

1-(Cyclohex-1-enyl)cyclohexyl Hydroperoxide: Intramolecular Propagation of Autoxidation as an Alternative Reaction to Allylic Rearrangement

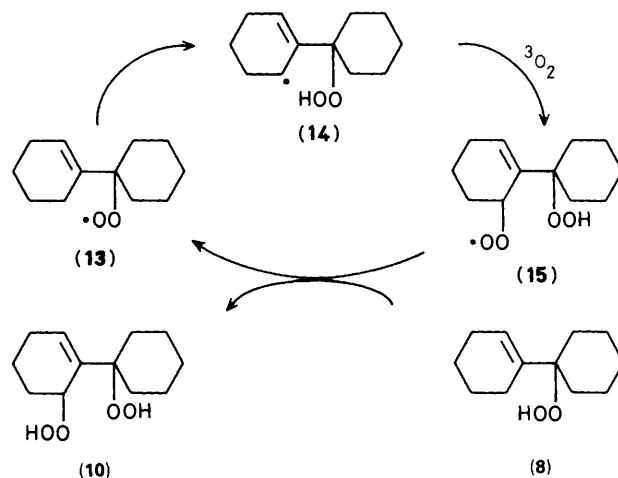
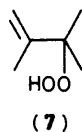
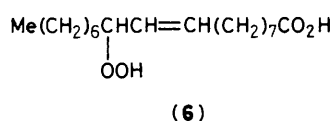
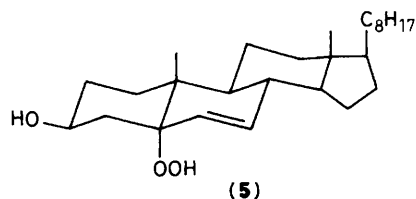
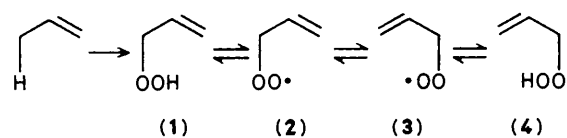
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The allylperoxyl radical derived from 1-(cyclohex-1-enyl)cyclohexyl hydroperoxide does not undergo allylic rearrangement, but in the presence of oxygen it undergoes autoxidation with an intramolecular propagation step, leading to the formation of 1-(6-hydroperoxycyclohex-1-enyl)cyclohexyl hydroperoxide.

Allylic hydroperoxides (1) are widespread compounds which are formed when alkenes are exposed to triplet (aerobic) or singlet oxygen, and which play important roles in many industrial and biological processes. In non-polar solvents they undergo rearrangement to the isomeric allylic hydroperoxides

(1) → (4) *via* the corresponding allylperoxyl radicals (2) and (3).¹⁻³ In the case of the 5 α -hydroperoxide (5) derived from cholesterol, the rearrangement occurs suprafacially.¹ This, together with the fact that neither (5)⁴ nor the hydroperoxides [*e.g.* (6)] derived from oleic acid⁵ incorporate labelled oxygen



Scheme 2

The hydroperoxide (8) is readily prepared by the reaction of cyclohexylidencyclohexane with singlet oxygen.⁷ When (8) in deuteriochloroform in the absence of oxygen was kept at room temperature for two months, or 40 °C for 97 h (conditions under which rearrangements have been observed with other allylic hydroperoxides^{4,8,9}), no rearrangement to the allylic isomer (9) could be detected (400 MHz n.m.r.). During 3 h at 80 °C, the hydroperoxide (8) appeared to decompose, to give a mixture of unidentified products (Scheme 1).

However, ¹H n.m.r. spectroscopy showed that under air or oxygen, (8) in chloroform was converted into a dihydroperoxide with the probable structure (10).[†] This was confirmed by a single crystal X-ray diffraction study of the diol (11)¹⁰ which was prepared by the reduction of (10) with triphenylphosphine.

It appeared surprising on steric and electronic grounds, however, that hydrogen abstraction should occur intermolecularly from the methylene group at position 6, rather than position 3 in the propagation step of the chain autoxidation.¹¹

We therefore propose that intramolecular abstraction of hydrogen by the peroxy radical at the sterically accessible 6-CH₂ group [(13) → (14)] is the dominant allyl radical-forming process in this autoxidation, as depicted in Scheme 2. The allylic radical (14) then reacts with oxygen to give the secondary peroxy radical (15) which does not abstract allylic hydrogen either inter- or intra-molecularly (else abstraction from the 3-CH₂ would be expected to occur). Instead it abstracts the hydroperoxylic hydrogen from the parent hydroperoxide (8) to give the dihydroperoxide (10) and the chain-propagating tertiary peroxy radical (13). The overall reaction occurs rapidly, as peroxy radicals abstract hydrogen about 100 times more rapidly from a hydroperoxy than an allylic methylene group;¹² the tertiary peroxy radical (13) will terminate the chain less readily than the secondary peroxy radical (15),¹² and the intramolecular hydrogen transfer is favoured for steric and entropic reasons.

As supporting evidence for our proposal, a mixture of the hydroperoxide (8) and the corresponding alcohol (12) was kept under oxygen and the progress of the reaction monitored by ¹H n.m.r. spectroscopy. The hydroperoxide (8) was again converted into the dihydroperoxide (10), whereas the alcohol (12) was unchanged.

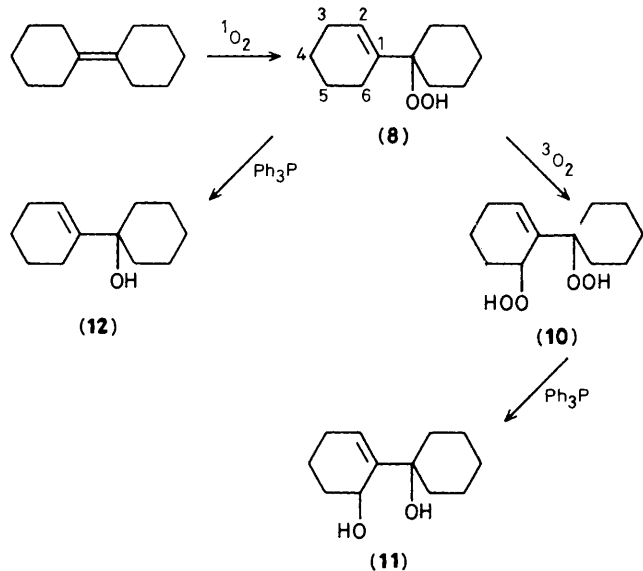
when the rearrangements are carried out under an atmosphere of ¹⁸O₂, suggests that the rearrangement follows a non-dissociative sigmatropic mechanism.

The rates of the rearrangements of the hydroperoxides show a surprising dependence on structure. For example, the self-initiated rearrangement of (5) in deuteriochloroform at 30 °C shows a half-life of about 7 h,⁴ but 2,3-dimethylbut-3-en-2-yl hydroperoxide (7) is reported to be resistant to rearrangement under similar conditions.⁶

In an attempt to elucidate the factors which control the rates of these rearrangements, we have examined the properties of the title compound (8) and have identified an alternative reaction which can occur to the exclusion of the rearrangement.

[†] Compound (10) has two distinct hydroperoxy protons at δ 8.98 and 9.12 (which exchange with D₂O) in the ¹H n.m.r. The conversion of (8) to (10) is quantitative (by n.m.r.).

Scheme 1



The autoxidation is therefore accelerated by fast intra- and inter-molecular propagation steps. We are not aware of any previous recognition of this phenomenon.

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