrolyte	charge passed[a] F/mol	yield %[b] **6**, cis/trans	yield %[b] **7**, cis/trans	overall yield (%)
1	**5a**	$Et_4NF{\cdot}4HF$/DME	10	**6a**, 21/5	**7a**, 14/none	40
2	**5a**	$Et_4NF{\cdot}4HF$/MeCN	7	**6a**, 40/7	**7a**, 10/traces	57
3	**5a**	$Et_4NF{\cdot}4HF$/MeCN[c]	4	**6a**, 55/5	**7a**, 40/none	100
4	**5a**	$Et_4NF{\cdot}4HF$/MeCN[c,d]	4	**6a**, 78/10	**7a**, 7/traces	95
5	**5a**	Et3N·3HF/MeCN[c,d]	5	**6a**, 75/18	**7a**, 6/traces	99
6	**5a**	$Et_4NF{\cdot}3HF$/MeCN	7	**6a**, 51/8	**7a**, 12/traces	71
7	**5b**	$Et_4NF{\cdot}4HF$/DME	10	**6b**, 36/7	**7b**, 8/traces[e]	51
8	**5b**	$Et_4NF{\cdot}4HF$/MeCN	4	**6b**, 56/10	**7b**, 10/traces[e]	76
9	**5b**	$Et_4NF{\cdot}4HF$/MeCN[c,d]	4	**6b**, 76/14	**7b**, 3/traces[e]	93
10	**5b**	$Et_4NF{\cdot}3HF$/MeCN	4	**6b**, 51/7	**7b**, 12/3[e]	73
11	**5d**	$Et_4NF{\cdot}4HF$/MeCN	4	**6d**, 35/5	**7d**, 5/traces	45
12	**5d**	$Et_4NF{\cdot}4HF$/MeCN[c]	4	**6d**	**7d**, 14/3	93

[a] Constant-current electrolysis (6 mA/cm^2) using an undivided cell. Anode and cathode were Pt plates (2 × 2 cm). [b] Based on ^{19}F NMR. [c] Constant-potential electrolysis was applied. [d] Under a nitrogen atmosphere. [e] (2-Fluorobenzofuran-3-ylidene)acetone (**8b**) was detected by MS and ^{19}F NMR in 2−5% yield.

SCHEME 2



5a **7a:** 40%

SCHEME 3

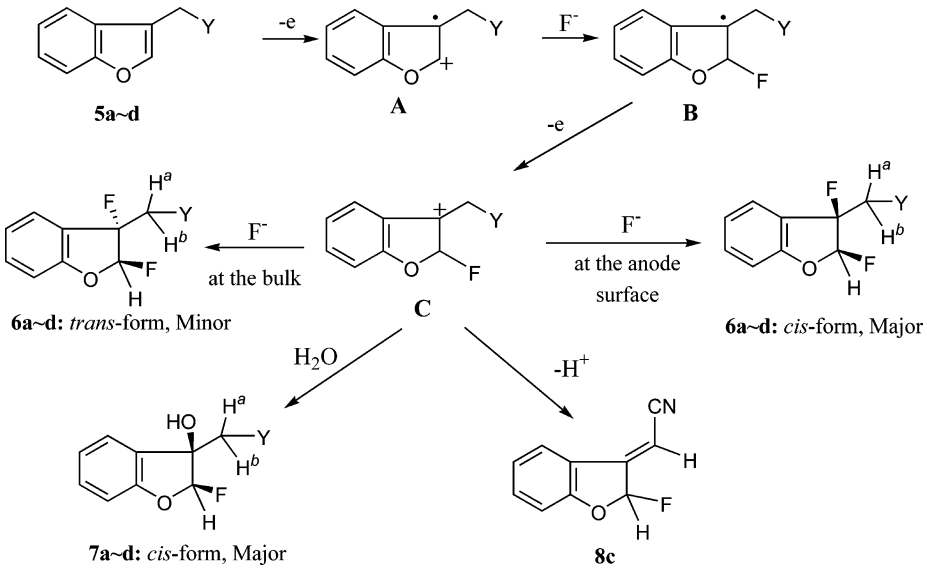
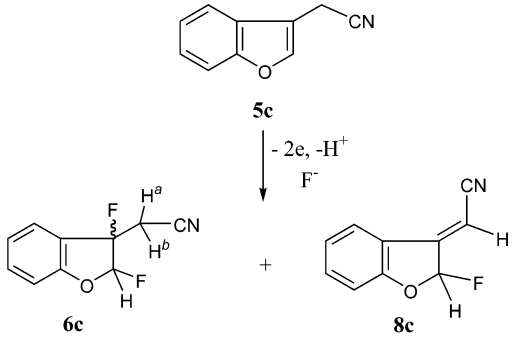


TABLE 3. Anodic Fluorination of Compound 5c



run	supporting electrolyte	charge passed F/mol	yield %[b,c] **6c**, cis/trans	**8c**	overall yield (%)
1	$Et_4NF{\cdot}4HF/MeCN$[a]	4	33/7	7	47
2	$Et_4NF{\cdot}4HF/MeCN$[d]	4	40/13	5	58
3	$Et_3N{\cdot}3HF/MeCN$[d]	4	35/16	16	67

[a] Constant-current electrolysis (6 mA/cm^2) using an undivided cell under a nitrogen atmosphere. [b] Based on ^{19}F NMR. [c] Traces of 2-fluoro-3-hydroxybenzofuran **7c** were detected by ^{19}F NMR [δ −49.24 (d, J = 62.88 Hz)]. [d] Constant-potential electrolysis (1.94 V vs SCE) was applied.

using constant-potential electrolysis under a nitrogen atmosphere (run 9). Traces of both the trans form of **7b** and dehydrofluorination product **8b** were detected by ^{19}F NMR and mass spectra (Table 2).

In the case of anodic fluorination of 3-benzofuranacetonitrile (**5c**), only the cis and trans isomers of the 2,3-difluoro-2,3-dihydrobenzofuran derivative **6c** were obtained; the expected 2-fluoro-3-hydroxy-2,3-dihydrobenzofuran derivative **7c** could not be obtained. However, the dehydrofluorination product **8c** was obtained instead of **7c** (Table 3). The yield of **8c** was slightly increased when the supporting electrolyte $Et_3N{\cdot}3HF$ salt was used (run 3, Table 3). As shown in Table 3, it was noticed that the overall fluorination yield was sharply decreased in comparison with the case of anodic fluorination of **5a** and **5b**. This may be attributed to the higher oxidation potential of compound **5c** than those of compounds **5a**,**b** (Table 1).

3-Methylbenzofuran devoid of an electron-withdrawing group (**5d**) was similarly fluorinated using $Et_4NF{\cdot}4HF$ in acetonitrile under both constant-current and -potential electrolyses (runs 11 and 12, respectively, Table 2) to give the corresponding cis/trans difluoro and monofluoro derivatives **6d** and **7d**, respectively. The fluorination yield under constant-potential electrolysis conditions is almost twice of that obtained under constant-current electrolysis conditions.

A proposed mechanism of the formation of 2,3-difluoro- and 2-fluoro-2,3-dihydrobenzofuran derivatives **6** and **7** is depicted in Scheme 3. The fluorination reaction seems to take place by electron transfer from the olefin moiety of the benzofuran ring to give the radical cation **A** followed by fluoride ion attack at the position α to ring oxygen to give the fluoro radical **B**, which undergoes further oxidation to give the cation **C**. The resulting cation **C** seems to adsorb on the anode surface. There are three possible pathways to capture the cation **C**: (a) a fluoride ion attacks at the anode surface to give the cis form of **6**, (b) a fluoride ion attacks in the bulk of the electrolytic solution to give the trans form of **6**, and (c) water attacks at the anode surface to give the cis form of **7**. $Et_3N{\cdot}3HF$ is known to contain a considerable amount of free triethylamine.[13] Therefore, it is reasonable to explain the formation of compound **8c** during the electrolysis of **5c** using $Et_3N{\cdot}3HF$ since Et_3N should promote the elimination of the acidic proton adjacent to the strongly electron-withdrawing cyano group of the cation **C**.

Attempts to perform chemical fluorination of **5a**−**d** using well-known *N*-fluoropyridinium triflates[14] failed, which attests to the advantages of using electrochemical fluorination methodology.

Treatment of *cis*-2,3-difluoro-2,3-dihydrobenzofuran **6a** with piperidine at room temperature resulted in dehydrofluorination to give the nonaromatic 2-fluoro-3-(ethoxycarbonyl) methylenebenzofuran derivative **8a** in-

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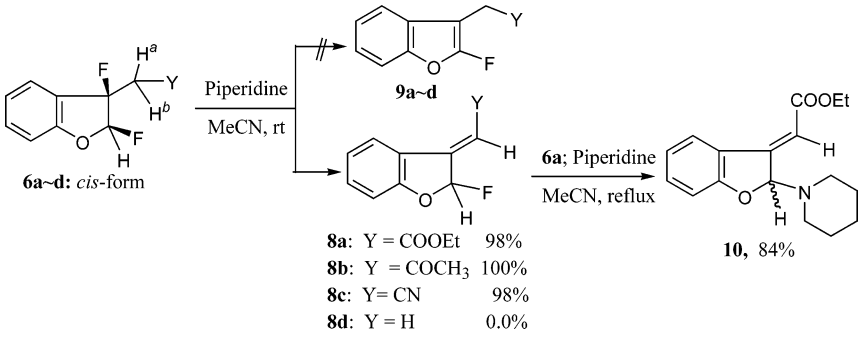
SCHEME 4



stead of its aromatized isomer **9a**, as shown in Scheme 4. The structure of **8a** was established on the basis of its ^{1}H, ^{19}F, and ^{13}C NMR spectra (see Experimental Section). Similar results were obtained when compounds **6b**,**c** were dehydrofluorinated under the same conditions. However, the dehydrofluorination of compound **6d** could not be achieved by treatment with piperidine either at room temperature or under refluxing conditions, and **6d** was mostly recovered.

Finally, when **8a** was treated with piperidine under refluxing conditions, it afforded the corresponding 2-piperidylbenzofuran derivative **10a** in high yield, as shown in Scheme 4.

In conclusion, we have found that the introduction of a substituent at the 3-position of a benzofuran moiety dramatically changed its behavior toward anodic fluorination to a positive pathway in contrast to the unsubstituted benzofuran ring. This finding opens a new avenue toward anodic fluorination of oxygen-containing heterocycles.

Experimental Section

Ethyl (3-benzofuranyl)acetate (**5a**),[9] 1-(3-benzofuranyl)-2-propanone (**5b**),[10] (3-benzofuranyl))acetonitrile (**5c**),[11] and 3-methylbenzofuran (**5d**)[12] were synthesized according to reported procedures.

Anodic Fluorination of Benzofuran Derivatives 5a−d. Electrolysis was performed with platinum electrodes (2 × 2 cm^2) in a 0.3 M solution of the appropriate fluoride salt in dimethoxyethane or acetonitrile (20 mL) containing the appropriate benzofuran derivatives **5a**−**d** (1 mmol). The electrolysis was conducted in an undivided cell either under a nitrogen atmosphere or open air conditions at room temperature. Constant-current (6 mA cm^{-2}) or controlled-potential electrolyses were applied until the starting substrates were completely consumed (monitored by TLC and GC-MS). The products were purified by silica gel column chromatography using ethyl acetate/hexane (1:5) as an eluent. In all cases, the cis isomers of difluorinated products were collected first followed by their trans isomers. After that, the *cis*-2-fluoro-3-hydoxybenzofuran derivatives were collected followed by their trans isomers. All collections were evaporated under reduced pressure, and each residue was purified again by a preparative thin-layer chromatography (25 TLC aluminum sheets 20 × 20 cm silica gel 60 F_{254}, Merck) using ethyl acetate/hexane eluent (1:5). The R_f values for the fluorination products of compound **5a** (as a model example) (**6a** (cis), **6a** (trans), and **7a** (cis)) were 0.46, 0.74, and 0.80, respectively.

Ethyl (2,3-Difluoro-2,3-dihydro-3-benzofuranyl)acetate (6a) Cis Form: mp 54−55 °C; ^{1}H NMR ($CDCl_3$) δ 1.31 (t, 3H, J = 7.25 Hz), 3.06 (ddd, 1H, J = 34.95, 17.31, 3.79 Hz), 3.45 (ddd, 1H, J = 17.31, 10.06, 3.63 Hz), 4.42 (q, 2H, J = 7.25 Hz), 6.51 (dd, 1H, J = 57.87, 9.56 Hz), 7.07 (m, 2H), 7.41 (m, 2H); ^{19}F NMR δ −56.09 (ddt, 1F, J = 57.34, 18.49, 3.7 Hz), −66.89 (m, 1F); ^{13}C NMR (DEPT) δ 14.12 (CH_3), 36.59 (dd, CH_2, J = 26.27, 3.9 Hz), 61.22 (CH_2), 111.48, 113.95 (dd, J = 235.87, 45.83 Hz), 122.86, 124.46, 132.90, (CH), 98.03 (dd, J = 183.33, 29.06 Hz), 123.32, 159.48, 167.85 (C); MS (*m*/*z*) 242 (M$^+$), 222 (M$^+$ − HF), 193, 165, 149, 127, 101, 84. Anal. Calcd for $C_{12}H_{12}F_2O_3$: C, 59.50; H, 4.99. Found: C, 59.36; H, 5.01.

Ethyl (2,3-Difluoro-2,3-dihydro-3-benzofuranyl)acetate (6a) Trans Form: yellow oil; ^{1}H NMR δ 1.23 (t, 3H, J = 7.09 Hz), 2.91 (ddd, 1H, J = 26.87, 15.83, 1.32 Hz), 3.19 (ddd, 1H, J = 15.83, 9.93, 3.79 Hz), 4.17 (q, 2H, J = 7.09 Hz), 6.39 (dd, 1H, J = 60.84, 1.81 Hz), 6.96 (d, 1H, J = 8.07 Hz), 7.08 (dd, 1H, J = 7.58, 7.09 Hz), 7.38 (m, 2H); ^{19}F NMR δ −63.64 (ddd, 1F, J = 61.03, 16.65, 3.7 Hz), −87.69 (m, 1F); MS (*m*/*z*) 242 (M$^+$), 222 (M$^+$ − HF), 165, 149, 145, 101, 89. Anal. Calcd for $C_{12}H_{12}F_2O_3$: C, 59.50; H, 4.99. Found: C, 59.41; H, 5.09.

1-(2,3-Difluoro-2,3-dihydro-3-benzofuranyl)-2-propanone (6b) Cis Form: mp 50−51 °C; ^{1}H NMR ($CDCl_3$) δ 2.28 (s, 3H), 3.11 (ddd, 1H, J = 34.29, 18.13, 3.29 Hz), 3.61 (ddd, 1H, J = 18.13, 10.88, 3.63 Hz), 6.57 (dd, 1H, J = 57.70, 9.73 Hz), 7.07 (dd, 2H, J = 8.24, 7.25 Hz), 7.40 (d, 2H, J = 7.25 Hz); ^{19}F NMR δ −55.71 (dd, 1F, J = 57.33, 18.49 Hz), −67.18 (m, 1F); MS (*m*/*z*) 212 (M$^+$), 192 (M$^+$ − HF), 177, 149, 127, 101, 75. Anal. Calcd for $C_{11}H_{10}F_2O_2$: C, 62.26; H, 4.75. Found: C, 62.27; H, 4.50.

1-(2,3-Difluoro-2,3-dihydro-3-benzofuranyl)-2-propanone (6b) Trans Form: yellow oil; ^{1}H NMR ($CDCl_3$) δ 2.24 (s, 3H), 2.98 (dd, 1H, J = 26.54, 16.65 Hz), 3.34 (ddd, 1H, J = 16.32, 11.54, 3.63 Hz), 6.28 (d, 1H, J = 60.84 Hz), 6.99 (dd, 2H, J = 8.07, 7.25 Hz), 7.40 (m, 2H); ^{19}F NMR δ −63.54 (dd, 1F, J = 61.04, 14.79 Hz), −88.11 (m, 1F); MS (*m*/*z*) 212 (M$^+$), 192 (M$^+$ − HF), 177, 149, 127, 101, 75, 43. Anal. Calcd for $C_{11}H_{10}F_2O_2$: C, 62.26; H, 4.75. Found: C, 62.14; H, 4.60.

(2,3-Difluoro-2,3-dihydro-3-benzofuranyl)acetonitrile (6c) Cis Form: mp 65−66 °C; ^{1}H NMR ($CDCl_3$) δ 3.20 (m, 2H), 6.24 (dd, 1H, J = 60.34, 11.54 Hz), 7.06 (d, 1H, J = 8.08 Hz), 7.16 (dd, 1H, J = 7.75, 7.58 Hz), 7.49 (dd, 1H, J = 8.08, 7.58 Hz), 7.63 (d, 1H, J = 7.75 Hz); ^{19}F NMR δ −56.84 (dd, 1F, J = 61.03, 16.65 Hz), −62.63 (m, 1F); MS (*m*/*z*) 195 (M$^+$), 155, 147, 127, 120, 101, 75, 63, 51. Anal. Calcd for $C_{10}H_7F_2NO$: C, 61.54; H, 3.62; N, 7.18. Found: C, 61.76; H, 3.62; N, 7.13.

(2,3-Difluoro-2,3-dihydro-3-benzofuranyl)acetonitrile (6c) Trans Form: yellow oil; ^{1}H NMR ($CDCl_3$) δ 3.05 (m, 2H), 5.97 (d, 1H, J = 60.01 Hz), 7.02 (d, 1H, J = 8.08 Hz), 7.19 (dd, 1H, J = 7.58, 7.42 Hz), 7.45 (dd, 1H, J = 7.91, 7.58 Hz), 7.57 (d, 1H, J = 7.42 Hz); ^{19}F NMR δ −62.15 (dd, 1F, J = 61.03, 12.95 Hz), −88.99 (m, 1F); MS (*m*/*z*) 195 (M$^+$), 155, 127, 120, 101, 75, 63, 51, 40. Anal. Calcd for $C_{10}H_7F_2NO$: C, 61.54; H, 3.62; N, 7.18. Found: C, 61.76; H, 3.51; N, 7.11.

2,3-Difluoro-2,3-dihydro-3-methylbenzofuran (6d) Cis Form: colorless oil; ^{1}H NMR δ 1.83 (dd, 3H, J = 21.27, 4.45 Hz), 6.10 (dd, 1H, J = 60.18, 12.36 Hz), 7.06 (m, 2H), 7.40 (m, 2H); ^{19}F NMR δ −56.97 (dd, 1F, J = 62.88, 16.65 Hz), −67.21 (m, 1F); MS (*m*/*z*) 170 (M$^+$), 155, 122, 96, 75, 63, 51. Anal. Calcd for $C_9H_8F_2O$: C, 63.53; H, 4.74. Found: C, 63.38; H, 4.85.

2,3-Difluoro-2,3-dihydro-3-methylbenzofuran (6d) Trans Form: colorless oil; ^{1}H NMR δ 1.80 (dd, 3H, J = 21.10, 1.35 Hz), 6.10 (dd, 1H, J = 61.99, 1.86 Hz), 7.06 (m, 2H), 7.36 (m, 2H); ^{19}F NMR δ −62.24 (dd, 1F, J = 61.04, 13.13 Hz), −84.55 (m, 1F); MS (*m*/*z*) 170 (M^+), 155, 127, 122, 101, 96, 75, 63, 51.

Ethyl (2-Fluoro-3-hydroxy-2,3-dihydro-3-benzofuranyl)acetate (7a) Cis Form: yellow oil; ^{1}H NMR δ 1.33 (t, 3H, J = 7.25 Hz), 2.95 (dd, 1H, J = 17.47, 3.95 Hz), 3.15 (dd, 1H, J = 17.47, 5.44 Hz), 4.28 (q, 2H, J = 7.25 Hz), 4.42 (s, 1H), 6.16 (d, 1H, J = 61.66 Hz), 6.97−7.10 (m, 2H), 7.32−7.38 (m, 2H); ^{19}F NMR δ −50.71 (ddd, J = 61.03, 5.55, 3.70 Hz); ^{13}C NMR (DEPT) δ 14.13 (CH_3), 37.63 (d, CH_2, J = 7.27 Hz), 61.53 (CH_2), 111.15, 116.88 (d, J = 239.22 Hz), 122.75, 123.85, 131.26 (CH), 80.12, 127.24, 158.28, 172.58 (C); MS (*m*/*z*) 240 (M^+), 220 (M^+ − HF), 204, 146, 133, 118, 105, 91, 77. Anal. Calcd for $C_{12}H_{13}FO_4$: C, 60.00; H, 5.45. Found: C, 60.20; H, 5.54.

1-(2-Fluoro-3-hydroxy-2,3-dihydro-3-benzofuranyl)-2-propanone (7b) Cis Form: yellow oil; ^{1}H NMR δ 1.68 (s, 3H), 2.99 (d, 1H, J = 13.85 Hz), 3.15 (d, 1H, J = 15.66 Hz), 4.51 (s, 1H), 6.17 (d, 1H, J = 62.65 Hz), 6.98−7.12 (m, 2H), 7.39−7.51 (m, 2H); ^{19}F NMR δ −49.87 (d, J = 62.88 Hz); MS (*m*/*z*) 210 (M^+), 192, 181, 175, 149, 131, 115, 101, 77, 43. Anal. Calcd for $C_{11}H_{11}FO_3$: C, 62.85; H, 5.27. Found: C, 62.71; H, 5.34.

2-Fluoro-3-hydroxy-2,3-dihydro-3-methylbenzofuran (7d) Cis Form: mp 66−67 °C; ^{1}H NMR δ 1.66 (d, 3H, J = 4.28 Hz), 2.18 (s, 1H), 5.92 (d, 1H, J = 61.83 Hz), 6.90−7.08 (m, 2H), 7.29−7.35 (m, 2H); ^{19}F NMR δ −52.27 (dm, J = 81.03 Hz); ^{13}C NMR (DEPT) δ 19.10 (CH_3, d, J = 6.71 Hz), 111.18, 117.42 (d, J = 240.35 Hz), 122.80, 123.19, 131.02 (CH), 79.70, 129.66, 157.99 (C); MS (*m*/*z*) 168 (M^+), 153, 133, 105, 91, 77, 65, 51. Anal. Calcd for $C_9H_9FO_2$: C, 64.28; H, 5.39. Found: C, 64.29; H, 5.19.

Direct Anodic Synthesis of Compound 7a. Potentiostatic electrolysis of **5a** (1 mmol) was performed in a 0.3 M solution of $Et_4NF{\cdot}4HF$ in acetonitrile (20 mL) containing water (0.5 mL). The electrolysis was conducted in an undivided cell in open air at room temperature. The electrolysis was applied until the starting substrate **5a** was completely consumed (monitored by TLC and GC-MS). The reaction mixture was passed through silica gel column chromatography using hexane/ethyl acetate eluent (5:1) to give only one product. Spectral data and elemental analysis were completely consistent with compound **7a**.

Dehydrofluorination of *cis*-2,3-Dihydrobenzofuran Derivatives 6a−c. To a stirred solution of the appropriate benzofuran derivative **7a**−**c** (1 mmol) in dry acetonitrile (10 mL) was added piperidine (0.12 mL, 1.2 mmol). The reaction mixture was stirred at room-temperature overnight. After the precipitated piperidyl hydrofluoride salt was removed by filtration, the filtrate was evaporated under vacuum. The solid product thus formed was recrystallized from hexane/ethyl acetate (3:1) to afford the corresponding pure benzofuranylidene derivatives **8a**−**c**.

Ethyl (2-Fluoro-2-hydrobenzofuran-3-ylidene)acetate (8a): mp 70−71 °C; ^{1}H NMR ($CDCl_3$) δ 1.35 (t, 3H, J = 7.25 Hz), 4.29 (q, 2H, J = 7.25 Hz), 6.44 (dd, 1H, J = 5.60, 1.32 Hz), 7.04 (m, 2H), 7.20 (dd, 1H, J = 58.36, 1.32 Hz), 7.41 (dd, 1H, J = 8.10, 7.58 Hz), 7.51 (d, 1H, J = 7.58 Hz); ^{19}F NMR δ −41.75 (dd, J = 59.18, 5.55 Hz); ^{13}C NMR (DEPT) δ 14.30 (CH_3), 61.01 (CH_2), 108.62 (d, CH, J = 232.51 Hz), 111.38, 114.07, 122.33, 122.72, 133.96 (CH), 121.49, 122.74, 161.57, 169.50 (C); MS (*m*/*z*) 222 (M^+), 193, 177, 149, 101, 84. Anal. Calcd for $C_{12}H_{11}FO_3$: C, 64.86; H, 4.99. Found: C, 64.81; H, 4.97.

(2-Fluoro-2-hydrobenzofuran-3-ylidene)acetone (8b): mp 79−80 °C; ^{1}H NMR ($CDCl_3$) δ 2.39 (s, 3H), 6.78 (d, 1H, J = 5.44 Hz), 7.03 (m, 2H), 7.16 (d, 1H, J = 56.88 Hz), 7.41 (dd, 1H, J = 8.08, 7.58 Hz), 7.52 (d, 1H, J = 7.75 Hz); ^{19}F NMR δ −42.44 (dd, J = 57.34, 5.55 Hz); ^{13}C NMR (DEPT) δ 31.51 (CH_3), 106.90, 110.31, 111.37, 121.05 (d, J = 221.34 Hz), 122.26, 134.01 (CH), 119.58, 121.33, 146.51, 161.98, 195.92 (C); MS (*m*/*z*) 192 (M^+), 177, 149, 131, 115, 101, 75, 43. Anal. Calcd for $C_{11}H_9FO_2$: C, 68.74; H, 4.72. Found: C, 68.44; H, 4.76.

(2-Fluoro-2-hydrobenzofuran-3-ylidene)acetonitrile (8c): mp 98−99 °C; ^{1}H NMR ($CDCl_3$) δ 5.68 (d, 1H, J = 5.77 Hz), 6.51 (d, 1H, J = 63.14 Hz), 7.04 (d, 1H, J = 8.25 Hz), 7.16 (dd, 1H, J = 7.75, 7.58 Hz), 7.49 (dd, 1H, J = 8.07, 7.75 Hz), 8.12 (d, 1H, J = 7.58 Hz); ^{19}F NMR δ −39.01 (dd, J = 62.88, 5.55 Hz); MS (*m*/*z*) 175 (M^+), 156, 149, 127, 120, 100, 87, 75, 63, 50. Anal. Calcd for $C_{10}H_6FNO$: C, 68.57; H, 3.45, N, 8.00. Found: C, 68.79; H, 3.61; N, 7.65.

Synthesis of Ethyl (2-Piperidyl-2-hydrobenzofuran-3-ylidene)acetate (10). To a solution of the ethyl (2-fluoro-2-hydrobenzofuran-3-ylidene)acetate (**8a**) (1 mmol) in dry acetonitrile (10 mL) was added piperidine (0.22 mL, 2.2 mmol). The reaction mixture was heated under reflux for 2 h and then left to cool to room temperature. The crude oily product was passed through silica gel column chromatography using a hexane/ethyl acetate mixture (5:1) as the eluent to afford the corresponding piperidyl benzofuranylidene derivative **10** as a yellow oil: ^{1}H NMR ($CDCl_3$) δ 1.25 (t, 3H, J = 7.25 Hz), 1.37−1.47 (m, 2H), 1.52−1.63 (m, 4H), 2.41−2.60 (m, 4H), 4.20 (q, 2H, J = 7.25 Hz), 4.80 (d, 1H, J = 0.82 Hz), 7.26 (m, 2H), 7.45 (dd, 1H, J = 7.42, 1.32 Hz), 7.66 (s, 1H), 7.81 (dd, 1H, J = 7.58, 1.48 Hz); ^{13}C NMR (DEPT) δ 14.35 (CH_3), 24.27, 26.20, 51.70, 60.77 (CH_2), 65.24, 111.25, 121.18, 122.50, 124.30, 143.68 (CH), 115.95, 127.12, 155.16, 170.48 (C); MS (*m*/*z*) 288 (M^+ + 1), 287 (M^+), 222, 214, 131, 84. Anal. Calcd for $C_{17}H_{21}NO_3$: C, 71.06; H, 7.37; N, 4.87. Found: C, 70.74; H, 7.26; N, 4.74.

Acknowledgment. This work was supported by Grant-in-Aid for Scientific Research on Priority Area (A) "Exploitation of Multi-Element Cyclic Molecules" from the Ministry of Education, Culture, Sports, Science and Technology, Japan. K.M.D. is greatly indebted to the JSPS for awarding him a postdoctoral fellowship (1999−2001).

Supporting Information Available: General part and general experimental method. This material is available free of charge via the Internet at http://pubs.acs.org.

JO035871G