

Electrochemical Reduction of Aryl thiocyanates: A Unique Autocatalytic Process and Evidence for a Concerted-Stepwise Mechanism Transition.

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Important aspects of the electrochemical reduction of aryl thiocyanates were investigated. A striking change in the reductive cleavage mechanism as a function of the substituent on the aryl ring of the aryl thiocyanate is observed. A similar behavior has been reported for benzyl halides.¹ This is different from what is widely reported for aryl halides where a stepwise mechanism is taking place regardless of the nature of the substituents on the aryl group. With nitro substituents, a stepwise mechanism involving the intermediacy of the radical anion takes place. With electron donating substituents, a transition between the concerted and stepwise mechanisms is observed on the basis of the analysis of the transfer coefficient (Figure 1). A nonlinear potential dependence of α is seen in this case, using both voltammetric as well as convolution analyses. Moreover, a very interesting autocatalytic process takes place during the electrochemical reduction of aryl thiocyanates (Scheme 1). This results in the dependence of the reduction potential, as well as the peak width, on the scan rates. For low values of the kinetic competition parameter λ ($\lambda = RTkC_0^0/Fv$), small C_0 's and high sweep rates, the autocatalytic process has practically no effect and the reduction peak reflects the intrinsic characteristics of the direct reduction of the aryl thiocyanate. When the kinetic competition parameter λ increases, i.e. high concentration and low scan rates, the autocatalytic process interferes more and more and the appearance of trace crossing is a characteristic feature of the efficiency of this process. As a result of this autocatalytic process, the reduction of the aryl thiocyanates takes place at less negative potentials than expected. This means that ET reactions may be involved in the bioactivity of aryl thiocyanates, since glutathione is a good electron donor. Moreover, aryl thiocyanates with electron-withdrawing substituents, which are easier to reduce, have been shown to be more active.² The autocatalytic process involves a nucleophilic substitution in a father-son type reaction. This is different from the "classical" autocatalytic process involving an electron transfer between an anion produced at the electrode and the starting substrate.

Finally, the reported mechanism helps to explain the results of the chemical reduction of aryl thiocyanates in the presence of electrophiles.³ With one equivalent of SmI_2 , a single dissociative ET takes place leading to thiyl radical and a cyanide anion. The thiyl radical dimerizes, yielding the corresponding disulfide. In the presence of 2 equivalents of SmI_2 , the aryl thiocyanates yield the corresponding thiolate and cyanide anions in a two-electron reduction process, as shown in the electrolyses. The thiolate ions then attack the electrophile present, yielding the observed substitution products.

References:

- (1) Andrieux, C. P.; Le Gorande, A.; Savéant, J.-M. *J. Am. Chem. Soc.* **1992**, *114*, 6892.
- (2) Morley, J. O.; Naji, M. *J. Chem. Soc. Perkin Trans. 2*, **1992**, 1301.
- (3) (a) Still, I. W. Toste, F. D. *J. Org. Chem.* **1996**, *61*, 7677. (b) Toste, F. D.; LaRonde, F. Still, I. W. *Tetrahedron Letters* **1995**, *36* (17), 2949.

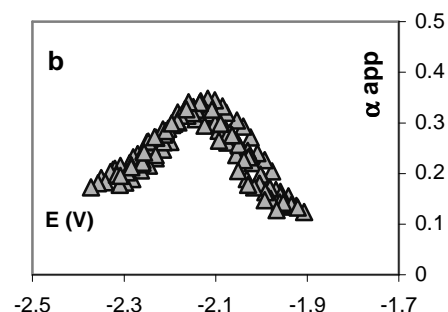
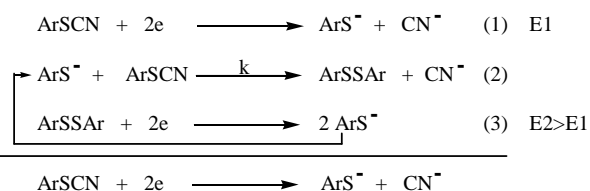


Figure 1: Variation of α_{app} with E for p-methylphenyl thiocyanate (0.85 mM) at scan rate $v = 7.2, 10, 20, 30, 40, 60$ and 80 V/s.



Scheme 1