

Oxidation of α -Hydroxy Ketones with *m*-Chloroperbenzoic Acid

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A series of α -hydroxy ketones have been oxidized by *m*-chloroperbenzoic acid at 0°. The products were mixtures of aldehydes and carboxylic acids. The reactions did not follow a Baeyer-Villiger mechanism, but have been suggested to go through an enediol intermediate. Second order rate constants have been measured.

We recently found that the oxidation of phenylallene with *m*-chloroperbenzoic acid (MCPBA) gave benzaldehyde as the main product.¹ It was suggested that this compound resulted from a further oxidation of an intermediate α -hydroxy ketone. Such compounds have previously been obtained as products from oxidation of allenes with peracids.^{2,3} Some of these non-enolizable compounds reacted further with more peracid at room temperature, while others were resistant.² Hence we wanted to study the behaviour of α -hydroxy ketones to peracids. Peracetic acid oxidation of benzoin and phenyl substituted derivatives of benzoin at room temperature already has been reported. The products, however, were exclusively benzoic acids.⁴ In analogy with the oxidation of ketones a Baeyer-Villiger mechanism for the reaction was suggested.⁴

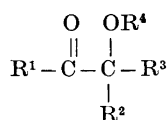
We have been interested in performing the oxidations in the cold with a moderately strong peracid. Therefore a dilute solution of the respective compounds was stirred at 0° with equivalent amounts of MCPBA. The consumption of peracid was followed by iodometric titration. The oxidation rates were high compared with those of simple ketones; acetophenone did not react even after one week at 0°, while benzoin (I) was completely oxidized after a few hours. The oxidized benzoin solution was washed with sodium carbonate in water, from which a mixture of *m*-chlorobenzoic acid and benzoic acid could be isolated. From the organic phase benzaldehyde was isolated in 90 % yield.

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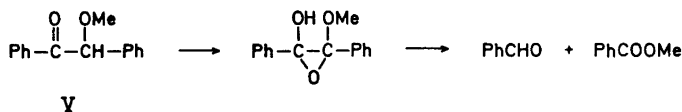
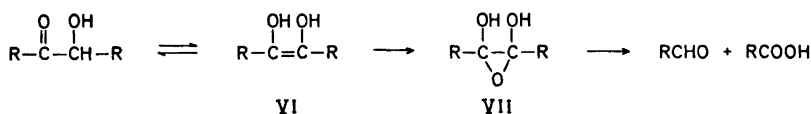
The oxidation of acetoin (II) gave only acetic acid in addition to some unreacted acetoin. The reaction rate obviously was too low to prevent further oxidation of acetaldehyde. 2-Hydroxy-1-phenyl-propan-1-one (III)⁵ also reacted slowly. The isolated products were benzoic acid and about 40 % unreacted starting material. On the other hand the isomeric 1-hydroxy-1-phenyl-propan-2-one (IV)¹ reacted very fast, though slower than benzoin, to give benzaldehyde in 81 % yield.

Introduction of an ether group in place of the hydroxy group, as in the methyl ether of benzoin (V),⁶ provided a mixture of benzaldehyde and methylbenzoate. The oxidation rate was decreased compared to that of benzoin (Table 1).

Table 1.



Comp.	R ¹	R ²	R ³	R ⁴	K ₂
I	phenyl	phenyl	H	H	10.5 × 10 ⁻³
II	CH ₃	CH ₃	H	H	0.7 × 10 ⁻³
III	phenyl	CH ₃	H	H	0.8 × 10 ⁻³
IV	CH ₃	phenyl	H	H	2.3 × 10 ⁻³
V	phenyl	phenyl	H	CH ₃	1.3 × 10 ⁻³
VIII	phenyl	phenyl	CH ₃	H	No reaction



From the higher migratory aptitude of a phenyl group compared to a methyl group,⁷ a Baeyer-Villiger oxidation of IV would be expected to be slow compared to the oxidation of III. The contrary, however, was found. We suggest that the peracid oxidation of α -hydroxy ketones at 0° go through an enediol intermediate (VI). Epoxidation of VI gives a 2,3-dihydroxy epoxide (VII) which rearranges⁷ to a mixture of an aldehyde and a carboxylic acid. A strong indication for the enediol intermediate in these reactions was found in the oxidation of methylbenzoin (VIII); in this case no reaction occurred even

after several days at 0°. If a Bayer-Villiger mechanism were operating, this compound should have reacted very fast.

The oxidations approximately followed second order kinetics. The rate constants were comparable to those observed in the allene oxidations.¹ Our results indicate that the rate-determining step involves the α -hydroxy ketone-enediol equilibrium, as seen in the difference in reaction rates between IV and V.

The reaction was not catalyzed by acid, as the Baeyer-Villiger oxidation is known to be.⁸ Indeed, when two drops of sulphuric acid were added to a solution of benzoin and MCPBA, the reaction was greatly retarded.

EXPERIMENTAL

Kinetics. 0.01 mol of the α -hydroxy ketone was added to a solution of 70 % MCPBA (0.01 mol) in dichloromethane (100 ml) at 0°. The solution was stirred at 0° and the amount of peracid titrated iodometrically. The first 50 % of the oxidations was found to follow a second order plot. Rate constants were calculated from these plots.

Oxidation of benzoin (I). Benzoin (4.24 g, 0.02 mol) was added to the solution of MCPBA (0.02 mol) in 200 ml CH₂Cl₂ at 0°. After 15 h at 0° the solution was washed with a sodium carbonate solution, dried (Na₂CO₃) and evaporated. The residue consisted of fairly pure benzaldehyde, 1.92 g (90 %). From the aqueous phase addition of acid precipitated a mixture of benzoic acid and *m*-chlorobenzoic acid.

Oxidation of acetoin (II). The equivalent amounts of acetoin and MCPBA were reacted as previously shown. Careful evaporation of the solvent after one week at 0° and distillation of the residue gave a mixture of acetic acid and unreacted starting material.

Oxidation of 2-hydroxy-1-phenyl-propan-1-one (III). Amounts and conditions were similar to those in the oxidation of benzoin. After 4 days at 0° anhydrous Na₂CO₃ (10 g) was added to the reaction mixture, stirred for one hour, filtered and the filtrate evaporated. The residue consisted mainly of unreacted material, 1.2 g (40 %). From the alkaline precipitate a mixture of benzoic acid and *m*-chlorobenzoic acid was isolated.

Oxidation of 1-hydroxy-1-phenyl-propan-2-one (IV). Amounts, reaction conditions and work up procedure were analogous to the former, except that the reaction was finished over night. The residue consisted of fairly pure benzaldehyde, 1.6 g (81 %).

Oxidation of the methyl ether of benzoin (V). Amounts, reaction conditions (three days at 0°) and work up procedure followed the former reaction. From the filtrate a mixture of starting material, benzaldehyde (30 % yield) and methylbenzoate (50 % yield) was isolated. Chromatography on neutral alumina (act. II-III) gave the pure methylbenzoate with benzene.

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