The Allylic Rearrangement of Hydroperoxides: Oxygen Entrapment of the Proposed Carbon Radical Intermediate

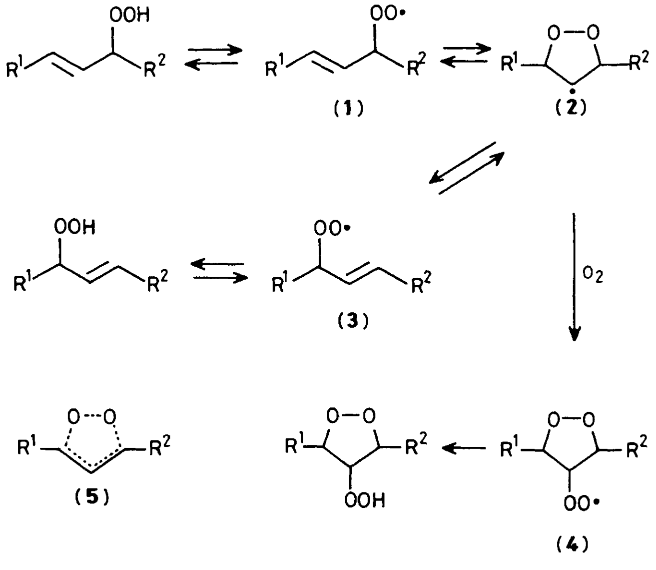
Ned Porter* and Paul Zuraw

Paul M. Gross Chemical Laboratories, Duke University, Durham, North Carolina 27706, U.S.A.

The proposed free radical intermediate for hydroperoxide allylic rearrangement is trapped by molecular oxygen, showing that this radical is not a competent intermediate in the rearrangement.

The rearrangement of allylic hydroperoxides has been known for over thirty years[1] and the mechanism of this conversion has been the focus of several investigations.[2,3] The proposed mechanism[2] for the rearrangement is presented in Scheme 1 and involves the formation of a cyclic species (**2**) which can open to form either (**1**) or (**3**). In a recent study,[3] two attempts were made to intercept the carbon radical (**2**). In the first approach, a hydroperoxide was chosen for study such that the intermediate (**2**) could undergo a carbon skeletal rearrangement.

In the second approach, the hydroperoxide rearrangement was investigated under 500 lb in^{-2} oxygen so that (**2**) could be converted into (**4**). Neither of these attempts was successful and no evidence favouring the intermediacy of (**2**) in the rearrangement could be found. An alternative structure, (**5**), for the allylperoxyl species was then suggested to account for the fact that (**2**) could not be trapped.† In this communication, we report that an authentic radical such as (**2**) can be trapped with oxygen.



Scheme 1

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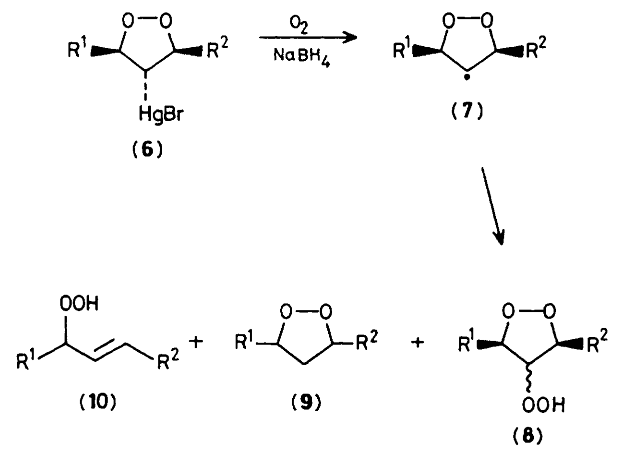
† It was suggested that (**5**) is the structure of a peroxyl radical formed during the autoxidation of alkenes and is not merely the transition state connecting (**1**) and (**3**).



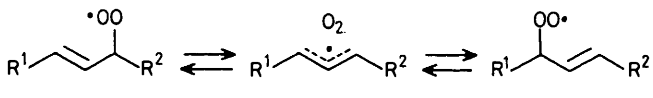
$R^1 = [CH_2]_4Me$, $R^2 = -CH{=}CH-[CH_2]_7CO_2Me$

Scheme 2

The radical precursor chosen for study was the alkylmercuriobromide (**6**) (Scheme 2) formed from peroxymercuration of methyl-*cis,trans*-13-hydroperoxy-octadeca-9,11-dienoate.[4,5] Reaction of (**6**) with sodium borohydride produced the radical (**7**).[6–9] Thus (**6**) (0.1 mmol) was placed in 5 ml of CH_2Cl_2 and 10 ml of H_2O and cooled to 0 °C. A fresh solution of sodium borohydride in 10 ml pH 7 buffer was quickly added in air and the reaction was stirred for 15 min. After dilution with CH_2Cl_2 and successive H_2O washes, the CH_2Cl_2 fraction was dried (sodium sulphate) and the volume of the solution reduced for h.p.l.c. analysis. The major products formed in this reaction are shown in Scheme 2. The compound (**9**) (28%) elutes from h.p.l.c. in 6 min while (**8**) (19%, two diastereoisomers at C-12) elutes at 11 min.‡ The hydroperoxide (**10**) elutes at 8.5 min (44%).

While formation of (**10**) from (**6**) probably occurs by an ionic mechanism,[10] the pathway from (**6**) to (**8**) and (**9**) is a well-precedented free radical reaction involving (**7**) as an intermediate. The isolation of alkyl hydroperoxides in this reducing medium is, perhaps, surprising. We find trace amounts of the alcohols corresponding to (**8**) and (**10**) under the two-phase conditions described here while homogeneous reductions in tetrahydrofuran or two-phase reactions in CH_2Cl_2–pH 10 buffer media give primarily these alcohols.

The hydridodemercuration of (**6**) thus establishes the fact that radical species such as (**7**) may be trapped with oxygen in the atmosphere. This observation suggests that radicals such as (**2**), if formed in allylic rearrangements of hydroperoxides (Scheme 1), would be trapped by oxygen. The intermediate (**2**) is therefore not a competent intermediate in the hydroperoxide rearrangement and the mechanism shown in Scheme 1 is thus invalidated. Comment should also be made about the radical species (**5**) proposed as an alternative structure for allylperoxy rearrangement.[11] This report suggests that the interconversion (**1**) → (**2**) → (**3**) does not occur at an appreciable rate. The concerted rearrangement[12] involving a transition state (**5**) remains one of at least two viable alternatives. It also seems reasonable to suggest that (**1**) and (**3**) may interconvert by β-scission of the peroxyl radicals to give free allyl radicals (Scheme 3) and molecular oxygen§ as is the case for pentadienyl radicals.[13]



Scheme 3

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‡ An Altex 10μ column (10% ethyl acetate, 90% hexane) provides analytically pure samples. *Spectroscopic data:* (**9**) ^1H n.m.r. (250 MHz) δ 5.62 (1H, vinyl), 5.40 (1H, vinyl), 4.93 (9, 1H, ring, α to R^2), 4.28 (1H, ring, α to R^1), 3.65 (s, 3H, CO_2Me), 2.84 (dd, 1H, 4-H of 1,2-dioxolane), 2.30 (t, 2H, α to C=O), 2.08 (2H, allyl), 1.92 (ddd, 1H, H_b), 1.78—1.19 (m), 0.86 (t, 3H, terminal Me); (**8**) ^1H n.m.r. (250 MHz) δ 9.03 (s, 1H, -OOH), 5.71 (m, 1H, vinyl), 5.47 (t, 1H, vinyl), 4.98 (dd, 1H, ring, α to O and R^2), 4.55 t (1H, ring, α to -OOH), 4.22 (ddd, 1H, ring, α to R^1). Decoupling experiments are consistent with the structures shown.

§ The suggestion that β-fragmentation of the peroxyl radical was responsible for hydroperoxide isomerization was considered and rejected by Brill (ref. 3). He assumed that the allyl radical–oxygen caged species has an appreciable steady state concentration relative to the allylperoxyl species. This is an incorrect assumption and is not required for the β-scission pathway to operate. The equilibrium constant for allyl ⇆ allylperoxyl could be large and $k\beta$ could still be significant. See, for example, J. A. Howard, J. H. B. Chenier, and T. Yamada, *Can. J. Chem.*, 1982, **60**, 2565.