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SYNTHETIC COMMUNICATIONS®
Vol. 33, No. 22, pp. 3947–3952, 2003

The Oxidation of 3-Aryl-1-propenes by Oxidative System of $RuCl_3$-$NaIO_4$-Phase Transfer Catalyst

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ABSTRACT

Methyleugenol **1a** was oxidized to give 3,4-dimethoxyphenylacetaldehyde by the oxidative system containing the $RuCl_3$-$NaIO_4$-phase transfer catalyst. The yield and spectroscopic properties were obtained from the stable acetaldoxim **3a**. Furthermore, this oxidation system could be applied to other arylpropenes, thus,

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DOI: 10.1081/SCC-120026319 0039-7911 (Print); 1532-2432 (Online)

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safrole, 4-methoxyallylbenzene, allylbenzene, and the corresponding arylacetaldehyde formed.

Key Words: Oxidation; Ruthenium chloride; Sodium periodade; Phase transfer catalyst; Arylacetaldehyde.

Arylacetaldehyde is used for perfume compositions[1] or as a useful intermediate of drugs, especially, 3,4-dimethoxyphenylacetaldehyde is an important intermediate of verapamil, a cardiac drug.[2]

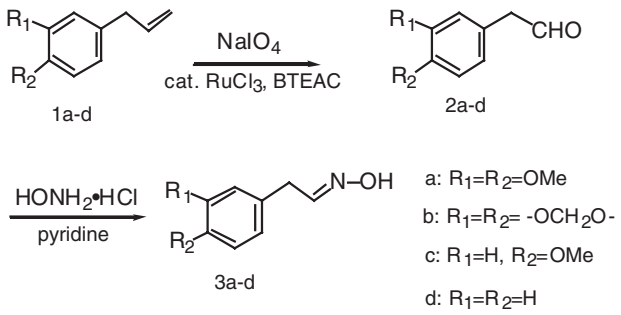
The synthetic methods for preparing the arylacetaldehydes by oxidation from the corresponding allyl compounds using ozone,[3,4] $OsO_4/NaIO_4$[5–9] or HCO_2H-30%$H_2O_2/Pb(OAc)_4$[10–12] have been reported. In addition, a number of preparations for arylacetaldehyde have been known, such as,

(a) Rearrangement of styrene oxides.[13]
(b) Decarboxylation of phenylglycidate.[14]
(c) Synthesis via enamine of α-oxophenylpropanoic acids.[15]

On the other hand, there are many synthetic methods using the oxidative cleavage of alkenes with a catalytic amount of ruthenium metal,[16] however few results have been reported on the oxidative cleavage of allyl compounds to produce the corresponding arylacetaldehydes.

Recently, we have reported the safe and facile oxidation of β-pinene to produce nopinone using $RuCl_3$-$NaIO_4$-phase transfer catalyst (PTC) system.[17] As an extension of this oxidation system, we now report the synthesis of 3,4-dimethoxyphenylacetaldehyde **2a** from methyleugenol **1a**.

We have found that the oxidation of methyleugenol **1a** using 1 mol% of $RuCl_3$, 5 mol% of benzyltriethylammonium chloride (BTEAC), and 5 mol equiv. of $NaIO_4$ in $EtOAc/H_2O$ for 2 h at room temperature gave 3,4-dimethoxy-phenylacetaldehyde **2a** with 100% conversion and 95% selectivity by GC. The other 5% by-product was found to be 3,4-dimethoxybenzaldehyde by GC-MS ($M^+ = 166$). The oxidation conditions, i.e., the oxidant, solvent, and amount of catalyst were nearly fixed according to our previous report[17] (see experimental section). We also applied this oxidative system to other 3-aryl-1-propenes such as safrole **1b**, 4-methoxyallylbenzene **1c**, and allylbenzene **1d**, and thus the corresponding arylacetaldehydes **2b–d** were obtained (Sch. 1). Since the peroxidation and/or polymerization of **2**, the yield could not be shown as optimized values. Therefore, the yield and spectroscopic properties were



Scheme 1.

obtained after transformation to the arylacetaldoxims **3a–d** which are useful precursors of amines or nitriles (Table 1). This oxidation did not proceed in the absence of $RuCl_3$ as a catalyst. We also have investigated the effect of PTC. All of the PTCs smoothly promoted the oxidation to give good conversion and selectivity of **2a** in comparison with the GC analysis value obtained in the absence of PTC as shown in Table 2.

In conclusion, we performed the syntheses of arylacetaldehydes from 3-aryl-1-propenes using $RuCl_3$-$NaIO_4$-PTC system.

EXPERIMENTAL SECTION

All reagents and solvents were obtained from commercial sources and used without further purification. Melting points: Yanagimoto micromelting apparatus, uncorrected values. IR: Jasco IR-810. ^{1}H NMR (recorded in $CDCl_3$ with TMS as an internal standard): Bruker AM-400 (400 MHz). MS: Hitachi M-80A mass spectrometer at 70 eV. GC: HP 5890 with an FID detector. Column: silicon OV-1 (df = 0.15 μm, 0.25 mm × 25 m); carrier gas N_2, 0.1 MPa; oven temperature, 70–200°C (programmed at 4°C/min); injection temperature, 250°C; detector temperature, 250°C.

Typical Procedure: 3,4-Dimetoxyphenylacetaldehyde (2a) and Aldoxim (3a)

To a solution of methyleugenol **1a** (8.0 g, 45 mmol), $RuCl_3$ (50 mg, 0.25 mmol), and benzyltriethylammonium chloride (0.5 g, 2.2 mmol) in EtOAc (80 mL), $NaIO_4$ (47.5 g, 225 mmol) in water (500 mL) was

Table 1. Physical and spectra data of arylacetaldoxim 3.

3	R_1	R_2	Yield[a] (%)	M.p. (°C)[b] (reported)	IR($CHCl_3$) ν_{max} (cm^{-1})	MS (m/e)	^{1}H NMR δ (ppm)
a	MeO	MeO	65	54–55 (90)[7]	3,450 1,610	195 (M^+)	3.48 (2H, d, $J = 5.4$), 3.69 (2H, d, $J = 6.3$), 3.87 (6H, s), 6.72–6.84 (5H, s), 6.89 (1H, t, $J = 5.4$), 7.53 (1H, t, $J = 6.3$)
b	-OCH_2O-		57	116–117 (115)[3]	3,450 1,610	179 (M^+)	3.44 (2H, d, $J = 5.4$), 3.65 (2H, d, $J = 6.3$), 5.99 (6H, s), 6.67–6.77 (3H, m), 6.89 (1H, t, $J = 5.4$), 7.49 (1H, t, $J = 6.3$)
c	H	MeO	63	58–63 (120)[18]	3,450 1,620	165 (M^+)	3.47 (2H, d, $J = 5.4$), 3.69 (2H, d, $J = 6.3$) 3.79 (3H, s), 6.85–7.5 (4H, m), 6.87 (1H, t, $J = 5.4$), 7.5 (1H, t, $J = 6.3$)
d	H	H	66	66–68 (98)[c][19]	3,450 1,620	135 (M^+)	3.52 (2H, d, $J = 6.3$), 7.12–7.36 (6H, m)

[a]Yield is based on **1**.
[b]Melting point of mixture of *syn* and *anti* isomers.
[c]Melting point of reference is a *syn* isomer.

Table 2. The effect of PTC in the oxidation of **1a**.

		Product **2a**	
Run[a]	PTC	Conv[b] (%)	Select[b] (%)
1	No addition	49	90
2	*n*-Bu_4NI	100	93
3	*n*-Bu_4NClO_4	100	92
4	$BnEt_3NCl$	100	95
5	$(n\text{-Oct})_3MeNCl$	92	94
6	*n*-Bu_4PBr	95	87
7	$BnPh_3PCl$	90	85

[a]Reaction conditions: 1, 45 mmol; $RuCl_3$, 0.25 mmol; PTC, 2.2 mmol; $NaIO_4$, 225 mmol; EtOAc/H_2O, r.t., 2 h.
[b]Conversion yield and selectivity of **2a** were determined by GC.

added slowly for 1 h at room temperature. The resulting solution was stirred for additional 1 h (conversion yield and selectivity of **2a** were 100 and 95% by GC, respectively). EtOAc (250 mL) was added to the reaction mixture. The organic layer was separated, washed with water, dried with anhydrous $MgSO_4$ and concentrated in vacuo to give an oil (6.3 g, 74%). The purity was determined to be 95% by GC. To the crude product, hydroxyamine hydrochloride (7.8 g, 112 mmol), pyridine (6 mL), and EtOH (44 mL) were added and refluxed for 1 h. After removal of solvent in vacuo, EtOAc (50 mL) and water (50 mL) were added, the organic layer was washed with 5% HCl, brine, dried with anhydrous $MgSO_4$, and concentrated in vacuo to give **3a** (5.7 g, 65% based on **1a**, *anti*:*syn* = 1:1; by ^1H NMR) as a solid.

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Received in Japan April 22, 2003