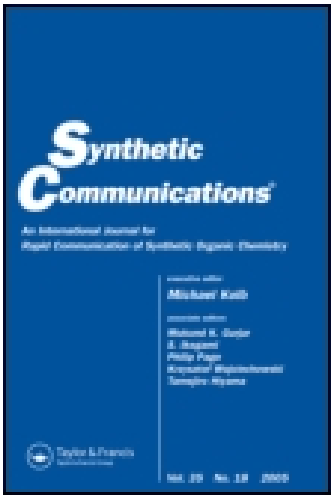


Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/lsyc20

Oxidation of Benzylic Alcohols to Their Corresponding Carbonyl Compounds using KIO_4 in Ionic Liquid by Microwave Irradiation

Abdol Reza Hajipour [a], Fatemeh Rafiee [a] & Arnold E. Ruoho [b]

[a] Pharmaceutical Research Laboratory, Department of Chemistry, Isfahan University of Technology, Isfahan, Iran

[b] Department of Pharmacology, University of Wisconsin Medical School, Madison, Wisconsin, USA

Published online: 27 Oct 2006.

To cite this article: Abdol Reza Hajipour, Fatemeh Rafiee & Arnold E. Ruoho (2006) Oxidation of Benzylic Alcohols to Their Corresponding Carbonyl Compounds using KIO_4 in Ionic Liquid by Microwave Irradiation, Synthetic Communications: An International Journal for Rapid Communication of Synthetic Organic Chemistry, 36:17, 2563-2568, DOI: 10.1080/00397910600781539

To link to this article: http://dx.doi.org/10.1080/00397910600781539

Synthetic Communications®, 36: 2563–2568, 2006

ISSN 0039-7911 print/1532-2432 online
DOI: 10.1080/00397910600781539

Oxidation of Benzylic Alcohols to Their Corresponding Carbonyl Compounds using KIO_4 in Ionic Liquid by Microwave Irradiation

Abdol Reza Hajipour and Fatemeh Rafiee
Pharmaceutical Research Laboratory, Department of Chemistry,
Isfahan University of Technology, Isfahan, Iran

Arnold E. Ruoho
Department of Pharmacology, University of Wisconsin Medical School,
Madison, Wisconsin, USA

Abstract: A chemoselective, straightforward, and rapid method for oxidation of alcohols to the corresponding carbonyl compounds using microwave irradiation and a catalytic amount of ionic liquid is reported. The reaction has been carried out with excellent yields and short reaction times.

Keywords: Oxidation, aldehydes, ketones, ionic liquid

INTRODUCTION

The use of ionic liquids (ILs) as solvent for chemical reactions offers several advantages from an environment perspective. These solvents are nonflammable and thermally stable, exhibit negligible vapor presser (nonvolatile), and also offer the potential for reclability.[1–4]

Microwave-assisted organic transformation coupled with ILs have attracted attention because of enhanced reaction rates, easier workup, and

Received in Poland February 2, 2006
Address correspondence to Abdol Reza Hajipour, Pharmaceutical Research Laboratory, Department of Chemistry, Isfahan University of Technology, Isfahan 84156, IR Iran. E-mail: haji@cc.iut.ac.ir

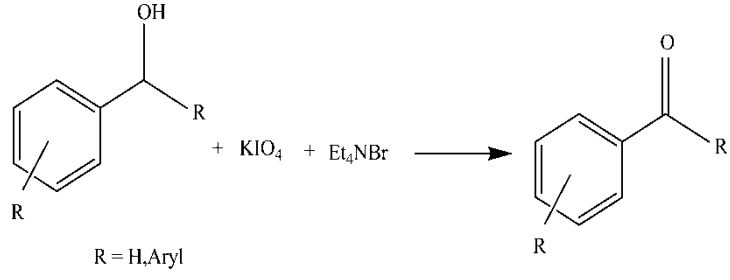
facilitated purification. The dipole characteristics of IL translate into rapid excitation by microwaves and consequently faster reactions.[5]

Oxidation of alcohols to carbonyl compounds is a fundamental type of reaction encountered at all levels and aspects of organic synthesis.[6] Most oxidants suffer at least from one of the following disadvantages: long reaction time, hygroscopicity, high acidity, highly toxicity, instability, dangerous procedure, low yields of products, photosensitivity, high cost of preparations, overoxidation to carboxylic acids, environmental harm, and mess.[7–9]

RESULTS AND DISCUSSION

In continuation of our ongoing program to develop environmentally benign methods,[6–9] we report an extremely clean, fast, green, and facial microwave-accelerated oxidation of alcohols to their corresponding carbonyl compounds using potassium periodate (KIO_4) in the presence of catalytic amount of tetraethylammonium bromide as ionic liquid. Potassium periodate (KIO_4) is a mild and inexpensive oxidizing agent, which cannot easily be used in ordinary organic solvent. However, using this reagent in the presence of tetraethylammonium bromide (Et_4NBr) as ionic liquid and with microwave irradiation accelerates the reaction rate of oxidation of alcohols (Scheme 1).

To evaluate the synergy of KIO_4/tetraetylammonium bromide (Et_4NBr) and microwave irradiation for oxidation of various alcohols, several experiment have been done. Oxidation of alcohols with KIO_4/Et_4NBr without microwave irradiation was unsuccessful. Also, we performed the oxidation of benzyl alcohol, 2-chlorobenzyl alcohol, and 4-methoxybenzylalcohol by using KIO_4 without Et_4NBr with microwave irradiation and observed that in all cases the yield was les than 15%. When we treated the benzyl alcohol, 2-chlorobenzyl alcohol, and 4-methoxybenzylalcohol with KIO_4 in the presence of Et_4NBr without microwave irradiation at 80°C for 3 h, the yields were not more than 25%, even after a long reaction time. The results for the oxidation of a variety of benzylic alcohols are summarized in



Scheme 1.

Table 1. Oxidation of alcohols by KIO_4/Et_4NBr by microwave irradiation[a]

Entry	Substrate	Time (min)	Yield (%)	Mp or bp (°C)/(torr)
1a	$PhCH_2OH$	2	98	177–179
1b	$2\text{-}MeOC_6H_4CH_2OH$	3	90	34–35
1c	$3\text{-}MeOC_6H_4CH_2OH$	2	90	100–102/10
1d	$4\text{-}MeOC_6H_4CH_2OH$	3	85	247–249
1e	$3,4\text{-}(MeO)_2C_6H_3CH_2OH$	4	70	42–43
1f	$2,5\text{-}(MeO)_2C_6H_3CH_2OH$	4	75	48–50
1g	$2\text{-}ClC_6H_4CH_2OH$	4	97	210–212
1h	$3\text{-}ClC_6H_4CH_2OH$	3	85	212–214
1i	$4\text{-}ClC_6H_4CH_2OH$	1	98	45–47
1j	$4\text{-}MeC_6H_4CH_2OH$	3	90	106–108/15
1k	PhCHOHPh	4	90	47–49
1l	$4\text{-}ClC_6H_4CHOHPh$	5	80	75–77
1m	$4\text{-}ClC_6H_4CHOHCH_3$	3	97	230–232
1n	$4\text{-}NO_2C_6H_4CH_2OH$	6	57	105–107
1o	$3\text{-}NO_2C_6H_4CH_2OH$	6	52	56–59
1p	PhCHOHCOPh	5	40	93–95
1q	$PhCH_2CH_2OH$	5	65	47–50
1r[b]	Cyclohexanol	8	20	197
1s[b]	$CH_3(CH_2)_3OH$	8	15	159–162

[a]Yields based on the isolated pure products after chromatography and confirmed by comparison with authentic samples (TLC, IR, and NMR).

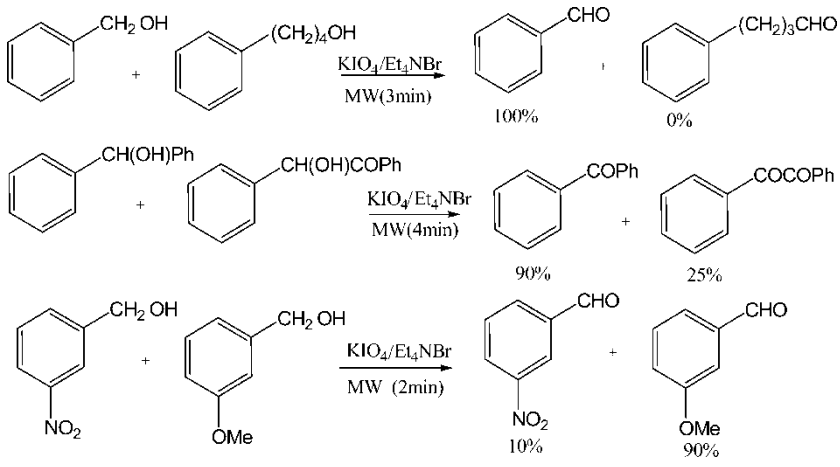
[b]Oxidation by using KIO_4/Et_4NBr (0.25 mmol)/$AlCl_3$ (5 mol%).

Table 1. The aliphatic alcohols did not oxidize with this system at all; however, these alcohols only oxidized with KIO_4/Et_4NBr /$AlCl_3$ (5 mol%, 0.006 g) with long reaction times and moderate yields.

To show the chemoselectivity of this method, the competitive reaction have been carried out as shown in Scheme 2. In comparison to benzylic alcohols, oxidation of aliphatic ones with this method occurs with lower yields and longer reaction time. The donor substituted group in the benzene ring of benzylic alcohols accelerates the reaction rate and the withdrawing groups reduce the reaction rate dramatically.

In this method, IL is recyclable. After 4 recycling the IL four times, we did not observe any significant loss of this IL capability, and benzyl alcohols were oxidized with the same yields as first run. We also did not observe any over-oxidation of producing aldehydes to the corresponding carboxylic acids.

In conclusion, we have developed a simple and efficient method for oxidation of benzylic alcohols to their corresponding carbonyl compounds using potassium periodate (KIO_4) in the presence of a catalytic amount of tetraethylammonium bromide as ionic liquid by microwave irradiation with high yields and short reaction times.



Scheme 2.

EXPERIMENTAL

General

Yields refer to isolated pure products. The products were characterized by comparison their spectral data (^{1}H NMR, IR) and melting and boiling points with authentic samples (authentic samples prepared by reported methods). All ^{1}H NMR spectra were recorded at 250 MHz in $CDCl_3$ relative to TMS (0.00 ppm). All of the reactions were carried out in a hood with strong ventilation. IR spectra were recorded on Shimadzu 435 IR spectrophotometer. Spectra of solids were carried out using KBr pellets.

Oxidation of 2-Methoxybenzylalcohol 1b: A Typical Procedure

A mixture of 2-methoxybenzyl alcohol (1 mmol, 0.138 g), KIO_4 (1 mmol, .0230 g), and Et_4NBr (0.25 mmol, 0.05 g) was ground thoroughly in a mortar. The mortar was covered with a watch glass and put inside a Samsung microwave (2450 MHz, 900 W). The completion of the reaction was monitored by TLC (EtOAc–cyclohexane 25 : 75). After completion of the reaction, the mortar was removed from the oven, and the mixture was cooled to room temperature. The resulting aldehydes (with no traces of carboxylic acids) and ketenes were isolated by straightforward extraction with diethyl ether and filtered. The filtrate was evaporated under reduced pressure, and the resulting residue was purified by flash chromatography on SiO_2 (eluent EtOAc–cyclohexane, 20 : 80). The yield was 0.124 g (90%) of

1b, mp 34–35°C. The ionic liquid was further washed with ether and reused several times.

ACKNOWLEDGMENTS

We gratefully acknowledge the funding support received for this project from the Isfahan University of Technology (IUT), I.R. Iran (A. R. H.), and Grants GM 033138, MH 065503, and NS 033650 (A. E. R.) from the National Institutes of Health. USA. Further financial support from Center of Excellency in Chemistry Research (IUT) is gratefully acknowledged.

REFERENCES

1. Zhou, Z. B.; Matsumoto, H.; Tatsumi, K. Low-melting, low-viscous, hydrophobic ionic liquids: *N*-alkyl (alkyl ether)-*N*-methylpyrrolidinium perfluoroethyltrifluoroborate. *Chem. Lett.* **2004**, *33*, 1636.
2. Wasserscheid, P.; Welton, T. *Ionic Liquids in Synthesis*; Wiley-VCH: Weinheim, 2003.
3. (a) For recent IL reviews, see Welton. *T. Chem. Rev.* **1999**, *99*, 2071; (b) Sheldon, R. Catalytic reactions in ionic liquids. *Chem. Commun.* **2001**, 2399; (c) Gordon, C. M. New developments in catalysis using ionic liquids. *Appl. Catal. A.* **2001**, 101; (d) Zhao, D.; Wu, M.; Kou, Y.; Min, E. Ionic liquids: Applications in catalysis. *Catal. Today.* **2002**, *74*, 157; (e) Zhao, H.; Malhotra, S. V. Poly (isonicotinic acid) modified glassy carbon electrode for electrochemical detection of norepinephrine. *Aldrichim. Acta* **2002**, *35*, 75.
4. (a) McNulty, J.; Capretta, A.; Wilson, J.; Dyck, J.; Adjabeng, G.; Robertson, A. A suzuki cross-coupling reaction of aryl halides in phosphonium salt ionic liquid under mild conditions. *J. Chem. Commun.* **2002**, 1986; (b) Gerritsma, D. A.; Robertson, A. J.; McNulty, J.; Capretta, A. Heck reactions of aryl halides in phosphonium salt ionic liquids: Library screening and applications. *Tetrahedron Lett.* **2004**, *45*, 7629.
5. Lee, G.; Lee, J. K.; Song, C. E.; Kim, D. C. Microwave-assisted Kabachnik–Fields reaction in ionic liquid. *Bull. Korean Chem. Soc.* **2002**, *23*, 667.
6. Hajipour, A. R.; Kooshki, B.; Ruoho, A. E. Nitric acid in the presence of supported P_2O_5 on silica gel: An efficient and novel reagent for oxidation of sulfides to the corresponding sulfoxides. *Tetrahedron Lett.* **2005**, *46*, 5503.
7. (a) Hajipour, A. R.; Arbabian, M.; Ruoho, A. E. Tetramethylammonium dichloroiodate: an efficient and environmentally friendly iodination reagent for iodination of aromatic compounds under mild and solvent-free conditions. *J. Org. Chem.* **2002**, *67*, 8622; (b) Hajipour, A. R.; Ruoho, A. E. Iodination of aromatic compounds under mild and solvent-free conditions. *Org. Prep. Proced. Int.* **2002**, *34*, 647; (c) Hajipour, A. R.; Mazloumi, G. An efficient and simple procedure for preparation of esters and anhydrides from acid chlorides in the presence of 1,4-diazabicyclo[2.2.2]octane (DABCO) under solvent-free conditions. *Synth. Common.* **2002**, *32*, 23; (d) Hajipour, A. R.; Ruoho, A. E. Oxidation of thiols to the corresponding disulfides with tetramethylammonium chlorochromate under non-aqueous conditions. *J. Chem. Res. Synop.* **2002**, 547;

(e) Hajipour, A. R.; Adibi, H.; Ruoho, A. E. Wet silica-supported permanganate for the cleavage of semicarbazones and phenylhydrazones under solvent-free conditions. *J. Org. Chem.* **2003**, *68*, 4553; (f) Hajipour, A. R.; Bageri, H.; Ruoho, A. E. Solid state oxidation of alcohols using 1-butyl-4-aza-1-azoniabicyclo[2.2.2]octane chlorochromate. *Bull. Korean Chem. Soc.* **2004**, *25*, 1238; (g) Hajipour, A. R.; Ruoho, A. E. Deprotection of tuioacetals by wet alumina supported Cr (VI) oxide under solvent-free condi- tions. *Sul. Lett.* **2002**, *25*, 151; (h) Hajipour, A. R.; Mirjalili, B. F.; Zarei, A.; Khazdooz, L.; Ruoho, A. E.A. novel method for sulfonation of aromatic rings with silica sulfuric acid. *Tetrahedron Lett.* **2004**, *45*, 6607.

8. (a) Hajipour, A. R.; Mallakpour, E.; Imanzadeh, G. A rapid and convenient synthesis of oximes in dry media under microwave irradiation. *J. Chem. Res.* **1999**, 228; (b) Hajipour, A. R.; Mallakpour, E.; Adibi, H. Benzyltriphenylphosphonium peroxymonosulfate: As a novel and efficient reagent for oxidation of alcohols under solvent-free condition. *Chem. Lett.* **2000**, 460; (c) Hajipour, A. R.; Mallakpour, E.; Afrousheh, A. A convenient and mild procedure for the synthesis of alkyl p-toluenesulfinates under solvent-free conditions using microwave irradiation. *Tetrahedron.* **1999**, *55*, 2311; (d) Hajipour, A. R.; Islami, F. A convenient and highly diastereoselective synthesis of optically active sulfinate esters from sulfonyl chlorides under solid state conditions. *Ind. J. Chem.* **1999**, *38B*, 461; (e) Hajipour, A. R.; Mallakpour, E.; Imanzadeh, G. Oxidation of alcohols to carbonyl compounds under solvent-free conditions using permanganate supported on alumina. *Chem. Lett.* **1999**, 99; (f) Hajipour, A. R.; Hantehzadeh, M. Asymmetric reduction of prochiral cyclic imines to alkaloid derivatives by novel asymmetric redusing reagent in THF or under solid-state conditions. *J. Org. Chem.* **1999**, *64*, 8475; (g) Hajipour, A. R.; Mallakpour, E.; Backnejad, H. Benzyltriphenylphosphonium cholorochromate: A mild and novel reagent for oxidation of benzylic and allylic alcohols under non-aqueous and aprotic conditions or microwave conditions. *Synth. Commun.* **2000**, *30*, 3855; (h) Hajipour, A. R.; Mallakpour, E.; Afrousheh, A. One-pot and simple reaction for the synthesis of alkyl p-toluenesulfinate esters under solid-phase conditions. Phosphorus. *Sulfur Silicon Relat. Elem.* **2000**, *160*, 67; (i) Hajipour, A. R.; Mallakpour, E.; Khoee, S. An efficient, fast and selective oxidation of aliphatic and benzylic alcohols to the corresponding carbonyl compounds under microwave irradiation. *Synlett* **2000**, 740; (j) Hajipour, A. R.; Baltork, I. M.; Nikbaghat, K.; Imanzadeh, G. Solid-phase synthesis of oximes. *Synth. Commun.* **1999**, *29*, 1697.
9. (a) Hajipour, A. R.; Mahboubkhah, N. 1-Benzyl-4-aza-1-azoniabicyclo[2.2.2] octane periodate: A mild and efficient oxidation for the cleavage of oxime double bonds under anhydrous conditions. *J. Chem. Res. Synop.* **1998**, 122; (b) Hajipour, A. R.; Ruoho, A. E. Solid state deprotection of thioacetals and thioketals using 1-benzyl-4-aza-1-azoniabicyclo[2.2.2]octane periodate and aluminum chloride. *Org. Prep. Proced. Int.* **2005**, *37*, 298; (c) Hajipour, A. R.; Ruoho, A. E. Methyltriphenylphosphonium peroxydisulfate and iodine as mild reagents for the iodination of activated aromatic compounds. *Org. Prep. Proced. Int.* **2005**, *37*, 279.