

ANODICALLY INITIATED AROMATIC IODINATION AND SIDE CHAIN SUBSTITUTION REACTIONS

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There is considerable current interest in electrochemically initiated aromatic substitution reactions.¹⁻⁷ These recent reports and our own studies on the oxidation of organic iodides⁸ stimulated this investigation of the electrochemical iodination of aromatic molecules.

Although direct electrochemical chlorinations of aromatic molecules are readily obtained by the oxidation of chloride ions, the oxidation of iodide ion in the presence of aromatic molecules does not ordinarily yield iodoaromatic products.⁹ This result is explicable in terms of one electron iodide oxidation to iodine atoms and molecular iodine, neither of which are active halogenating agents. We hypothesized that electrochemical iodinations might be feasible, however, under somewhat different conditions where either positive iodine species or aromatic cation radicals would be generated. This hypothesis was explored by carrying out the controlled potential oxidation of a mixture of a number of simple aromatic molecules and iodine in acetonitrile-lithium perchlorate solution. The reactions were carried out in a three-compartment cell using a platinum sheet anode and a silver-silver nitrate reference electrode. The anolyte was initially 0.2 M in iodine and about 0.01 M in aromatic. After passage of about ten millifaradays of electricity, the products were simply worked up by evaporating the solvent; adding ether; and washing this mixture with water, aqueous thiosulfate and water; and drying and evaporating the ether. Except for the anthracene and nitrobenzene reactions, it was found that aromatic iodination was indeed successful. In the case of several alkyl substituted aromatics, a second very interesting side chain substitution reaction was observed. These alkyl substituted products were acetamides which apparently formed by reaction of benzylic type carbonium ions with acetonitrile.^{8,10} The yields of various ring and side chain substituted products, based on the initial amount of aromatic, are compiled in Table I.

TABLE I

Aromatic	% Yield	
	Mono Iodoaromatic	Side Chain Substitution
Benzene	11	--
Toluene	16 para; 16 ortho; <2 meta	0
p-Xylene	50	12 a.
p-Xylene b.	66	9
Mesitylene	73	0
Anisole c.	13 para; 6 ortho; <1 meta	--
Anthracene	0	--
Nitrobenzene	0	--
Triphenylmethane	15	36 d.

a. N-p-Tolylacetamide

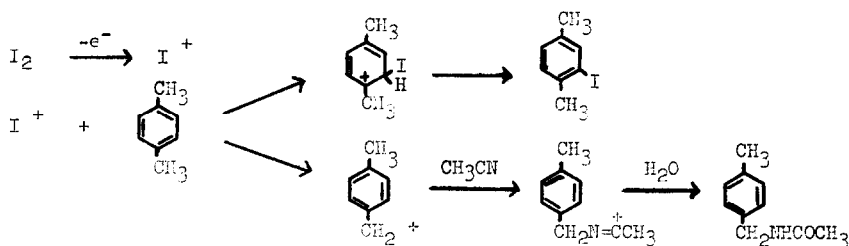
b. Using tetra-n-propylammonium fluoborate as electrolyte

c. Some tarry products also formed

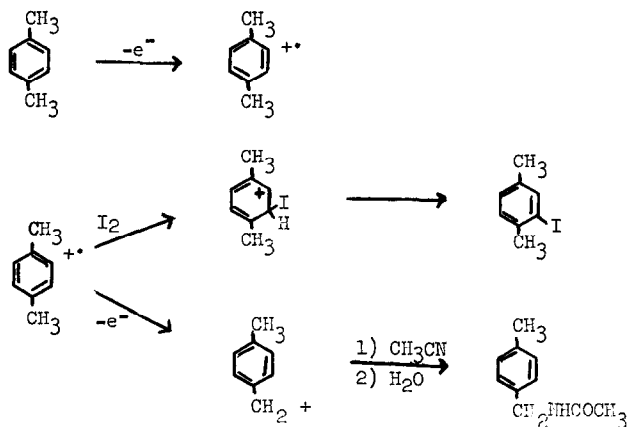
d. Triphenylmethanol

Two general classes of mechanism must be considered for these reactions. Pathways involving: 1. - initial iodine oxidation followed by electrophilic substitution by some positive iodine species or 2. - reactions initiated by oxidation of the aromatic substrate.

1.



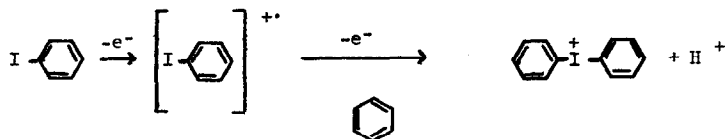
2.



Although the indicated steps following initial oxidation are only operational, there is some analogy for each of the overall mechanisms. The electrochemical oxidation of certain aromatic substrates in acetic acid, for example, produces ring and side chain acetoxylation via initial oxidation of the aromatic substrate.¹ These reactions involve trapping of aromatic cations with nucleophilic reagents. In the present reaction ring iodination could similarly result from trapping a cation radical with the free radical trap iodine. Alternatively, one might invoke electrophilic iodination and side chain substitution in analogy with the reactions of aromatic molecules with iodine monochloride. This positive iodine compound has been shown to give ring and/or side chain substitution with many aromatic molecules.¹¹ There seems to be little reason to invoke oxidation of the aromatic in these ring substitutions although they could intervene in the side chain reactions found only with the easily oxidized hexamethylbenzene and durene.

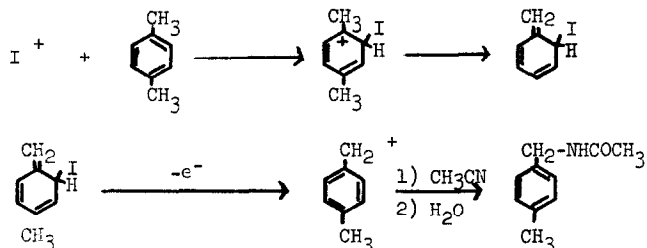
Our present results are only consistent with mechanisms exemplified by 1. In contrast to the work with anodic acetoxylation,¹ we have found that all those molecules which are cleanly iodinated have relatively high oxidation potentials. Those molecules with oxidation potentials less than that of the relatively high concentrations of molecular iodine, e.g., anthracene, give products characteristic of aromatic oxidation in the absence of iodine. Furthermore, we find that all successful iodinations and side chain substitutions arise from oxidations whose current-potential and current-time behavior are essentially the same as that of iodine in the absence of aromatic substrate. Finally, this kind of mechanism explains why

the iodoaromatics are formed as stable products. In earlier work we have demonstrated that iodoaromatics are electro-oxidized more easily than their non-iodinated counterpart and undergo coupling to yield diaryliodonium ions,⁸ e.g.:



It seems clear that one must in fact avoid oxidation of the aromatic molecule for successful conversion to the mono-iodinated product.

A number of mechanistic alternatives exist for the steps following iodine oxidation. The ring iodinations undoubtedly involve electrophilic attack by iodine cations or these cations complexed to traces of water, iodine or acetonitrile,¹² since high ortho, para to meta substitution ratios are obtained and nitrobenzene is unreactive. As such, they represent the most clear cut case of an electrochemically initiated electrophilic aromatic substitution reaction. The mechanism of side chain substitution may very well be more complex. An interesting scheme proposed by Keefer and Andrews¹¹ for side chain chlorination with iodine monochloride can, for example, be adapted to the present case. It may be noted that α -iodoaromatics could also be involved since they would be oxidatively converted to the observed side



chain substituted products.⁸ Whatever the detailed pathways, it is clear that both the ring and side chain substitution mechanisms will be closely related to the oxidation pathway for molecular iodine.¹³

Studies of iodine oxidation and the more detailed aspects of the reactions reported here are in progress.

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References

- (1.) L. Ebersson and K. Nyberg, J. Am. Chem. Soc., 88, 1686(1966); L. Ebersson, Ibid., 89, 4669(1967).
- (2.) H.W. Salzberg and M. Leung, J. Org. Chem., 30, 2873(1965).
- (3.) K. Kogama, T. Susuki, and S. Tsutsumi, Tetrahedron Letters, 627(1965).
- (4.) V.D. Parker and B.E. Burgert, Ibid., 4065(1965).
- (5.) M. Stacey, J.L. Tatlow and A.G. Sharpe, Advan. Fluorine Chem., 1, 129(1960).
- (6.) S. Tsutsumi and T. Inoue, Bull. Chem. Soc. Japan, 38, 661(1965).
- (7.) B. Belleau and N. Weinberg, J. Am. Chem. Soc., 85, 2525(1963).
- (8.) L.L. Miller and A.K. Hoffman, J. Am. Chem. Soc., 89, 593(1967).
- (9.) M.J. Allen, Organic Electrode Processes, Chapman and Hall, Ltd., London, 1958, pp. 147-158.
- (10.) L. Ebersson and K. Nyberg, Acta. Chm. Scand., 18, 1567(1964); J.J. Ritter and F.P. Minieri, J. Am. Chem. Soc., 70, 4045(1948).
- (11.) R.M. Keefer and L.J. Andrews, J. Org. Chem., 31, 541(1966); Ibid., J. Am. Chem. Soc., 86, 4158(1964).
- (12.) For a review concerned with various positive iodine species, see: J. Arotsky and M.C.R. Symons, Quart. Revs., 16, 282(1962).
- (13.) A.I. Popov and D.H. Geske, J. Am. Chem. Soc., 80, 1340(1958).