Oxidation of *s*-Alcohols with "Oxone" in Aprotic Solvents in the Presence of Wet-Aluminium Oxide

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Synopsis. The oxidation of secondary aliphatic, alicyclic, and benzylic alcohols with Oxone in aprotic solvents in the presence of "wet-aluminum oxide" afforded the corresponding ketones in good yields under mild conditions.

"Oxone" (**1**), a white free-flowing powder, is a stable double salt, consisting of potassium hydrogenperoxomonosulfate ($KHSO_5$), potassium hydrogensulfate, and potassium sulfate in 2 : 1 : 1 molar ratio.[1] Recent development in Oxone chemistry has been exclusively based on the behavior of **1**, intimately analogous to conventional peracids.[2,3] Thus, **1** has been conveniently used for oxygen-transfer-type reactions; viz. epoxidation of olefins,[4,5] allylic alcohols,[6] and unsaturated acid,[7] and oxidation of sulfides to sulfoxides[8] and/or sulfones[9] etc. However, the reactions with **1** so far studied were usually carried out in mixed solvents with water,[2—10] because of the negligible solubility of **1** in organic solvents; to our knowledge, the only exceptional case in a water-free solvent is the oxidation of sulfides mediated by a quarternary ammonium salt.[11] This paper describes the oxidation of various *s*-alcohols with Oxone in aprotic solvents under mild conditions in the presence of aluminium oxide (referred as Alumina). This reaction might be expected to provide a readily available methodology for Oxone oxidations with simple manipulation, and also with facile product isolation.

Results and Discussion

The oxidation was conducted by mixing **1**, an alcohol, and an aprotic solvent in the presence or absence of Alumina. The heterogeneous mixture was stirred under argon in order to exclude any influence of autoxidation. It should be noted that sufficiently effective stirring throughout a given period is essential to ensure a smooth, reproducible (±5%<) reaction. The progress of the reaction can easily be followed by GLC analysis of the supernatant withdrawn at intervals. The analysis revealed that in the absence of Alumina, the oxidation of 2-methylcyclohexanol (**2**) at 25 °C in dichloromethane gave no detectable amount of 2-methylcyclohexanone (**3**), even within 24 h. The reaction with commercial "dry-Alumina" for 24 h led to the result that only 15% of **3** was obtained; 85% of **2** remained unreacted (GLC). On the other hand, a substantial consumption of 2 (92%) was observed for only 2 h in the presence of "wet-Alumina" (see Experimental), resulting in a dramatical increase of **3** (80%; isolated yield). Thus, "wet-Alumina" was proved to play an essential role in the oxidation. In the last case, it was observed that **2** is consumed as soon as the reaction started and that **3** increases with the progress of the reaction. There was no extensive formation of a by-product.

The oxidation was also conducted in acetonitrile and hexane in the presence of "wet-Alumina". In acetonitrile, Oxone showed a higher reactivity than in dichloromethane, and the substrate was almost consumed within 2 h at 25 °C. However, a considerable formation of a by-product was observed, giving an inferior yield of **3** (35%) to that in dichloromethane. This compound also increased with a prolonged reaction and/or with the increased concentration of the oxidant at the expense of **3**, clearly indicating that **3** is susceptible to further oxidation in acetonitrile. An extensive formation of unknown by-products was also observed during the oxidations of 3- and 4-methyl, and 4-*t*-butylcyclohexanol in acetonitrile.[#] The oxidation in hexane was considerably slow under similar conditions, affording only a poor yield of **3**. Thus, dichloromethane might be a solvent of choice for the reactions of Entries 1—4.

The oxidation of the other alcohols (Entries 5—12) was performed in a manner similar to that of **2**, except that acetonitrile was used as a solvent in the place of dichloromethane, since a selective formation of the corresponding ketones, as well as much faster reactions than in dichloromethane, was observed in this solvent.

All of the tabulated alcohols underwent smooth oxidation in the presence of "wet-Alumina" and afforded the corresponding ketones in good yields. The results are presented in Table 1. A steric hindrance of an alkyl substituent on a cyclohexane-ring is small (Entries 1—3 and 6); even **2** or menthol, having a methyl and an isopropyl group adjacent to the hydroxyl groups, gave **3** or menthone, respectively, in high yield.

The present reaction is fairly clean and procedures for the isolation of a product are facile. Insoluble reagents can be readily removed by filtration, and the product can be isolated by evaporation of the solvent. Hence, it is emphasized that this system may be treated in a way quite similar to supported reagents comprising Alumina and various oxidants,[12,14] except that the present procedure can be instantly carried out without any laborious impregnation of the oxidant onto the support. When the purification

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[#] Identification of these compounds is now under way independently and will be reported in due course.

Table 1. Oxidation of *s*-Alcohols with Oxone in Aprotic Solvents in the Presence of "Wet-Alumina"[a)]

Entry No.	Alcohols	Solvents[b)]	Temp °C	Time h	Ketones %[c)]
1	2-Methylcyclohexanol	DM	25	2	80
2	3-Methylcyclohexanol	DM	25	2	91
3	4-Methylcyclohexanol	DM	25	2	80
4	4-*t*-Butylcyclohexanol	DM	30	2	74
5	Cyclododecanol	AN	30	5	84
6	*l*-Menthol	AN	30	2	87
7	Borneol	AN	30	5	70
8	2-Heptanol	AN	30	2	80
9	2-Octanol	AN	30	2	85
10	1-Phenylethanol	AN	30	5	88
11	Diphenylmethanol	AN	30	5	89
12	Benzoin	AN	30	5	96

a) Under argon, 0.3 g of alcohol and 2.4 g of "wet-Alumina" were used in every run; [Oxone]/[Alcohol]=2.5 (mole ratio). b) 10 cm^3 of dichloromethane (DM) or acetonitrile (AN) was used. c) Isolated yield.

of carbonyl compounds, so obtained, was necessary due to contamination with parent alcohols and/or by-products, the crude products could be chromatographed immediately after evaporation of the solvent. Moreover, the reaction could be performed in an organic solvent, which overcomes the limited solubility of an organic substrate and/or an undesirable loss of water-miscible product attendant on the conventional reaction in a water-mixed solvent. Hence, this procedure serves as a novel and convenient tool for Oxone oxidation and may be a promising approach for the transformation of a variety of functional groups as well.

Experimental

^{1}H NMR spectra were measured with a JEOL PMX-60 model spectrometer for solutions in carbon tetrachloride or deuterated chloroform. IR spectra were recorded for thin films (neat or Nujol mull) on a JASCO A-100 spectrophotometer. GLC was carried out on a Shimadzu GC-4CM instrument with a 2 m column packed with 5% PEG-20M on Chromosorb GAW-DMCS, with temperature programming.

Materials. Oxone purchased from Aldrich Chemical Co., Inc. was used without purification. All of the alcohols were also commercially available. Solvents were rigorously dried and distilled. "Wet-Alumina" was prepared by vigorous shaking of commercial super-dried aluminium oxide (ICN BIOMEDICALS Alumina A, Super I; 20 g) with distilled water (4 g) untill a free-flowing powder was obtained.

General Oxidation Procedures. The following procedures are representative. To a heterogeneous mixture of "wet-Alumina" (2.4 g) and Oxone (2.5 times moles of an alcohol) in dichloromethane (10 cm^3) in a round-bottomed flask was added 2-methylcyclohexanol (0.3 g) in one portion with magnetic stirring. The flask was flushed with dry argon and then tightly sealed with a silicon-rubber septum, through which the supernatant was withdrawn by a microsyringe in the course of the reaction. The oxidation was conducted at a controlled temperature in a thermostat with efficient stirring. After a given period, the cooled mixture was filtered through a Pyrex Buchner funnel with a fritted disk, and the residue was repeatedly washed with either a solvent or dry ether. Evaporation of the combined filtrate on a rotary evaporator in vacuo gave an oil, which was chromatographed on silica gel eluted with hexane and ethyl acetate, giving pure **3** (0.236 g; 80%).

The purities of the products were checked by GLC: they were identified by a comparison of the GLC retention times, and the NMR and IR spectra with those of authentic samples.

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References

1) L. F. Fieser and M. Fieser, "Reagents for Organic Synthesis," John Wiley & Sons, New York (1967), Vol. 1, p. 952.

2) Concerning with the oxidations of olefins and sulfides (Ref. 3) with peracids, see the following reviews for comparison: a) B. Plesnicar, "Oxidation in Organic Chemistry," Part C, ed by W. S. Trahanovsky, Academic Press, New York (1978), p. 225. b) S. N. Lewis, "Oxidation," ed by R. L. Augustine, Marcel Dekker, Inc., New York (1969), Vol. 1, p. 223. c) D. Swern, "Organic Reactions," Vol. 7 (1953), p. 378.

3) (4a) p. 280. (4b) p. 244.

4) R. Bloch, J. Abecassis, and D. Hassan, *J. Org. Chem.*, **50**, 1544 (1985).

5) R. Curci, M. Fiorentino, L. Troisi, J. O. Edwards, and R. H. Pater, *J. Org. Chem.*, **45**, 4758 (1980).

6) G. Cicala, R. Curci, M. Fiorentino, and O. Laricchiuta, *J. Org. Chem.*, **47**, 2670 (1982).

7) P. F. Corey and F. E. Ward, *J. Org. Chem.*, **51**, 1925 (1986).

8) F. A. Davis, S. G. Lal, and H. D. Durst, *J. Org. Chem.*, **53**, 5004 (1988).

9) B. M. Trost and D. P. Curran, *Tetrahedron Lett.*, **22**, 1287 (1981).

10) R. J. Kennedy and A. M. Stock, *J. Org. Chem.*, **25**, 1901 (1960).

11) B. M. Trost and R. Braslau, *J. Org. Chem.*, **53**, 532 (1988).

12) A. Mckillop and D. W. Young, *Synthesis*, **1979**, 401 and 481.

13) G. H. Posner, *Angew. Chem., Int. Ed. Engl.*, **17**, 487 (1978).

14) G. H. Posner, "Preparative Chemistry Using Supported Reagents," ed by P. Laszlo, Academic Press, Inc., San Diego (1987), p. 287.