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# ALLENE EPOXIDATION. OXIDATIVE CYCLIZATIONS OF ALLENYL ALCOHOLS.[1]

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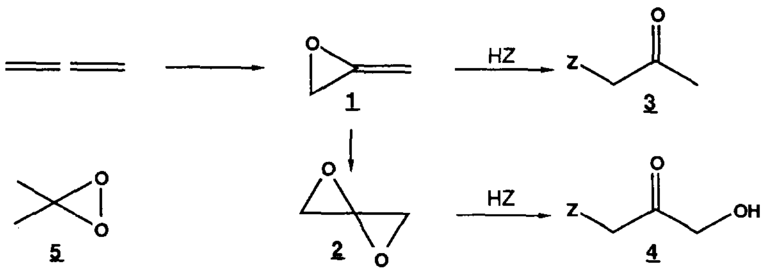
_Summary:_ *The dimethyldioxirane oxidation of various allenic alcohols yields highly functionalized tetrahydrofuran and tetrahydropyran derivatives via intramolecular nucleophilic addition of the hydroxy group to an intermediate allene diepoxide.*

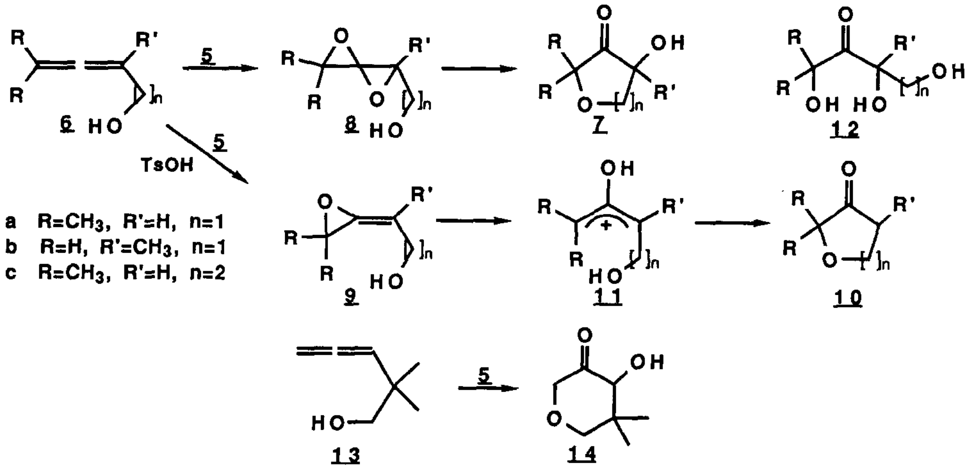
Earlier work on the epoxidation of allenes has revealed a rich and varied chemistry,[2] which is known to involve reactive intermediates such as allene oxides 1 and allene dioxides 2.[3,4] These species are usually transformed further under the reaction conditions to a variety of products including nucleophilic adducts 3 and 4.[5,6] We have recently demonstrated that the intriguing oxidant dimethyldioxirane (5)[7] allows for the efficient synthesis of a variety of isolable spirodioxides of type 2, which can be converted to adducts 4 by the subsequent addition of nucleophiles.[8] In this report we examine the effect of this new oxidation system on allenic alcohols that are capable of cyclization by intramolecular attack of the neighboring hydroxyl on reactive intermediates. It should be noted that Bertrand has observed products generated by cyclizations of intermediates derived from mono-oxidation of such compounds under Payne oxidation conditions.[9] We have shown that peracids behave similarly and, in some circumstances, lead to products derived from dioxidation of the allene.[10] The neutral, non-nucleophilic oxidant 5 is now demonstrated to promote the latter process leading to highly functionalized products.

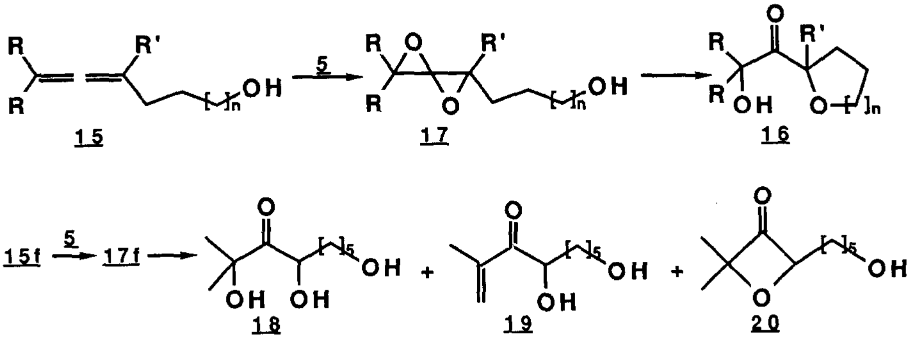


These "oxidative cyclizations" were generally performed by adding the allenic alcohols to three or more equiv of a cold solution of dioxirane 5 in acetone. The reaction was allowed to proceed until TLC indicated the disappearance of starting material (usually ca. 10 min), following which the product was concentrated and purified by preparative TLC.

In this manner, the trisubstituted α-allenyl alcohol 6a was converted to hydroxytetrahydrofuranone 7a as the dominant product in 55% isolated yield.[11,12] This transformation is best understood in terms of cyclization of the intermediate spirodioxide 8a formed by sequential epoxidation of 6a. The initially formed allene oxide 9a is not ordinarily trapped to a significant extent by competing processes under these conditions. However, a reaction in the presence of 0.5 equiv of *p*-toluenesulfonic acid gave mainly the simple tetrahydrofuranone 10a. This shift in product distribution is rationalized by invoking a competitive acid-catalyzed opening of 9a to hydroxyallyl cation 11a which subsequently collapses to give 10a. Interestingly, oxidation of the geminally disubstituted alcohol 6b under the usual conditions gave only triol 12b (89%), presumably by attack of trace amounts of water on the less substituted spirodioxide 8b.

Standard oxidation of β-allenyl alcohol 6c gave a remarkably clean transformation to hydroxytetrahydropyranone 7c in 92% yield.[13] Once again, the presence of *p*-TsOH led to the non-hydroxylated analog 10c. Somewhat surprisingly the monosubstituted alcohol 13 cyclized to hydroxyketone 14 under the usual conditions, unlike the terminally unsubstituted α-allenyl alcohol 6b.





a $R=CH_3$, $R'=H$, n=1 (88%)
b $R=H$, $R'=CH_3$, n=1 (48%)
c $R=CH_3$, $R'=H$, n=2 (75%)
d $R=H$, $R'=CH_3$, n=2 (65%)
e $R=H$, $R'=H$ , n=2 (55%)
f $R=CH_3$, $R'=H$, n=3 (see text)

Oxidative cyclization also occurs efficiently with γ-allenyl alcohols 15a and 15b which generate tetrahydrofurans 16a and 16b, respectively. In this instance, nucleophilic attack by the hydroxyl group takes place as expected at the more proximate carbon center of 17 to give a five-membered ring. Analogous cyclizations transform δ-allenyl alcohols 15c, 15d and 15e into tetrahydropyrans 16c, 16d and 16e, respectively.

Strong support for the proposed intermediacy of spirodioxides is provided by the results for the ε-allenyl alcohol 15f. The usual oxidation conditions gave a mixture of triol 18, enone 19 and oxetanone 20, the products anticipated from decomposition of spirodioxide 17f without involvement of the hydroxyl function. However, the inclusion of solid $K_2CO_3$ in the reaction as a buffering agent permitted the isolation of 17f in good purity and 96% yield. Satisfyingly, slow isomerization of this spirodioxide to oxepane 16f could be effected by prolonged heating in $CDCl_3$ containing $K_2CO_3$ (78% yield).

Thus, a variety of allenyl alcohols can be oxidatively cyclized by dimethyldioxirane (5) to produce interesting, highly oxidized derivatives of oxygen heterocycles in an efficient manner. We are currently adapting this methodology to more challenging synthetic problems.

## REFERENCES AND NOTES

1. Acknowledgement is made to the donors of the Petroleum Research Fund, administered by the American Chemical Society and the National Institutes of Health for partial support of this work. Departmental equipment grants aided in the purchase of the Varian XL-300 NMR (PHS-SID-RR-1882-01), the Bruker AM-500 NMR (PHS-SID-RR-02858 and NSF-CHE-85-13707) and the Kratos MS 80 (NSF-CHE-81-11957) mass spectrometer.
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11. All oxacycles were characterized by consistent $^{1}$H and $^{13}$C NMR, IR, and high-resolution MS data.
12. Approximately 10% of triol 12a was also isolated in several reactions.
13. This compound decomposed on standing or attempted purification by TLC.

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