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$O_3/Pb(OAc)_4$: a new and efficient system for the oxidative cleavage of allyl alcohols

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Abstract—Allyl alcohols undergo oxidative cleavage, affording the corresponding carbonyl compounds in good yields, when treated with ozone–lead(IV) acetate under mild conditions.

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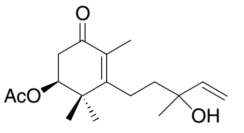
1. Introduction

The oxidation of tertiary alcohols is a reaction seldom utilized for synthetic purposes because of the structural requirements of the substrate for achieving good selectivities and yields. These reactions consist of one or two-electron oxidation processes leading to rearrangement, cyclization or fragmentation products.[1]

Among this type of alcohols, vinyl derivatives are of particular interest because they form part of the structure of natural compounds, such as sesquiterpenes **1** or **2**, or diterpenes manool (**3**), larixol (**4**) or cupressic acid (**5**).



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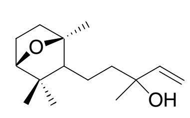

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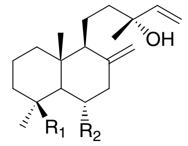
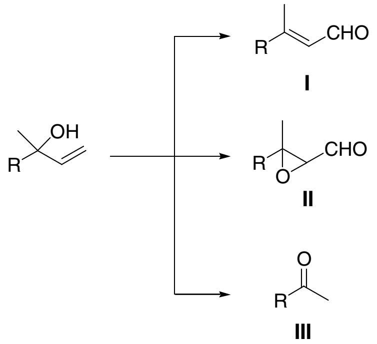


3 R_1: Me; R_2: H
4 R_1: Me; R_2: OH
5 R_1: COOH; R_2: H

Three reaction modes have been reported for this methyl vinyl carbinol moiety under oxidative conditions (Scheme 1). PCC oxidation affords transposed 3-methyl α,β-unsaturated aldehydes **I**.[2] The use of Collins reagent results in oxidative rearrangement to α-epoxyaldehydes **II**.[3] The third reaction mode, which involves C2–C3 fragmentation leading to methylketones **III**, takes place by utilizing potassium permanganate or chromium trioxide–acetic acid; however, in all cases the resulting ketone **III** is obtained in low to moderate yields, mainly due to work-up difficulties.[4,5] The obtention of small amounts of the oxidative cleavage type-**III** methylketones has been described when some manool (**3**) or



Scheme 1.

Keywords: Allyl alcohols; Oxidative cleavage; Ozonolysis; Lead(IV) acetate.

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Table 1. Oxidative cleavage of some allyl alcohols with the $O_3/Pb(OAc)_4$ system

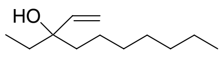
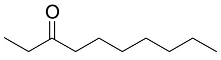
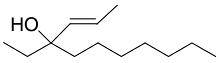
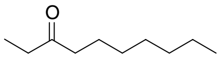
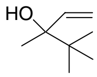
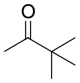
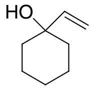
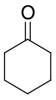
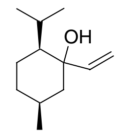
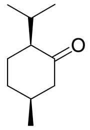
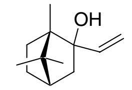
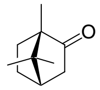
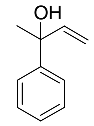
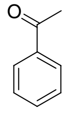
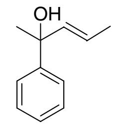
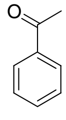
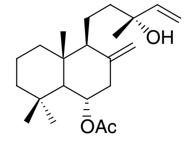
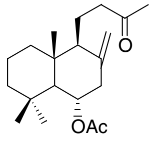
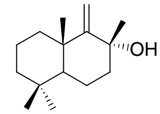
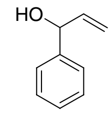
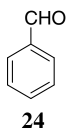
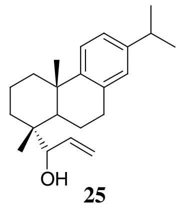
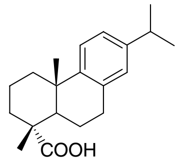
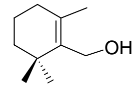
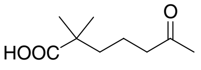
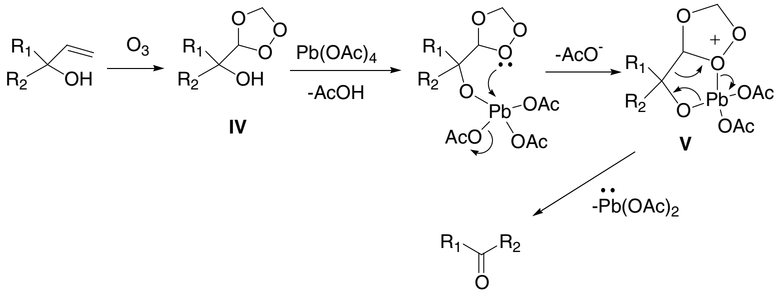
Entry	Substrate	Time (min)	Product	Procedure (%)
1	 **6**	60	 **7**	A (86)
2	 **8**	60	 **7**	A (90)
3	 **9**	90	 **10**	A (82)
4	 **11**	60	 **12**	A (89)
5	 **13**	90	 **14**	A (91) B (85)
6	 **15**	90	 **16**	A (94)
7	 **17**	60	 **18**	A (91) B (87)
8	 **19**	60	 **18**	A (87)
9	 **20**	75	 **21**	A (81)
10	 **22**	75	—[a]	
11	 **23**	60	 **24**	A (92) B (87)

Table 1 (*continued*)

Entry	Substrate	Time (min)	Product	Procedure (%)
12	 **25**	75	 **26**	A (78)
13	 **27**	75	 **28**	A (75)

[a] A complex mixture of compounds was obtained.



Scheme 2.

larixol (**4**) derivatives were ozonyzed in MeOH;[6] however, the procedure is not useful for synthetic purposes, because a mixture of compounds in low yield is usually obtained. The protic solvent seems to play an important role in this 'anomalous' ozonyzation, because it is known that ozonolysis of allyl alcohols, utilizing CH_2Cl_2 as solvent, affords the corresponding α-hydroxycarbonyl compounds in good yields.[7] Our studies on some of compounds cited here are in agreement with the literature data.

We have centred our attention on the latter oxidative cleavage, which can be utilized to prepare a variety of synthons starting from natural terpenoids.[8–10] In order to avoid the drawbacks involved in the use of potassium permanganate or chromium trioxide, we investigated alternative reagents. The ozone–lead(IV) acetate system was found to be a suitable oxidant to achieve this purpose. When an ozone–oxygen stream is bubbled through a solution of allyl alcohol in dichloromethane containing lead(IV) acetate (1.5 equiv), the carbonyl derivative resulting from the oxidative cleavage is obtained in good yields (Table 1).

Secondary and primary allyl alcohols (entries 11–13) also undergo oxidative cleavage. The benzylic alcohol **23** was transformed into benzaldehyde (**24**), whereas compound **25** afforded the carboxylic acid **26**, probably resulting from the overoxidation of the corresponding aldehyde. On the other hand, the primary cyclic alcohol **27** gave the ketoacid **28**.

A tentative mechanism is depicted in Scheme 2. The carbon–carbon bond cleavage takes place via the cyclic intermediate **V** derived from the hydroxyozonide **IV**. This supposition is supported by the fact that the same results were observed when lead(IV) acetate was added after completion of ozonolysis of allylic alcohol (experimental procedure B) and by the failure observed for compound **22**, which does not possess a suitable geometry to form the intermediate **V**.

2. Experimental procedure

Procedure A[†]: A stirred mixture of alcohol (1 mmol) and $Pb(OAc)_4$ (1.5 equiv) in CH_2Cl_2 (15 mL) was

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[†] The utilization of both procedures gave similar results (entries 5, 7 and 11 in Table 1). Oxidation of compound **20** was carried out at −78 °C, utilizing the procedure A, and monitorizing the reaction by TLC; when the ozonyzation was carried out at 0 °C, partial oxidation of exocyclic carbon–carbon double bond was observed. In the work-up for entries 12 and 13, washing with satd $NaHCO_3$ solution was eluded. $NaHSO_3$ was not added after oxidation of alcohol **23**.

slowly bubbled with an O_3/O_2 mixture at 0 °C for the specified time. The solution was flushed with argon, and $NaHSO_3$ (2 equiv) was added. The mixture was filtered and the filtrate diluted with ether (25 mL), and washed successively with sat. $NaHCO_3$ solution (2 × 10 mL) and brine (2 × 10 mL). The organic phase was dried over anhyd Na_2SO_4 and evaporated to yield the product.

Procedure B[†]: A stirred solution of alcohol (1 mmol) in CH_2Cl_2 (15 mL) was slowly bubbled with an O_3/O_2 mixture at −78 °C, and the course of the reaction was monitored by TLC. When the starting material was consumed, the solution was flushed with argon, and $Pb(OAc)_4$ (1.5 equiv) was added. The mixture was further stirred for 45 min at room temperature and $NaHSO_3$ (2 equiv) was added. After working-up, as described above, the product was obtained.

Acknowledgements

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References and notes

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