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TOPIC(s) : Alternative solvents

Selective TEMPO-oxidation of dialcohols to dialdehydes in alternative solvents

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PURPOSE OF THE ABSTRACT

Oxidation of alcohols to the corresponding carbonyl compound is a fundamental reaction type in organic chemistry, but still very challenging in terms of selectivity, environmental friendliness and costs.[1] Many different methods for the oxidation of alcohols are known and most of them suffer from the use of toxic and/or expensive metal species like chromium, palladium or platinum.[2] A greener alternative is the usage of 2,2,6,6-tetramethylpiperidine 1-oxyl radical (TEMPO) as catalyst. This stable nitroxyl radical can catalyse the selective oxidation of alcohols in a two-phase system, requiring only chemical bleach as an oxidation agent.[3] However, the TEMPO-oxidation is very limited in terms of solvent choice. Replacing dichloromethane as an organic solvent usually leads to selectivity problems, which could only be solved by reaction optimization for each individual substrate.[4] This problem is even more challenging in the case of primary dialcohols, which are very sensitive for over-oxidation. Within our search for a suitable alternative solvent being attractive from the perspective of both economy and sustainability, we investigated the oxidation of aliphatic dialcohols to the corresponding dialdehydes with TEMPO and polyamine-immobilized piperidinyloxyl radical (PIPO)[5] as catalyst in aliphatic nitriles as organic solvents. In initial experiments, we investigated the TEMPO-catalysed oxidation of aliphatic mono-alcohols in different solvents. We could show that nitriles are suitable solvents for TEMPO-oxidation when utilizing sodium hypochlorite as oxidation reagent and sodium hydrogensulfate as phase transfer catalyst.[6] Nitrile solvents are already used in special applications, for example as solvent for electrolytes in electric double layer capacitor.[7] Recently, our research group investigated a green access towards nitriles by dehydration of aldoximes via aldoxime dehydratases.[8] Beside such a sustainable and cyanide-free access towards nitriles the biodegradability of nitriles is literature known,[9] which make nitriles to attractive solvents. Based on these encouraging preliminary results, we then investigated the more challenging oxidation of primary dialcohols to their corresponding dialdehydes with TEMPO in the same solvent system. Despite an intensive reaction optimization, no conditions for a selective oxidation to the dialdehydes could be found with TEMPO as catalyst. However, when changing the catalyst from TEMPO to PIPO we were pleased to find a dramatic improvement of selectivity. After a reaction optimization addressing substrate loading, phase transfer catalyst amount and sodium hypochlorite amount, we could find conditions in which 1,8-octanediol (1) is converted to octanedial (2) with >99% conversion, 90% selectivity and 69% isolated yield. In addition, we could demonstrate the generality of this novel solvent system by applying the same reaction conditions successfully to the analogous conversions of four other diols, which also proceed with excellent conversion and high selectivity.

FIGURES

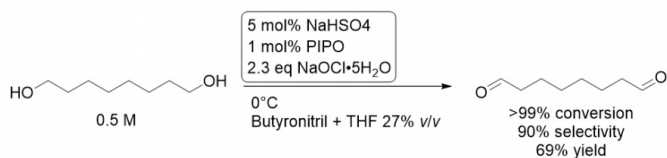


FIGURE 1

Optimized oxidation conditions for 1,8-octanediol (1) to octandial (2)

Reaction scheme of the optimized reaction conditions for the oxidation of 1,8-octanediol (1) to octandial (2) in butyronitrile as solvent, sodium hypochlorite as oxidation agent and sodium hydrogensulfate as phase transfer catalyst.

#	Product	t / min ^a	Conv. / % ^b	Sel. / % ^c	Yield / % ^d
1		45	96	91	37 ^d
2		40	>99	90	69 ^d
3		40	>99	93	56 ^d
4		40	>99	97	80

^a Reactions were performed in 15 mL scale using butyronitrile as solvent with THF as cosolvent (27% v/v) at 0 °C, 1 mol% PIPO as catalyst, 2.3 eq NaOCl·5 H₂O, 5 mol% NaHSO₄ and 0.5 M substrate concentration. The reactions were quenched by addition of 1 M HCl (50 mL).

^b Conversions are defined as consumption of the substrate

^c Selectivities are defined as: $\frac{\text{GC-Ald}}{\text{GC-Ald} + \text{GC-By products}}$

^d Yields were calculated by isolation of the aldehydes from the crude reaction mixture by phase-separation after quenching with acid, extraction of the organic phase and purification via automated column chromatography.

FIGURE 2

Examples of PIPO catalysed oxidation of dialcohols to dialdehydes

Examples of the substrate scope for the oxidation of diols to diols with PIPO as catalyst and butyronitrile as solvent.

KEYWORDS

Alcohol oxidation | TEMPO | Green solvents | Aldehydes

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