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# Novel Vanadium-Catalyzed Oxidation of Alcohols to Aldehydes and Ketones under Atmospheric Oxygen

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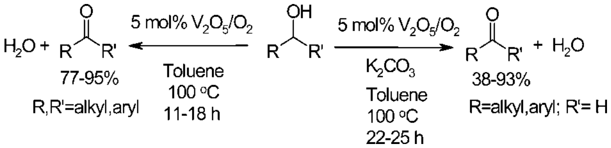
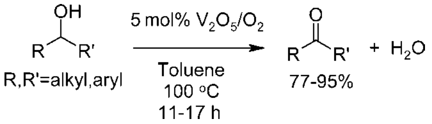
## ABSTRACT



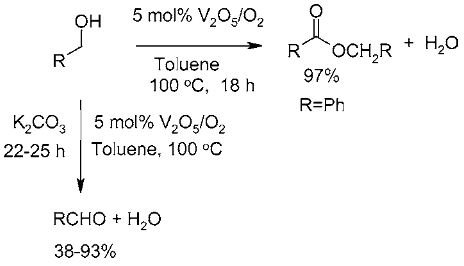
**Oxidation of alcohols to aldehydes and ketones has been studied in high yields using atmospheric oxygen and a catalytic amount of $V_2O_5$ in toluene under heating (ca. 100 °C). Secondary alcohols can be chemoselectively converted into ketones in the presence of primary hydroxy groups.**

The oxidation of alcohols to aldehydes and ketones plays a central role in organic chemistry both at the laboratory and industry level.[1,2] Several methods are available to effect this conversion, and continuous attention is drawn to newer and more selective methods of oxidation. Catalytic oxidation with molecular oxygen is particularly attractive from an economic and environmental point of view. Recently, CuCl−Phen,[3] polyoxometalates,[4] Mo−Cu,[5] Os−Cu,[6] CoLn,[7] RuLn,[8,9] Ni−hydrotalcite,[10] manganese oxide octahedral molecular sieves,[11] and VOLn[12] have been designed and developed for the aerobic oxidation of alcohols and await the further discovery of suitable catalytic systems, especially without sacrificial

**Scheme 1**



**Scheme 2**



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[1] Sheldon, R. A.; Kochi, J. K. *Metal-Catalyzed Oxidations of Organic Compounds*; Academic Press: New York, 1981.

[2] Cainelli, G.; Cardillo, G. *Chromium Oxidations in Organic Chemistry*; Springer: Berlin, 1984.

[3] Marko, I. E.; Giles, P. R.; Tsukazaki, M.; Chelle-Regnaut, I.; Gautier, A.; Brown, S. M.; Urch, C. J. *J. Org. Chem.* **1999**, *64*, 2433.

[4] (a) Haimov, A.; Neumann, R. *Chem. Commun.* **2002**, 876. (b) Yamaguchi, K.; Mizuno, N. *New. J. Chem.* **2002**, *26*, 972.

[5] Lorber, C. Y.; Smidt, S. P.; Osborn, J. A. *Eur. J. Inorg. Chem.* **2000**, 655.

[6] Muldoon, J.; Brown, S. N. *Org. Lett.* **2002**, *4*, 1043.

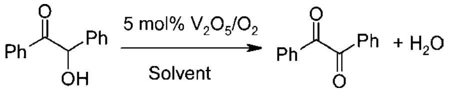
[7] (a) Yamada, T.; Mukaiyama, T. *Chem. Lett.* **1989**, 519. (b) Punniyamurthy, T.; Iqbal, J. *Tetrahedron Lett.* **1994**, *35*, 4007. (c) Kalra, S. J. S.; Punniyamurthy, T.; Iqbal, J. *Tetrahedron Lett.* **1994**, *35*, 4847. (d) Iwahama, T.; Yoshino, Y.; Keitoku, T.; Sakaguchi, S.; Ishii, Y. *J. Org. Chem.* **2000**, *65*, 6502.

[8] (a) Bleloch, A.; Johnson, B. F. G.; Ley, S. V.; Price, A. J.; Shephard, D. S.; Thomas, A. W. *Chem. Commun.* **1999**, 1907. (b) Masutani, K.; Uchida, T.; Irie, R.; Katsuki, T. *Tetrahedron Lett.* **2000**, *41*, 5119. (c) Csjernyik, G.; Ell, A. H.; Fadini, L.; Pugin, B.; Backvall, J.-E. *J. Org. Chem.* **2002**, *67*, 1657.

[9] Yamaguchi, K.; Mori, K.; Mizugaki, T.; Ebitani, K.; Kaneda, K. *J. Am. Chem. Soc.* **2000**, *122*, 7144.

10.1021/ol036166x CCC: $27.50

**Table 1.** Aerobic Oxidation of Benzoin with $V_2O_5$



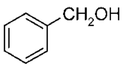
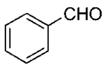
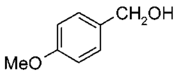
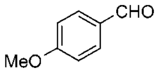
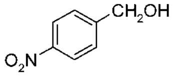
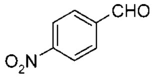
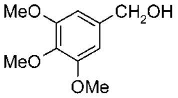
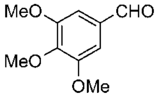
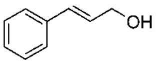
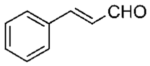
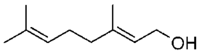
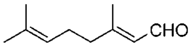
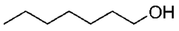
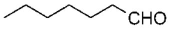
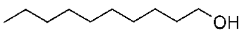
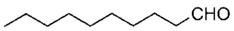
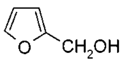
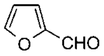
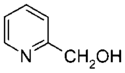
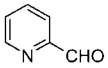
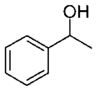
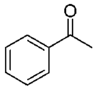
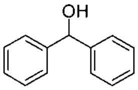
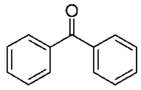
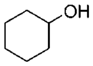
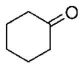
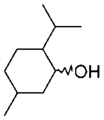
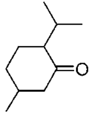
| entry | solvent | temp (°C) | yield (%)[a,b] |
|---|---|---|---|
| 1 | $CH_2Cl_2$ | 20 | 6 |
| 2 | $CH_3CN$ | 80 | 31 |
| 3 | $H_2O$ | 100 | 30 |
| 4 | toluene | 100 | 95 |

reducing agents. In continuation of our studies on the oxidation of organic compounds,[13] we report here a novel method for the oxidation of alcohols to aldehydes and ketones using a catalytic amount of $V_2O_5$ under atmospheric oxygen (Schemes 1 and 2).

The oxidation of benzoin was first investigated as a standard substrate using $V_2O_5$ under atmospheric oxygen (Table 1). Dichloromethane, acetonitrile, water, and toluene were employed as the solvents. We were pleased to find that the alcohol was oxidized to benzil in 6−95% yields. Among the solvents examined, toluene was found to be the best for this protocol.

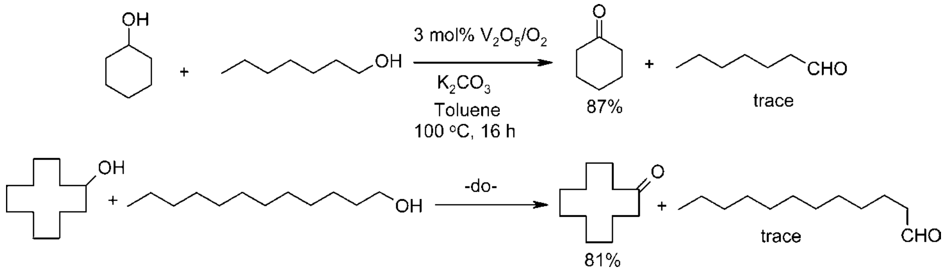
To evaluate the scope of this protocol, the oxidation of other alcohols was further studied (Table 2, entries 1−14).[12] As above, secondary alcohols, cyclohexanol, (±)-menthol, phenylethanol, and diphenylmethanol oxidized to the corresponding ketones in high yields. The oxidation of primary alcohols to aldehydes required 0.5 equiv of $K_2CO_3$, and in its absence, the corresponding esters were obtained (Scheme 2). Aromatic alcohols having electron-donating and -withdrawing groups in the aromatic ring, 4-methoxy-, 3,4,5-trimethoxy-, and 4-nitrobenzyl alcohol, were converted to

**Table 2.** Aerobic Oxidation Results of Alcohols Using $V_2O_5$

| entry | substrate | time (h) | product | yield (%)[a,b] |
|---|---|---|---|---|
| 1 |  | 24 |  | 82[c] |
| 2 |  | 22 |  | 92 |
| 3 |  | 25 |  | 79 |
| 4 |  | 24 |  | 94 |
| 5 |  | 22 |  | 87[c] |
| 6 |  | 24 |  | 81[c] |
| 7 |  | 24 |  | 43[c] |
| 8 |  | 24 |  | 38 |
| 9 |  | 24 |  | 91[c] |
| 10 |  | 24 |  | 87[c] |
| 11 |  | 13 |  | 95[c,d] |
| 12 |  | 13 |  | 94[d] |
| 13 |  | 15 |  | 89[c,d] |
| 14 |  | 18 |  | 77[d] |

[a] Mixture of $V_2O_5$ (5 mol %), alcohol (2 mmol), $K_2CO_3$ (1 mmol), and toluene (3 mL) was stirred at ca. 100 °C for the appropriate time under atmospheric oxygen. [b] Isolated yield. [c] GC yield. [d] Reactions carried out in the absence of $K_2CO_3$.

**Scheme 3**

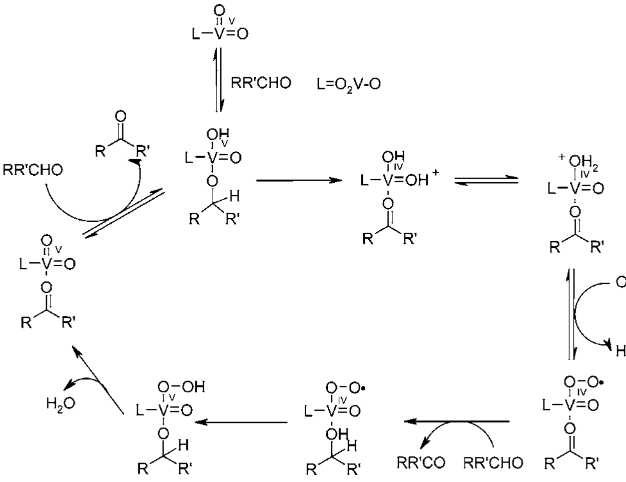


the corresponding aldehydes in 83−93% yields (entries 2−4). Similarly, allylic alcohols, geraniol and cinnamyl alcohol, oxidized to aldehydes without cleavage of the carbon−carbon double bonds. Furthermore, pyridine-2-methanol and furfurol were oxidized to the corresponding aldehydes in high yields. Saturated alcohols, heptyl and decyl alcohol, were moderately reactive, and the aldehydes were obtained in 38−43% yields.

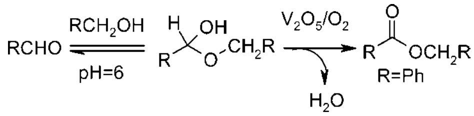
To study the chemoselectivity, a mixture of primary and secondary alcohols was next subjected to oxidation in the presence of 0.5 equiv of $K_2CO_3$ (Scheme 3). When cyclohexanol and heptyl alcohol were allowed to react, the former oxidized to cyclohexanone in 87% yield and the latter gave heptanal in <5% yield. A similar result was obtained in the oxidation of cyclododecanol and *n*-dodecanol, affording cyclododecanone and dodecanal in 81 and <3% yields, respectively. These studies clearly reveal that this method can be applied for the chemoselective oxidation of secondary alcohols in the presence of primary hydroxy groups.

Regarding the mechanism, a catalytic cycle is proposed for the oxidation of alcohols to aldehydes and ketones in Scheme 4.[14a] The formation of ester from the oxidation of primary alcohol in the absence of $K_2CO_3$ may be due to the formation of a hemiacetal and its subsequent oxidation to ester as shown in Scheme 5.[14b] This is due to the weakly acidic nature of the reaction medium (pH = 6). The addition of $K_2CO_3$ in the oxidation of primary alcohols increases the pH to 9, inhibiting the hemiacetal formation.

**Scheme 4**



**Scheme 5**



In conclusion, a novel and efficient protocol is presented for the aerobic oxidation of alcohols to aldehydes and ketones. Secondary alcohols can be chemoselectively converted into ketones in high yields in the presence of primary hydroxy groups. It is noteworthy that the aldehydes do not undergo further oxidation to carboxylic acids.

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**Supporting Information Available:** General experimental procedure and data. This material is available free of charge via the Internet at http://pubs.acs.org.

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(10) Choudary, B. M.; Kantam, M. L.; Rahman, A.; Reddy, C. V.; Rao, K. K. *Angew. Chem., Int. Ed.* **2001**, *40*, 763.

(11) Son, Y.-C.; Makwana, V. D.; Howell, A. R.; Suib, S. L. *Angew. Chem., Int. Ed.* **2001**, *40*, 4280.

(12) (a) Maeda, Y.; Kakiuchi, N.; Matsumura, S.; Nishimura, T.; Uemura, S. *Tetrahedron Lett.* **2001**, *42*, 8877. (b) Maeda, Y.; Kakiuchi, N.; Matsumura, S.; Nishimura, T.; Kawamura, T.; Uemura, S. *J. Org. Chem.* **2002**, *67*, 6718. (c) Kirihara, M.; Ochiai, Y.; Takizawa, S.; Takahata, H.; Nemoto. *Chem. Commun.* **1999**, 1387.

(13) (a) Das, S.; Punniyamurthy, T. *Tetrahedron Lett.* **2003**, *44*, 6033. (b) Velusamy, S.; Punniyamurthy, T. *Eur. J. Org. Chem.* **2003**, 3913. (c) Velusamy, S.; Punniyamurthy, T. *Tetrahedron Lett.* **2003**, *44*, 8955.

(14) (a) Bonchio, M.; Bortolini, O.; Conte, V.; Primon, S. *J. Chem. Soc., Perkin Trans. 2* **2001**, 763. (b) Tohma, H.; Maegawa, T.; Kita, Y. *Synlett* **2003**, 723.