A Novel Anodic Substitution Reaction: Oxidative Displacement of Fluorine by an Acetoxy Group

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Summary Anodic oxidation of 2- and 4-fluoroanisole in a potassium acetate–acetic acid solution produces 2- and 4-acetoxyanisole, respectively, *via* a non-conventional reaction path.

ANODIC substitution reactions are commonly represented by equation (1)

$$\text{R–E} + \text{Nu}^- \rightarrow \text{R–Nu} + \text{E}^+ + 2\text{e} \qquad (1)$$

where Nu^- is the nucleophile, and E^+ the electrophile, generally a proton or an alkoxonium ion.[1] Almost all examples of this reaction are classified as *ECEC* reactions (*E*: electron transfer step, *C*: chemical step).[1]

We now report a novel anodic substitution reaction, unusual from the mechanistic point of view. When 4-fluoroanisole (**1**) was oxidized at a controlled anode potential (1·5 V *vs.* S.C.E.) at a Pt anode in an undivided cell in 0·5M KOAc–HOAc the major product was 4-acetoxyanisole (**2**)† and only traces of the expected substitution products (2- and/or 3-acetoxy-4-fluoroanisole) were observed. No reaction took place in the absence of current. A high current yield of (**2**) was obtained at low conversion (70–80% based on a one-electron process when $<$0·5 F mol^{-1} of substrate had passed). The yield gradually decreased on prolonged electrolysis (40% after a passage of 1 F mol^{-1}), probably owing to further oxidation of (**2**).‡ Coulometry at constant potential gave an *n* value of **1**. On single sweep voltammetry an *n* value of 2 was calculated.§ Anodic oxidation of (**1**) in the absence of acetate ion (Bu_4NBF_4–HOAc) produced neither (**2**) nor any other aryl acetates.[2] 2-Fluoroanisole behaved similarly on anodic oxidation in 0·5M KOAc–HOAc yielding 2-acetoxyanisole. On the other hand anodic oxidation of 3-fluoroanisole, 4-bromoanisole, and 4-chloroanisole, respectively, in the same medium yielded normal substitution products (displacement of hydrogen by an acetoxy group) and only traces of acetoxyanisoles were detected.

Our observation that a 2- or 4-fluorosubstituent in anisole changes the usual product pattern in anodic acetoxylation is not consistent with the common *ECEC* reaction sequence in anodic substitution, since this would require a loss of F^+ from (**5**) in equation (2); that is extremely unlikely from an energetic point of view. A reaction mechanism must take into account the fact that 4-bromo- and 4-chloro-anisole yield normal substitution products.

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† All products were satisfactorily identified by comparison with authentic samples or by spectroscopic methods.

‡ The voltammetric peak potential of (**2**) is *ca.* 0·1 V lower than that of (**1**).

§ This value was determined in MeCN–HOAc (4:1) containing 0·17M NaOAc and 0·07M LiClO_4.

A reaction path involving a loss of fluorine radicals from either (**3**) or (**4**) [reactions (2)—(4)]

$$\mathrm{Ar{-}F} \xrightarrow[-e]{} \underset{(\mathbf{3})}{[\mathrm{Ar{-}F}]^{+\cdot}} \xrightarrow[\mathrm{AcO^-}]{} \underset{(\mathbf{4})}{[\mathrm{F{-}Ar{-}OAc}]^{\cdot}} \xrightarrow[-e]{} \underset{(\mathbf{5})}{[\mathrm{ArOAc\ F}]^{+}} \qquad (2)$$

Ar = 2- or 4-anisyl

$$(\mathbf{4}) \rightarrow [\mathrm{Ar{-}OAc}]^{+\cdot} + \mathrm{F^-} \qquad (3)$$

$$(\mathbf{5}) \rightarrow \underset{(\mathbf{6})}{[\mathrm{Ar{-}OAc}]^{2+}} + \mathrm{F^-} \qquad (4)$$

(yielding HF by hydrogen abstraction from a surrounding molecule or ion) might be energetically feasible, since the heat of formation of HF in a homolytic reaction is considerably higher than that of either HCl or HBr. However, several observations contradict such a radical pathway. A loss of a fluorine radical from (**3**) would yield an anisyl cation that should yield (**2**) independently of acetate ions. The result obtained from the oxidation of (**1**) in the absence of acetate ions is inconsistent with that. A loss of a fluorine radical from (**4**) would yield (**2**). However, the voltammetric *n* value of 2 is not consistent with such a reaction path. We have not been able to detect any products resulting from radical reactions.[3]¶

We are left with the assumption that at some intermediary stage in the formation of (**2**) a fluoride ion is lost as shown in equations (3) and (4). This idea seems attractive since the fluoride ion (as in KF) is strongly solvated in acetic acid.[4] The different *n* values obtained by coulometry and voltammetry give an indication that an intermediate (formed after two *E* steps), *e.g.* (**6**), is oxidizing the starting material.

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¶ It has been shown that acetoxyl radicals are not intermediates in the formation of acetoxyaromatic compounds during the electrolysis of a mixture of acetate ion and an aromatic compound in acetic acid.

[1] For a review, see: L. Eberson and K. Nyberg, *Adv. Phys. Org. Chem.*, 1976, **12**, 1.

[2] L. Eberson, *J. Amer. Chem. Soc.*, 1976, **89**, 4669; Traces of biaryl derivatives were detected. The major products are probably oligomers and polymers, *cf.* ref. 2.

[3] For a review, see: L. Eberson and K. Nyberg, *Accounts Chem. Res.*, 1973, **6**, 106.

[4] J. Emsley, *J. Chem. Soc.* (A), 1971, 2511.