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STUDIES ON ELECTROLYTIC SUBSTITUTION REACTIONS. II.
ANODIC ACETAMIDATION, A NOVEL ANODIC SUBSTITUTION REACTION*

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On the basis of polarographic studies and preparative investigations at controlled anode potentials[1,2], we have previously postulated that anodic acetoxylation of an organic substrate in acetic acid/acetate ion proceeds via an initial two-electron transfer from the substrate to the anode. The dicationic intermediate reacts with acetate ion to form a Wheland-type intermediate which leads to product by loss of a proton. Side-chain acetoxylation was observed for methylbenzenes[2,3], and this reaction was also assumed to occur via a dicationic species, which would form a benzyl cation by loss of a proton from one of the methyl groups. Results and discussions pertinent to this problem have been published recently by other authors[4], and it is apparent that a mechanism involving cationic intermediates is an attractive pathway for a number of anodic processes. We wish to present

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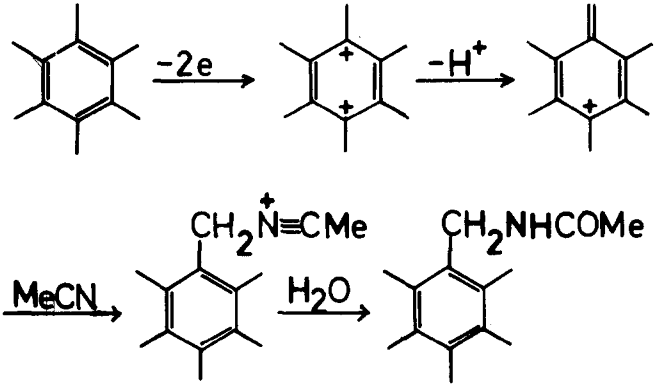
further evidence for this mechanism in another system, acetonitrile/perchlorate, and at the same time demonstrate a novel anodic substitution process.

Acetonitrile/sodium perchlorate has been extensively used as a medium for anodic polarography of organic compounds[5], notable aromatic hydrocarbons and derivatives thereof. Because of its high resistance towards oxidation which is even higher than that of acetic acid/sodium acetate, this system offers an additional possibility of testing the assumption of a benzyl cation intermediate in the oxidation of methylbenzenes, especially if compounds of a relatively low oxidation potential are chosen. Durene and hexamethylbenzene ($E_{1/2}$ vs. the Ag/Ag^+ (0.1 N) electrode 1.29 and 1.16 V, respectively) were chosen as suitable substrates, since acetoxylation occurs exclusively in the side-chain with these compounds. If a benzyl cation is formed on anodic oxidation it would be expected to react with acetonitrile to form a nitrilium salt, from which an N-benzylacetamide would result by reaction with water. This behavior is exhibited by carbonium ions generated by Kolbe electrolysis of certain carboxylic acids in acetonitrile containing a small percentage of water[6].

A solution of 1,2,4,5-tetramethylbenzene (0.025 mole), anhydrous sodium perchlorate (0.05 mole) and acetonitrile (150 ml) was electrolyzed at Pt electrodes for nine hours, using an anode potential of 1.0 V vs. SCE. The current was about 0.5 A. The acetonitrile was removed by evaporation in vacuo and the residue was treated with water. The organic material was taken up in ether, the ether solution was dried with magnesium sulphate and then the ether was evaporated. The residue was subjected to chromatography on silica gel. Elution with a mixture of chloroform and ether gave a solid (2.1 g), m.p. 141.5-142.5°, which was identified as 2,4,5-trimethylbenzylacetamide (I) on the basis of evidence given below. Elementary analyses were in good agreement with the empirical formula of I, $C_{12}H_{17}NO$ (Found: C 75.1, H 9.06, N 6.98, O 8.70. Calc. for $C_{12}H_{17}NO$: C 75.4, H 8.96, N 7.32, O 8.37). The infra-red spectrum showed characteristic amide bands at 3300, 1640, and 1540 cm^{-1}, and the NMR-spectrum gave signals at $\delta = 1.96$, 2.29, 4.32 (doublet, J = 5 cps) and 6.97 ppm with integrated areas in the proportions 3:9:2:2. The signals were assigned to the protons of the acetyl group, the methyl groups in the ring, the methylene group, and the aromatic ring, respectively. The yield of I was 38 % (lit.[7] m.p. 137-139°).

Hexamethylbenzene (0.02 mole) was electrolyzed in the same way at an anode potential of 0.8 V (current 0.3 A.) for 3.5 hours. The electrolysis mixture was worked up as described above. The residue was subjected to chromatography on silica gel. Elution with benzene gave unreacted hexamethylbenzene (1.0 g) and with chloroform gave a solid, m.p. 230-230.5° (2.5 g) after recrystallization from n-hexane-benzene. The product was identified as pentamethylbenzylacetamide (II) on the basis of elementary analyses and spectral data. (Found: C 76.6, H 9.61, N 6.37, O 7.51. Calc. for $C_{14}H_{21}NO$: C 76.7, H 9.65, N 6.39, O 7.29). The infra-red spectrum exhibited amide absorptions at 3300, 1630, and 1525 cm^{-1} and the NMR-spectrum had signals at $\delta = 1.92$, 2.20, and 4.45 (doublet, J = 4 cps) with integrated band areas in the proportions 3:15:2. The signals were assigned to the protons of the acetyl group, the methyls in the ring, and the methylene group. The yield of pentamethylbenzylacetamide (previously unreported) was 42 %.

The formation of N-benzylacetamides is analogous to the formation of side-chain acetoxylated compounds from durene and hexamethylbenzene on anodic oxidation in acetic acid/acetate. The primary electrode process in the acetonitrile system is a two-electron transfer from the organic substrate to the anode[5c], followed by nitrilium salt formation, and finally, on water treatment, by formation of an N-benzylacetamide:



There is little possibility of formulating a mechanism involving anodic oxidation of acetonitrile as the initial step; in view of the low preparative anode potentials used and the high oxidation potential of acetonitrile such mechanisms would be highly improbable. The complete analogy between anodic oxidation of durene and hexamethylbenzene in acetonitrile and acetic acid, respectively, suggests that they have a common mechanism. Since the formation of N-benzylacetamides must proceed via a benzyl cation this provides additional evidence that the same species is formed during the acetoxylation process.

Interesting enough, it was found important to exclude water during the electrolysis, but to add it afterwards. When the electrolyte contained as little as 3 % of water, the yield of N-benzylacetamides decreased to about 5 % and the major product was the corresponding benzyl alcohol. This behaviour suggests that nitrilium salts might be isolatable from the electrolysis mixtures if the water treatment is omitted. This problem and other aspects of this novel anodic substitution process are under investigation.

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