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Fe(III)-EDTA Mediated Autoxidation of 2,6-Di-*t*-butylphenol and Substituted Hydroquinones by Molecular Oxygen

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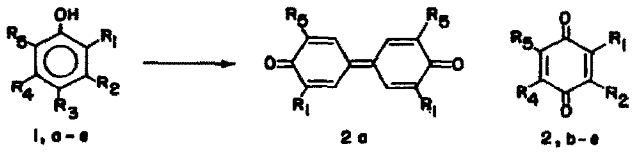
Abstract: *Fe(III)-EDTA in aq. MeOH offers a simple environmentally acceptable synthetic tool to oxidize 2,6-di-t-butylphenol to 3,3',5,5'-tetra-t-butyl-4,4'-diphenoquinone by molecular oxygen with 100% selectivity and several alkyl-substituted hydroquinones to their quinones, in excellent yields, under mild conditions.*

The pursuit of catalyst systems, which enable the use of molecular oxygen as a primary oxidant for the oxidation of organic substrates,[1] under mild conditions, necessitated by a growing environmental concern, has led to the development of several metal complexes, such as Cu(II) chloride-amine complex,[2] cobalt complexes, especially salcomines,[3] heteropolyanions containing manganese[4] etc. as efficient catalysts for the oxidation of substituted phenols. Hydroquinones have also been oxidized to the corresponding benzoquinones by a variety of reagents,[5] which are either toxic or expensive. Catalyst systems utilizing molecular oxygen for this oxidation are also available.[6]

Cobalt-salen complexes requiring anhydrous conditions have been modified to tolerate aqueous systems.[7] Frostin-Rio *et al.*[8] reported the oxidation of 2,6-di-*t*-butylphenol by molecular oxygen to the diphenoquinone in 95-100% selectivity using Mn-porphyrin in the presence of a reducing agent which, when omitted, resulted in a drastic fall in the conversion to the product. The zeolite-supported porphyrin offered the additional advantage of its chemical or electrochemical regeneration.[9]

We report, for the first time, to our knowledge, the autoxidation of 2,6-di-*t*-butylphenol(**1a**) to 3,3',5,5'-tetra-*t*-butyl-4,4'-diphenoquinone(**2a**) with 100% selectivity by Fe(III)-EDTA[10] in aq. MeOH in near-quantitative yields. By this system, the substituted hydroquinones(**1,b-e**) have also been oxidized to the corresponding 1,4-benzoquinones(**2,b-e**), in excellent yields (**Scheme and Table**).



a, $R_1 = R_5 = t\text{-Bu}, R_2 = R_3 = R_4 = H$; b, $R_1 = R_5 = t\text{-Bu}, R_2 = R_4 = H, R_3 = OH$; c, $R_1 = R_4 = t\text{-Bu}, R_2 = R_5 = H, R_3 = OH$; d, $R_1 = R_2 = R_4 = Me, R_5 = H, R_3 = OH$; e, $R_1 = Me, R_2 = R_4 = R_5 = H, R_3 = OH$;

Scheme

In a typical procedure, oxygen was bubbled through a solution of the compound(1, 2.0 mmol) in 80% aq. MeOH(50 mL) containing Fe(III)-EDTA (0.2 mmol, 2 mL of 0.1M soln.) at 30°C and pH 8.0-8.5 for a given reaction time. The progress of the reaction was followed by TLC (SiO_2 gel) and HPLC and the reaction mixture, at the end, was extracted with a suitable solvent followed by the normal work-up. Identity of the products was established by comparison of their m. ps. and IR and NMR spectra with those of the authentic samples.

The catalytic effect of the Fe(III)-EDTA in the oxidation of 1,b-e has been clearly demonstrated by carrying out parallel blanks under the same conditions(**Table**). Without the complex, TLC showed no evidence for **2a** even after 8h.

Table: Aerobic Oxidation of 2,6-Di-*t*-butylphenol and hydroquinones in the presence of Fe(III)-EDTA.

Substrate	Product	Reaction Time(h)	Isolated Yield(%)	% Conversion in 15 minutes With Catalyst	Without Catalyst
1a	**2a**	8.0	95	—	—
1b	**2b**	0.33	97	98	31
1c	**2c**	1.0	89	52	13
1d	**2d**	0.25	98	100	45
1e	**2e**	2.5	80	18	1

The absence of 1,4-benzoquinone in the oxidation of **1a** suggests that the iron-oxygen complexes are probably not involved and that the reaction proceeds by the formation of the phenoxy radical from the phenoxide ion by a one-electron transfer to the metal followed by homo-coupling to the dihydrodiphenoquinone, which is subsequently oxidized to **2a**. The phenoxy radical from **1a**, generated by Fe (III) reagents, *viz* $H_3Fe(CN)_6$ in methanol,[11] or alkaline $K_3Fe(CN)_6$ in a two-phase system[12] under anerobic conditions, or even under aerobic conditions,[12,13] underwent fast dimerization leading essentially to **2a**. Under specific conditions, low yields of 1,4-benzoquinone were also reported.[12] Simple uncatalyzed autoxidation[14] of **1a** (10% NaOH-*t*-BuOH) also gave only **2a**, suggesting trapping of the phenoxy radical by dioxygen is not preferred.

The simplicity of the system coupled with the excellent yields of the reaction products make **Fe(III)-EDTA** an attractive environmentally acceptable synthetic tool in the oxidation of substituted phenols by molecular oxygen.

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