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SHORT COMMUNICATION

Direct Synthesis of 1,4-Difluoronaphthalene

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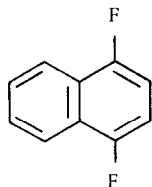
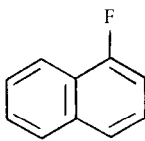
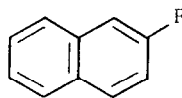
1,4-Difluoronaphthalene ( $I$ ) is an attractive molecule for investigation in magnetic resonance [1,2], and in chemical carcinogenesis [3] as a synthon for highly condensed difluoro-polycyclic aromatic hydrocarbons (PAH). It is not readily prepared by the conventional methods of synthesis of fluoroaromatics. Thus, Schiemann et al. [4] achieved the first successful synthesis of  $I$  starting with 1-fluoronaphthalene ( $II$ ) and using the sequence  $RH(II) \rightarrow RNO_2 \rightarrow RNH_2 \rightarrow RN_2^+X^- \rightarrow RF(I)$  (where  $R = 1-C_{10}H_6F$ ).<sup>4</sup> However, difficulties were encountered in directing the nitration of  $II$  to the desired 4-position [1]. Recently, Adcock et al. [2] circumvented this problem by employing the following lengthier yet unambiguous and more reliable route  $RH(II) \rightarrow RCOCH_3 \rightarrow RC(CH_3)=NOH \rightarrow RNH_3^+X^- \rightarrow RN_2^+PF_6^- \rightarrow RF(I)$ . Wittig and Harle prepared  $I$  from 1,4-dibromo-2,5-difluorobenzene by applying the benzyne route to naphthalenes [5]. Lately,  $I$  was obtained by an anodic fluorination of  $II$  [6]. We report a one-step synthesis of  $I$  by a direct fluorination of naphthalene, applying xenon difluoride as the fluorinating agent. This reaction has previously been reported to give a mixture of  $II$  and 2-fluoronaphthalene ( $III$ ), but not  $I$  [7].

The reaction was carried out in dichloromethane solution, in a Kel-F tube in an open system under anhydrous conditions, without HF initiation. The <sup>19</sup>F NMR spectrum of the crude reaction mixture (after aqueous work-up) contained the following absorptions:  $\delta = 115.0$  (sextet,  $J_1 = 10.2$  Hz,  $J_2 = 9.6$  Hz,  $J_3 = 5.6$  Hz, relative area 11), 123.4 (quartet,  $J_1 = 10.6$  Hz,  $J_2 = 5.9$  Hz, relative area 53), and 127.9 ppm (triplet,  $J = 7.7$  Hz, relative area 36). The absorptions at 115.0 and 123.4 ppm were ascribed to  $II$  and  $III$ , respectively (on the basis of a comparison with the corresponding spectra of authentic samples) [8]. The remaining triplet at 127.9 ppm

represented  $\overset{\text{I}}{\text{C}}$  (vide infra). No other fluorinated naphthalene derivatives were detected in the  $^{19}\text{F}$  NMR spectrum. A calibration of this spectrum with an authentic sample of  $\overset{\text{II}}{\text{C}}$  gave the following crude yields: 15% ( $\overset{\text{I}}{\text{C}}$ ), 45% ( $\overset{\text{II}}{\text{C}}$ ) and 9% ( $\overset{\text{III}}{\text{C}}$ ). The glc of the crude product showed only three major bands, representing naphthalene, a mixture of  $\overset{\text{II}}{\text{C}}$  and  $\overset{\text{III}}{\text{C}}$ , and  $\overset{\text{I}}{\text{C}}$ , respectively. It should be noted that in the previously reported fluorination of naphthalene with xenon difluoride, glc effected a separation between  $\overset{\text{II}}{\text{C}}$  and  $\overset{\text{III}}{\text{C}}$  [7]. Our attempts to resolve  $\overset{\text{II}}{\text{C}}$  and  $\overset{\text{III}}{\text{C}}$  failed. The structure of  $\overset{\text{I}}{\text{C}}$  was established by the elemental analysis, the melting point [2,4,5], the molecular ion at  $m/e$  164 in the mass spectrum and the practical identity of the  $^{19}\text{F}$  NMR chemical shift and pattern with those of an authentic sample of  $\overset{\text{I}}{\text{C}}$  measured by Adcock et al. [2]. This  $^{19}\text{F}$  NMR spectrum is characterized by a "virtual" coupling [9] ( $J_{\text{F-H-2}} = J_{\text{F-H-3}} = 7.7$  Hz). Such a coupling has been observed, e.g. in the  $^{19}\text{F}$  NMR spectra of 5,8-difluoroquinoline [10] ( $J_1 = J_2 = 7.0$  Hz) and 1,4,5-trifluoronaphthalene [1].

Compound  $\overset{\text{II}}{\text{C}}$  (or a  $\sigma$ -complex derived therefrom) presumably serves as an intermediate in the synthesis of  $\overset{\text{I}}{\text{C}}$ . The issue of  $\alpha$  versus  $\beta$  orientation in the naphthalene series is enlightened by the fact that the combined yields of  $\overset{\text{I}}{\text{C}}$  and  $\overset{\text{II}}{\text{C}}$  significantly surpasses the yield of  $\overset{\text{III}}{\text{C}}$  ( $(\overset{\text{I}}{\text{C}} + \overset{\text{II}}{\text{C}}) : \overset{\text{III}}{\text{C}} = 6.7$ ). Furthermore, the formation of  $\overset{\text{I}}{\text{C}}$  rather than other isomeric difluoro-naphthalenes, reflects the overwhelming preference of para-orientation (by the fluorine substituent of  $\overset{\text{II}}{\text{C}}$ ) in this fluorine-substitution reaction.

The direct one-step preparation of  $\overset{\text{I}}{\text{C}}$  widens the fluorination capabilities of xenon difluoride [11,12], indicating the applicability of this relatively mild fluorinating agent to the synthesis of difluoro-PAH.

 $\overset{\text{I}}{\text{C}}$  $\overset{\text{II}}{\text{C}}$  $\overset{\text{III}}{\text{C}}$ 

### Experimental

Melting points were taken on a Tottoli Buchi capillary melting point apparatus and are uncorrected. Infrared spectra were recorded on a Perkin-

Elmer Model 457 spectrophotometer. Ultraviolet spectra were recorded on a Unicam Model SP800A spectrophotometer.  $^{19}\text{F}$  NMR spectra were taken on a Varian HA-100D spectrometer at 94.1 MHz.  $^{19}\text{F}$  chemical shifts ( $\delta$ ) are reported in parts per million upfield from  $\text{CCl}_3\text{F}$ , using  $\text{C}_6\text{F}_6$  as internal standard. GLC analyses and separations were carried out on a Packard Model 7400 instrument, using a flame ionization type detector for analyses and a thermal conductivity detector for preparative glc (vide supra).

#### 1,4-difluoronaphthalene ( $I_{\nu}$ )

A solution of naphthalene (1.9 g, 14.8 mmole) in dry dichloromethane (35 ml) was added, under anhydrous conditions to xenon difluoride [13] (2.5 g, 14.8 mmole) in a Kel-F tube protected from moisture at  $-196^\circ$ . After 1 h at  $-78^\circ$ , the reaction mixture changed its color from yellow to brown. It was occasionally shaken and xenon evolution was observed. After a gradual warming up to room temperature, and stirring for 6 h, a dark green color developed. The mixture was diluted with additional dichloromethane (50 ml) and cautiously decomposed with aqueous sodium bicarbonate. The organic fraction was washed twice with sodium bicarbonate and once with water, dried over anhydrous sodium sulfate, and the solvent evaporated in vacuum. GLC of the remaining crude product (12'  $\times$  1/4" column of Apiezon L (2.5%) on Chromosorb W (60-80 mesh), column temperature  $130^\circ$ , flow rate 60 ml/min) gave three peaks: naphthalene (ret. time (r.t.) relative to  $\text{CH}_2\text{Cl}_2$ , 19.5 min, 22%),  $I_{\nu} + I_{\nu'} + I_{\nu''}$  (r.t. 17.6 min, 60%) and  $I_{\nu}$  (r.t. 15.3 min, 15%). A pure sample of  $I_{\nu}$  was obtained by preparative glc (15'  $\times$  1/4" column as above, column temperature,  $130^\circ$ , f.r. 60 ml/min). It was obtained as a colorless, semicrystalline solid, mp  $31^\circ$ . Lit., mp  $31.5^\circ$  [4],  $30.5-31^\circ$  [5],  $32^\circ$  [2];  $^{19}\text{F}$  NMR,  $\delta(\text{CDCl}_3) = 127.9$  ppm (t, J = 7.7 Hz),  $\delta(I_{\nu}) - \delta(I_{\nu'}) = 4.5$  ppm ( $\text{CDCl}_3$ ) (lit.,  $\delta = 127.9$  ppm;  $\delta(I_{\nu}) - \delta(I_{\nu'})$  [2] = 3.93 (DMF), 4.57 ppm ( $\text{C}_6\text{H}_6$ ) (t, J = 7.2 Hz (DMF), 7.0 Hz ( $\text{C}_6\text{H}_6$ )), UV,  $\lambda_{\text{max}}$  (cyclohexane) = 265 (log  $\epsilon$  4.44), 270 (4.27), 278 (4.34), 287 (4.75), 290 (4.56), 303 (3.23), 310 (3.35) and 317 nm (3.18); IR,  $\nu(\text{neat}) = 1660, 1510, 1465, 1400, 1262, 1230, 1075, 1033, 1010, 871, 790, 701$  and  $570 \text{ cm}^{-1}$ ; mass spectrum, m/e 164 ( $\text{M}^+$ ).

Anal. Calc. for  $\text{C}_{10}\text{H}_6\text{F}_2$ : C, 73.2; H, 3.7; Found: C, 73.5; H, 3.9.

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