

Received: July 10, 1990; accepted: October 6, 1990

**POLYHALOAROMATICS. PART V\*. SYNTHESIS OF POLY- AND PERFLUORO-1,3,5,7-TETRAHYDROBENZO[1,2-c:4,5-c']DIFURANS**

Jacek PORWISIAK and Wojciech DMOWSKI\*\*

Institute of Organic Chemistry, Polish Academy of Science  
01-224 Warsaw (Poland)

**SUMMARY**

Treatment of dichloro- or dibromopyromellitic acids **1** or **2** with a mixture of sulphur tetrafluoride and hydrogen fluoride gave the respective 4,8-dihalo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difurans (**3**) and (**4**) in high yields. Dichloro compound **3** easily undergoes halogen-exchange with potassium fluoride to give perfluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran (**5**). Reduction of dibromo-compound **4** with lithium aluminium hydride gave, depending on the reaction conditions, 1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran (**6**) or 4-bromo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran (**7**).

**INTRODUCTION**

It has been reported that the sulphur tetrafluoride fluorination of sterically crowded benzenepolycarboxylic acids affords 1,1,3,3-tetrafluoro-1,3-dihydroisobenzofurans as the main or only products. Thus, 1,2,3,4-benzenetetracarboxylic [1] or benzenepentacarboxylic acid [2] gave, respectively, 4,7-bis(triflu-

---

\* For Part IV see: Bull. Pol. Ac. Sc., Chim., **37** (1989) 297

\*\* To whom correspondence should be addressed.

oromethyl)-1,1,3,3-tetrafluoro-1,3-dihydroisobenzofuran and 4,5,7-tris(trifluoromethyl)-1,1,3,3-tetrafluoro-1,3-dihydroisobenzofuran. Fluorination of mellitic acid gave a 5 : 1 mixture of dodecafluoro-1,3,4,6,7,9-hexahydrobenzo[1,2-c:3,4-c':5,6-c'']-trifuran and 4,8-bis(trifluoromethyl)-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydro[1,2-c:4,5-c']difuran [2,3]. Octafluorobenzodifurans were also obtained by fluorination of dibromo- and dinitropyromellitic acids [3,4]; this was in contrast to the fluorination of unsubstituted pyromellitic acid which, when reacted with sulphur tetrafluoride, gave 1,2,4,5-tetrakis(trifluoromethyl)benzene and aryloyl fluorides but no cyclic ethers were found [5].

In the first paper of this series [6] we reported a high yield sulphur tetrafluoride fluorination of tetrachlorophthalic anhydride to tetrachloro-1,1,3,3-tetrafluoro-1,3-dihydroisobenzofuran, and later, its facile conversion to octafluoro-1,3-dihydroisobenzofuran [7]. The main goal of the present work was the synthesis of a new perfluorinated tricyclic compound, decafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran, by fluorination of dihalopyromellitic acids [8] with sulphur tetrafluoride, followed by the halogen exchange of the resultant 4,8-dihalo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difurans with potassium fluoride. We also report facile reduction of the 4,8-dibromo compound to the corresponding 4,8-dihydro and 4-bromo-8-hydro derivatives; the former compound has been earlier prepared by a rather tedious procedure [9].

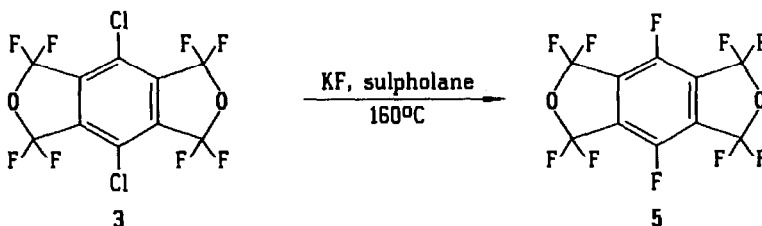
## RESULTS AND DISCUSSION

Treatment of dihalopyromellitic acids **1** or **2** with a mixture of sulphur tetrafluoride and anhydrous hydrogen fluoride at the temperature range of 200 - 240°C resulted in dehydration and fluorination of all four carboxylic groups to give 4,8-dihalo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difurans (**3**) or (**4**) in high yields. The IR spectra of crude products usually exhibited the presence of ca. 5% (GLC estimate) of aryloyl fluorides ( $\nu_{\text{COF}} = 1875$  or  $1865 \text{ cm}^{-1}$ ). The use of an

excess of sulphur tetrafluoride (3 moles per mole of each carboxylic group) was necessary to minimise the acid fluoride formation. The contents of aryloyl fluorides increased to ca. 15% when equimolar amounts of SF<sub>4</sub> were used. These fluorides, however, can be easily removed by crystallisation. Other, unidentified impurities were removed by sublimation. Because of the different solubilities of difurans 3 and 4, they were worked up in diethyl ether or benzene solutions, respectively.



The aromatic ring chlorines in compound 3 readily undergo halogen exchange with potassium fluoride under unusually mild conditions. The reaction conducted in sulpholane at 160°C was completed in less than one hour to give decafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran (5) in good yield.

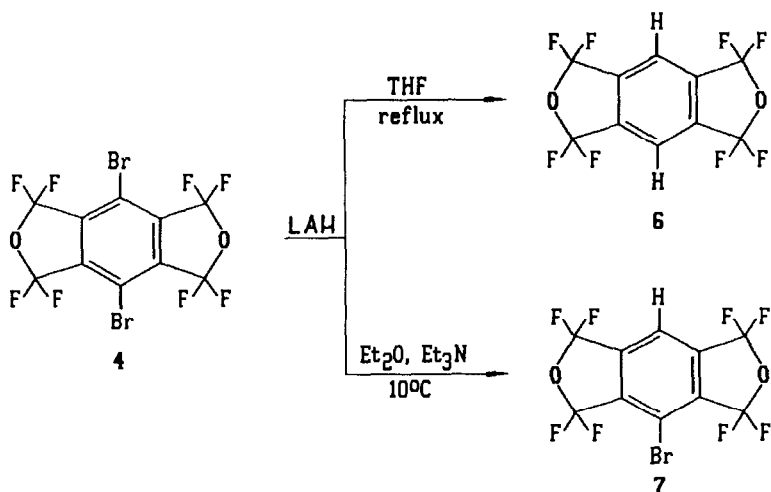


The reaction of 3 with potassium fluoride, as evidenced by appearance of an orange colouration, starts at ca. 130°C. When the reaction temperature was increased, the colour changed to deep red, thus indicating a high concentration of Meisenheimer type salts. Later, the colour faded and at the end of the reaction only a brownish-yellow colouration of the tar remained. Due to the tendency of both compounds 3 and 5 to sublime, the

halogen exchange reactions were conducted in a closed reactor under slightly increased pressure. Vigorous stirring was found to be an essential factor.

Replacement of bromine atoms in compound **4** by fluorines requires more drastic conditions (*ca.* 240°C) which results in increased tar formation and thus, lower yield and lower purity of the required product **5**.

Attempted reduction of chlorine atoms in compound **3** with lithium aluminium hydride in refluxing tetrahydrofuran failed; most of the substrate remained unreacted. Also, catalytic reduction (10%Pd/C) with hydrogen gave no satisfactory results. In contrast, bromine atoms in compound **4** easily undergo substitution by hydrogens. Thus, treatment with lithium aluminium hydride in refluxing tetrahydrofuran gave a high yield of 1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2c:4,5c']-difuran (**6**). It has been found possible to selectively reduce one bromine only, by performing the reaction in diethyl ether at 10°C in the presence of triethylamine as a moderator; 4-bromo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2c:4,5c']-difuran (**7**) was obtained as the main product.



## EXPERIMENTAL

Melting points were determined in capillaries and are uncorrected.  $^1\text{H}$ ,  $^{19}\text{F}$  and  $^{13}\text{C}$  NMR spectra were recorded with a Bruker 500 MHz spectrometer in  $\text{CDCl}_3$  solutions; chemical shifts are in p.p.m. from internal TMS for proton and carbon nuclei (positive downfield) and from internal  $\text{CFCl}_3$  for fluorine nuclei (positive upfield). Purities of compounds were checked by GLC using a 3.5 m x 4 mm column packed with Chromosorb G coated with 5% silicon oil SE-52.

Dihalopyromellitic acids [8] and sulphur tetrafluoride [10] were prepared in this laboratory according to the procedures described previously. The hydrogen fluoride was commercial material. Potassium fluoride (FLUKA A.G., pure grade) was dried at  $200^\circ\text{C}$  for 48 hours and used whilst hot. Sulpholane was freshly vacuum distilled. Tetrahydrofuran and diethyl ether were dried with sodium wire and redistilled from lithium aluminium hydride.

### 4,8-Dichloro-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo-[1,2-c:4,5-c']difuran (3) (nc)

Dichloropyromellitic acid **1** (43.7 g, 0.135 mole) was placed in a 500 ml stainless steel autoclave, then cold (ca.  $-10^\circ\text{C}$ ) liquid anhydrous hydrogen fluoride (40 g, 2 mole) was added and the autoclave was quickly closed. After cooling in an acetone-dry ice bath, the autoclave was evacuated and sulphur tetrafluoride (190 g, 1.5 mole) was condensed in it. The charged autoclave was heated in a rocking muffle furnace at  $210^\circ\text{C}$  for 20 hours. After completion of the reaction the autoclave was allowed to cool to ambient temperature and the gases ( $\text{SO}_2$ ,  $\text{SF}_4$ , HF) were let off (at the end slight heating was applied). The solid material was dissolved in diethyl ether (150 ml), the solution was washed with 5% aqueous potassium hydroxide (3 x 20 ml) followed by water, dried over anhydrous magnesium sulphate, then decolourised by filtration through a layer of silica-gel

(30 g). The solid material obtained after evaporation of the solvent was recrystallised from methanol (100 ml), then vacuum sublimed (100 - 120°C, 12 Torr) to give compound 3 (42.5 g, yield 84%) of 99.6% purity as white crystals; m.p. 194.5 - 195°C (Found: C, 32.2; Cl, 19.0; F, 40.5%.  $C_{10}Cl_2F_8O_2$  requires: C, 32.0; Cl, 18.9; F, 40.5%);  $^{19}F$  NMR: 71.5 p.p.m. (s);  $^{13}C$  NMR: 123.1 p.p.m. (tt,  $CF_2$ ,  $^1J_{C-F} = 262.8$  Hz,  $^3J_{C-F} = 3.2$  Hz), 124.8 p.p.m. (s, C-Cl arom.), 137.1 p.p.m. (t, C-arom.,  $^2J_{C-F} = 30.8$  Hz).

**4,8-Dibromo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo-[1,2-c:4,5-c']difuran (4)**

Dibromopyromellitic acid 2 (10 g, 0.024 mole), anhydrous hydrogen fluoride (7 g, 0.35 mole), and sulphur tetrafluoride (60 g, 0.47 mole) were placed in a 100 ml autoclave, as described above, and reacted at 240°C for 40 hours. The crude product was dissolved in benzene (100 ml), the solution was washed with 5% aqueous potassium hydroxide (3 x 10 ml), filtered through silica-gel (10 g) and evaporated. Vacuum sublimation (130 - 150°C, 2 Torr) followed by recrystallisation from hexane-benzene mixture (10 : 1) gave compound 4 (9.8 g, yield 84%) of 99.5% purity. White crystals; m.p. 231.5 - 232.0°C (ref. [3], m.p. 230 - 231°C) (Found: C, 25.7; Br, 34.5; F, 32.7%.  $C_{10}Br_2F_8O_2$  requires: C, 25.9, Br, 34.45; F, 32.75%);  $^{19}F$  NMR: 72.0 p.p.m. (s);  $^{13}C$  NMR: 111.8 p.p.m. (s, C-Br arom.), 123.3 p.p.m. (tt,  $CF_2$ ,  $^1J_{C-F} = 263.0$  Hz,  $^3J_{C-F} = 3.2$  Hz), 138.9 p.p.m. (t, C-arom.,  $^2J_{C-F} = 30.5$  Hz).

**Decafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran (5) (nc)**

The halogen exchange reaction was carried out in an electrically heated 500 ml cylindrical glass reactor (SOVIREL) fitted with a strong anchor-shaped stirrer and a thermometer. The stirrer and the thermometer were placed as close as possible to the bottom of the reactor.

Dichloro compound **3** (56.4 g, 0.15 mole), potassium fluoride (70 g, 1.2 mole) and sulpholane (200 ml) were placed in the reactor, the reactor was firmly closed (all stopcocks were wired) and slowly warmed up to 160°C while stirring. After one hour stirring at this temperature the reaction mixture was allowed to cool to ambient temperature and poured into water (2 l). Diethyl ether (500 ml) was added and the mixture was mechanically stirred until all solid material from the water phase was dissolved in ether (ca. 1 hour). The organic layer was separated, the water layer was extracted with ether (2 x 200 ml) and the combined ether solutions were dried over anhydrous magnesium sulphate. A brownish solid obtained after evaporation of ether was subjected to vacuum sublimation (70 - 90°C, 14 Torr). Crystallisation of the sublimate from diethyl ether gave compound **5** (37 g, yield 72%) of 95% purity. Recrystallisation from ether gave decafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']-difuran (33 g) of 99.5% purity; m.p. 134 - 134.5°C (white crystals) (Found: C, 35.1; F, 55.5%. C<sub>10</sub>F<sub>10</sub>O<sub>2</sub> requires: C, 35.1; F, 55.5%); <sup>19</sup>F NMR: 68.5 p.p.m. (s, CF<sub>2</sub>), 121.3 p.p.m. (s, CF); <sup>13</sup>C NMR: 124.0 p.p.m. (tt, CF<sub>2</sub>, <sup>1</sup>J<sub>C-F</sub> = 260.8 Hz, <sup>3</sup>J<sub>C-F</sub> = 3.3 Hz), 127.8 p.p.m. (m, C-arom.), 148.0 p.p.m. (dd, CF-arom., <sup>1</sup>J<sub>C-F</sub> = 272.0 Hz, <sup>4</sup>J<sub>C-F</sub> = 7.9 Hz).

**1,1,3,3,5,5,7,7-Octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c'] difuran (6)**

The reaction was carried out under dry nitrogen. A solution of dibromo compound **4** (4.6 g, 10 mmoles) in dry tetrahydrofuran (10 ml) was added dropwise to a stirred suspension of lithium aluminium hydride (1 g, 26 mmoles) in 50 ml of tetrahydrofuran at such a rate as to keep the reaction mixture boiling spontaneously (ca. one hour). When the vigorous reaction ceased, heat was applied to keep the reflux for an additional one hour. The excess of LiAlH<sub>4</sub> was destroyed by adding methanol (3 ml), then the reaction mixture was poured into 1% hydrochloric acid (200 ml). The solution was extracted with diethyl ether (3 x 15 ml), the extract was dried over anhydrous

magnesium sulphate and evaporated. The solid residue was vacuum sublimed (60 - 70°C, 0.4 Torr), and the sublimate was recrystallised from n-hexane (10 ml) to give compound **6** (2.8 g, 91% yield) of 99.6% purity as white crystals; m.p. 149 - 150°C (ref. [9], m.p. 149 - 150°C) (Found: C, 39.2; H, 0.4; F, 49.6%. C<sub>10</sub>H<sub>2</sub>F<sub>8</sub>O<sub>2</sub> requires: C, 39.2; H, 0.65; F, 49.7%); <sup>1</sup>H NMR: 8.02 p.p.m. (s); <sup>19</sup>F NMR: 69.3 p.p.m. (s); <sup>13</sup>C NMR: 118.2 p.p.m. (d, C-H arom., <sup>1</sup>J<sub>C-H</sub> = 174.6 Hz), 124.5 p.p.m. (tt, CF<sub>2</sub>, <sup>1</sup>J<sub>C-F</sub> = 260.5 Hz, <sup>3</sup>J<sub>C-F</sub> = 2.8 Hz), 137.6 p.p.m. (td, C-arom., <sup>2</sup>J<sub>C-F</sub> = 32.2 Hz, <sup>2</sup>J<sub>C-H</sub> = ca. 6 Hz).

**4-Bromo-1,1,3,3,5,5,7,7-octafluoro-1,3,5,7-tetrahydrobenzo[1,2-c:4,5-c']difuran (7) (nc)**

The reaction was carried out under dry nitrogen. A stirred solution of compound **4** (2.3 g, 5 mmoles) and triethylamine (0.05 ml) in dry diethyl ether (30 ml) was cooled to 10°C then lithium aluminium hydride (0.2 g, 5.3 mmoles) was added in small portions during 2.5 hours. The reaction temperature was kept at 10 - 12°C. The reaction was quenched by adding water (5 ml) and conc. hydrochloric acid (1 ml). The ether layer was separated, dried over magnesium sulphate and evaporated. A solid residue (1.5 g) was found by the GLC to contain 96% of compound **7**, 2% of **6** and 2% of **4**. Recrystallisation from n-hexane gave compound **7** (0.5 g, 26% yield) of 98.6% purity. White crystals; m.p. 139 - 141°C (Found: C, 31.5; H, 0.3; Br, 20.7; F, 39.5%. C<sub>10</sub>HBrF<sub>8</sub>O<sub>2</sub> requires: C, 31.2; H, 0.25; Br, 20.75; F, 39.5%); <sup>1</sup>H NMR: 7.93 p.p.m. (s); <sup>19</sup>F NMR: 69.4 p.p.m. (s, CF<sub>2</sub>), 71.9 p.p.m. (s, CF<sub>2</sub>); <sup>13</sup>C NMR: 113.8 p.p.m. (s, C-Br), 116.3 p.p.m. (d, C-H, <sup>1</sup>J<sub>C-H</sub> = 175.5 Hz), 123.5 p.p.m. (tq, CF<sub>2</sub>, <sup>1</sup>J<sub>C-F</sub> = 260.9 Hz, <sup>3</sup>J<sub>C-F</sub> = <sup>3</sup>J<sub>C-H</sub> = 3.3 Hz), 124.3 p.p.m. (tt, CF<sub>2</sub>, <sup>1</sup>J<sub>C-F</sub> = 262.7 Hz, <sup>3</sup>J<sub>C-F</sub> = 2.8 Hz), 137.5 p.p.m. (tm, C-arom., <sup>2</sup>J<sub>C-F</sub> = 29.0 Hz), 139.4 p.p.m. (t, C-arom., <sup>2</sup>J<sub>C-F</sub> = 31.5 Hz).



**ACKNOWLEDGMENT**

This work has been supported by the Polish Academy of Sciences within the project CFBP-01.13.1.21.

**REFERENCES**

- 1 A.I.Burmakov, L.A.Alekseeva and L.M.Yagupolskii, Zhurn.Org. Khim., 6 (1970) 144.
- 2 A.I.Burmakov, L.A.Alekseeva and L.M.Yagupolskii, Zhurn.Org. Khim., 6 (1970) 2498.
- 3 L.M.Yagupolskii, A.I.Burmakov, L.A.Alekseeva and B.V.Kunshenko, Zhurn.Org.Khim., 9 (1973) 689.
- 4 V.G.Lykmanov, L.A.Alekseeva and L.M.Yagupolskii, Zhurn.Org. Khim., 13 (1977) 2129.
- 5 W.R.Hasek, W.C.Smith and V.A.Engelhardt, J.Am.Chem.Soc., 82 (1960) 543.
- 6 W.Dmowski and J.Wielgat, J.Fluorine Chem., 37 (1987) 429.
- 7 W.Dmowski and J.Wielgat, J.Fluorine Chem., 41 (1988) 241.
- 8 J.Porwisiak and W.Dmowski, Synth.Comm., 19 (1989) 3221.
- 9 R.V.Belinskaya and L.M.Yagupolskii, Zhurn.Obshch.Khim., 38 (1968) 1726.
- 10 W.Dmowski and R.Kolinski, Pol.J.Chem., 47 (1973) 1211.