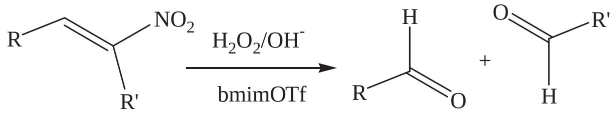
Oxidative Cleavage of Nitroalkenes with Hydrogen Peroxide in Environmentally Acceptable Solvents

Olga Bortolini,*[1] Antonio De Nino,[1] Marco Fogagnolo,[2] Giancarlo Fantin,[2]
Loredana Mariuolo,[1] and Amedeo Tocci[1]
[1]*Dipartimento di Chimica Università della Calabria, Via Bucci 12 C, 87036 Rende, Italy*
[2]*Dipartimento di Chimica, Università di Ferrara, Via Borsari 46, 44100 Ferrara, Italy*

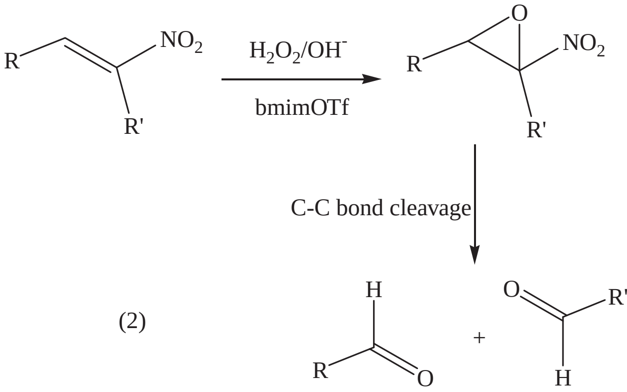
(Received January 11, 2007; CL-070040; E-mail: o.bortolini@unical.it)

Hydrogen peroxide serves as an efficient oxidant for the nitroalkene C=C bond cleavage to aldehydes in ionic liquids.

Oxidative cleavage of carbon–carbon double bonds is an important transformation in synthetic organic chemistry.[1] Ozonolysis[2] or oxometal reagents[3] in combination with oxygen donors as $NaIO_4$ are frequently used for this purpose. However, because of the known drawbacks of these reagents, catalytic oxidations using eco-friendly oxidants[4] like hydrogen peroxide[5] or molecular oxygen[6] have attracted increasing attention. In this frame, we have recently re-evaluated the epoxidation of electron-deficient olefins with alkaline hydrogen peroxide (Weitz–Scheffer reaction) in ionic liquids,[7] a novel alternative to traditional volatile and carcinogenic solvents,[8] that allow easy product recovery, solvent recycling and, in some cases, different product selectivity.



(1)



(2)

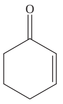
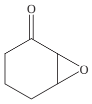
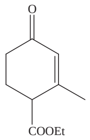
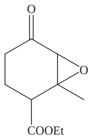
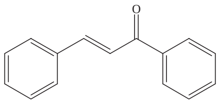
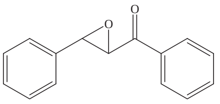
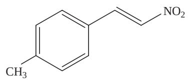
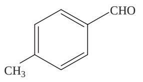
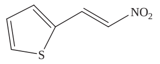
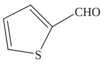
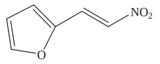
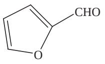
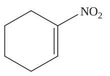
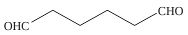
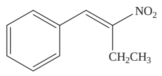
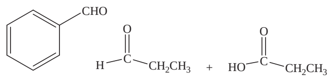
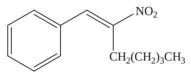
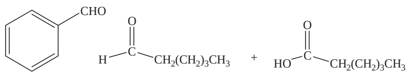
As described in our previous publications[7] the epoxidation of several α,β-unsaturated cyclic ketones with basic aqueous solutions of H_2O_2 in bmim(TfO) (bmim = 1-butyl-3-methylimidazolium, $TfO^- = CF_3SO_3^-$)[9] at room temperature proceeds rapidly with formation of the corresponding epoxides in 97–99% yield; see for example Entry 1 of Table 1. The presence of substituents on the molecular framework do not affect the course of the epoxidation, including that of base-sensitive substrates as the Hagemann's ester[10] (Entry 2). The epoxidation of acyclic α,β-unsaturated ketones[11] as chalcone may be satisfactory carried out under similar conditions with excellent conversion and product yield (Entry 3). The extension of this epoxidation protocol to electron-deficient olefins bearing nitro substituents, however, evidenced both different reactivity and dissimilar product selectivity with respect to conventional conditions.[12] The epoxidation of 2-nitro-*para*-methylstyrene, 2-(2-nitrovinyl)thiophene and 2-(2-nitrovinyl)furan, in fact, afforded almost exclusively the related carbon–carbon bond cleavage products i.e. *para*-methylbenzaldehyde, 2-thiophenecarboxaldehyde, 2-furaldehyde according to eq 1. No over-oxidation to carboxylic acid derivatives is observed under the conditions adopted for this oxidation. The possibility to observe 2-nitrostyrene C=C bond cleavage using H_2O_2/OH^- was reported by Newman and Angier.[13] Substitution on the carbon bearing the nitro substituent appeared a fundamental requisite to avoid cleavage in favour of the epoxidation reaction. Our conditions, however, did not conform to this requisite and C=C bond cleavage is observed also with β-substituted substrates as nitrocyclohexene (Entry 7), β-ethyl- and β-pentyl-nitrostyrene (Entries 8 and 9). The detection of hexane-1,6-dial and benzaldehyde plus propanal or hexanal in the latter cases was particularly important in order to elucidate the mechanism of this reaction. Cleavage of nitroalkenes proceeds via epoxidation, followed by rupture of the carbon–carbon bond according to eq 2. Support to this assumption may be found in the detection of β-ethyl- and β-pentyl-nitrostyrene epoxides in the initial moments of the epoxidations and in an independent experiment carried out on nitrostyrene epoxide, prepared using a different oxidation procedure.[14] When dissolved in bmim(TfO), in the presence of the oxidant H_2O_2/OH^-, the nitrostyrene epoxide is quantitatively converted into the corresponding benzaldehyde in few minutes. No over-oxidation or additional products, for example benzoic acid or diol, are detected. On the other hand, relatively small amounts of over-oxidation products i.e. propanoic acid and hexanoic acid originating from propanal and hexanal are detected in the oxidation of the β-substituted-nitrostyrenes of Entries 8 and 9.

Work is in progress to optimize the conversion of nitro derivatives, including saturated substrates, to aldehydes and ketones with low cost and eco-friendly oxidants in ionic liquids.

References and Notes

1 D. G. Lee, T. Chen, in *Comprehensive Organic Synthesis*, ed. by B. M. Trost, I. Fleming, S. V. Ley, Pergamon Oxford, **1991**, p. 541.
2 P. S. Bayley, *Ozonation in Organic Chemistry*, Academic Press, New York, **1978**, Vol. 1.
3 a) C.-M. Ho, W.-Y. Yu, C.-M. Che, *Angew. Chem., Int. Ed.* **2004**, *43*, 3303. b) D. Yang, C. Zhang, *J. Org. Chem.* **2001**, *66*, 4814, and references.

Table 1. Epoxidation and C=C bond cleavage of electron-deficient olefins with H_2O_2/OH^- in bmim(OTf) at 25 °C: [substrate]:[H_2O_2]:[OH^-] = 1:3:2; for details see Supporting Information

Entry	Alkene	Product	Time /h	Yield[a] /%
1			0.1	97
2			0.5	98
3			3	99
4			0.5	98
5			1	84
6			1	94
7			72	42
8			16	$70^{b,c}$
9			16	$75^{b,c}$

[a]Based on GC analysis. [b]Calculated on the recovered Ph–CHO. [c]No benzoic acid was detected.

4 R. Noyori, M. Aoki, K. Sato, *Chem. Commun.* **2003**, 1977.

5 a) W. A. Herrmann, T. Weskamp, J. P. Zoller, R. W. Fischer, *J. Mol. Catal. A: Chem.* **2000**, *153*, 49. b) C. D. Brooks, L. C. Huang, M. McCarron, R. A. W. Johnstone, *Chem. Commun.* **1999**, 37. c) E. Antonelli, R. D'Aloisio, M. Gambaro, T. Fiorani, C. Venturello, *J. Org. Chem.* **1998**, *63*, 7190. d) M. Shimizu, H. Orita, K. Suzuki, T. Hayakawa, S. Hamakawa, K. Takehira, *J. Mol. Catal. A: Chem.* **1996**, *114*, 217. e) B. M. Choudary, P. N. Reddy, *J. Mol. Catal. A: Chem.* **1995**, *103*, L1.

6 a) Y. Hayashi, M. Takeda, Y. Miyamoto, M. Shoji, *Chem. Lett.* **2002**, 414. b) X. Baucherel, J. Uziel, S. Jugé, *J. Org. Chem.* **2001**, *66*, 4504.

7 a) O. Bortolini, V. Conte, C. Chiappe, G. Fantin, M. Fogagnolo, S. Maietti, *Green Chem.* **2002**, *4*, 94. b) O. Bortolini, S. Campestrini, V. Conte, M. Fogagnolo, G. Fantin, S. Maietti, *Eur. J. Org. Chem.* **2003**, 4804.

8 T. Welton, *Coord. Chem. Rev.* **2004**, *248*, 2459.

9 For the synthesis of bmim(TfO) see: P. Bonhote, A.-P. Dias, N. Papageorgiou, K. Kalyanasundaram, M. Gratzel, *Inorg. Chem.* **1996**, *35*, 1168.

10 R. R. Crenshaw, G. M. Luke, T. A. Jenks, G. Bialy, M. E. Bierwagen, *J. Med. Chem.* **1972**, *15*, 1162.

11 B. Wang, Y.-R. Kang, L.-M. Yang, J.-S. Suo, *J. Mol. Catal. A: Chem.* **2003**, *203*, 29.

12 N. A. Sokolov, Y. G. Chernov, Y. V. Glazkov, *J. Org. Chem. USSR* **1972**, *8*, 2371.

13 H. Newman, R. B. Angier, *J. Chem. Soc. D* **1969**, 369.

14 Nitrostyrene epoxide was prepared by oxidation with trifluoromethyl methyl dioxirane (TFD) in CH_2Cl_2 at 0 °C, see Supporting Information available electronical on the Journal-web site; http://www.csj.jp/journals/chem-lett/index.html.

15 R. Ballini, M. Petrini, *Tetrahedron* **2004**, *60*, 1017.

16 C. Narayana, N. K. Reddy, G. W. Kabalka, *Synth. Commun.* **1992**, *22*, 2587.

Published on the web (Advance View) February 24, 2007; doi:10.1246/cl.2007.472