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OXIDATIVE CLEAVAGE OF PHENOL TO MONOMETHYL MUCONATE BY USING CUPROUS CHLORIDE

Jiro Tsuji and Hiroshi Takayanagi

Faculty of Engineering, Tokyo Institute of Technology, Meguro, Tokyo Japan

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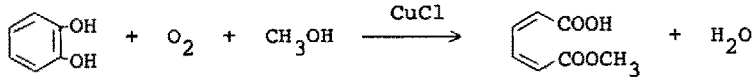
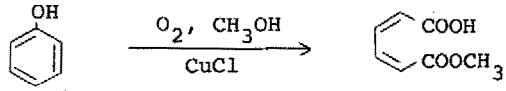
In our continued effort to discover a mild oxidation process by imitating enzyme reactions, we have found the facile oxidative cleavage of catechol to monomethyl muconate in a high yield in the presence of cuprous chloride in pyridine containing methanol under atmospheric pressure of oxygen.[1]



It was confirmed that one atom of oxygen from oxygen molecule is incorporated into monomethyl muconate produced by the oxidation.[2] The reaction can be regarded as the first model reaction of pyrocatechase.[3] It is known that in the metabolic pathway aromatic compounds are converted into phenols which are then oxygenated further by a hydroxylase to catechol before being cleaved to muconate Thus, it is challenging to find a method for cleaving phenol directly to muconate with oxygen by using an appropriate catalyst. We now wish to report that the expected oxidative cleavage of phenol to give muconate in a moderate yield takes place again in pyridine in the presence of cuprous chloride under atmospheric pressure of oxygen, although the reaction is slow. Monomethyl muconate is the sole product.



The oxidation was carried out in the following way. Cuprous chloride(1.6g, 8 mmol), methanol(0.64 ml) and pyridine(30 ml) were placed in a 100 ml glass vessel, which is used usually for catalytic hydrogenation. The vessel was connected to a gas buret filled with oxygen and shaken at room temperature. Absorption of about 100 ml of oxygen(4 mmol) was observed. Then phenol(376 mg, 4 mmol) dissolved in 20 ml of pyridine was added. The mixture was shaken at room temperature. Absorption of oxygen took place slowly(160 ml in 30 hr and

200 ml after 40hr). The absorption nearly stopped after 60 hr, during which total 222 ml(9 mmol) were absorbed. Pyridine was removed under reduced pressure and the residue was treated with dichloromethane and 6N hydrochloric acid. The organic layer was evaporated and the acidic product was extracted with a saturated aqueous sodium bicarbonate solution, which was acidified to give monomethyl muconate after usual work-up. Nearly pure monomethyl cis,cis-muconate(274 mg, 44%, m.p. 80°) was obtained after recrystallization from hexane Neither free muconic acid nor dimethyl muconate was obtained. The oxidation seems to proceed very slowly and phenol was detected when the reaction was stopped before the cease of the oxygen absorption.

The formation of monomethyl muconate as a sole product of the oxidation suggests that the oxidation proceeds through the formation of catechol. This step seems to be very slow. The very slow rate suggests a possibility that some other metallic compounds contained in cuprous chloride may be acting as a cocatalyst in the oxygenation of phenol. Comparative experiments using commercially available cuprous chloride without purification and pure cuprous chloride prepared by the known method[4] gave no difference. Addition of cupric chloride, ferric chloride, and ferrous chloride to the reaction system showed no appreciable difference.

Cuprous chloride in pyridine and methanol is an efficient catalytic system for the oxidative polymerization of 2,6-dimethylphenol.[5] Effect of methyl group in the oxidation is apparent. No muconate derivative was obtained by the oxidation of m- and p-cresols and resinous material was formed.

References

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