Ruthenium(II) Catalysed Rearrangement of the Natural Cyclic Peroxide G_3; X-Ray Crystallographic Structure Determination of a Butenolide Derivative

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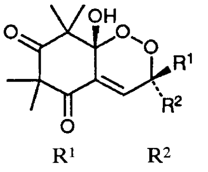
The natural cyclic peroxide G_3 is rearranged in the presence of a Ru^{II}–tertiary phosphine complex, to an ene pentadione and to a bicyclic hemiacetal butenolide; the structures have been respectively assigned by CPG–MS analysis and X-ray studies.

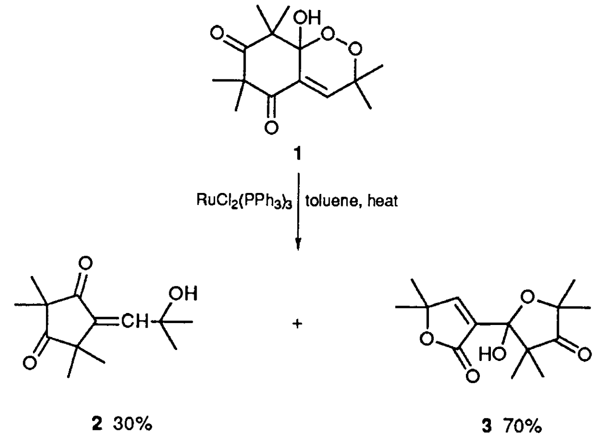
For some years there has been a growing interest in 1,2-dioxins (cyclic peroxides) as synthetic and biosynthetic intermediates.[1,2] We are currently interested in three closely related cyclic peroxides designated as G substances (growth regulators) which are formed in the leaves of *Eucalyptus grandis* and some other myrtaceous plants.[3,4] In addition to auxin like activity,[4] the G factors (Scheme 1) are known to affect stomatal conductance and photosynthesis,[5] to reduce water loss[6] and are associated to frost resistance in *E. grandis*.[7]

To our knowledge the chemical reactivity of these compounds is not yet known. We report in this paper our first experiments concerning the behaviour of the G_3 cyclic peroxide with a well defined metallic catalyst, the Ru^{II}–tertiary phosphine complex. This reaction may be a valuable chemical simulation for the interpretation of possible biosynthetic mechanisms of cyclic peroxide transformations.[8] Ru^{II} complexes (where the metal is member of the iron triad) have been recently used with success[9] in analogous reactions, due (*i*) to their ability to induce one-electron exchange reactions and (*ii*) to their high solubility in aprotic solvents.



G	R^1	R^2
G_1	Et	Me
G_2	Me	Et
G_3	Me	Me

Scheme 1



Scheme 2

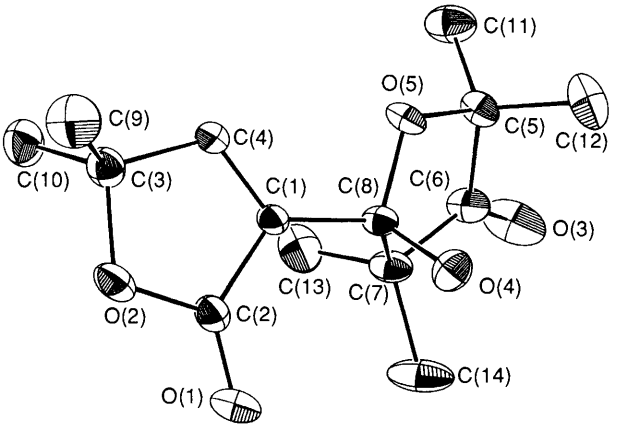
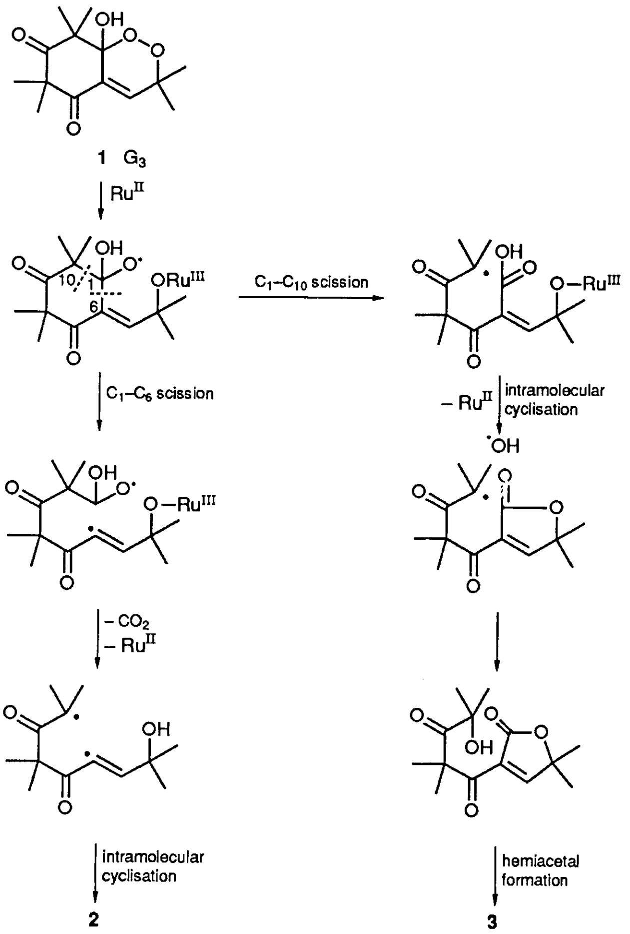


Fig. 1 Molecular structure of compound **3**

The G_3 cyclic peroxide isolated from *E. grandis*[10] or synthesized from syncarpic acid,[11] was refluxed in toluene with a catalytic amount of $RuCl_2(PPh_3)_3$. The reaction was followed by TLC to complete consumption of the G_3 substrate (2 h). It is noteworthy that no reaction occurred at room temperature or in the absence of the Ru^{II} complex. The two products observed by TLC were chromatographed on silica gel column (eluent diethyl ether : light petroleum 4 : 6, R_f **2** = 0.22, R_f **3** = 0.10). The structures were assigned as **2** and **3** (Scheme 2).

The ^1H NMR spectrum of liquid compound **2** (80 MHz, $CDCl_3$-TMS) indicated a mixture of two major compounds each possessing an ethylenic proton (δ 6.31 and 6.82) and a hydroxy group (δ 5.82 and 6.05). The high field NMR region displays six major peaks (δ 1.42, 1.29, 1.20 and δ 1.52, 1.47, 1.19) and many minor ones of various intensities; GC–MS analysis† indicated a 70 : 30 mixture of two compounds having the same molecular weight (m/z = 224) and identical fragmentation pattern. We assume that compound **2** is present as *Z* and *E* forms. A bicyclic hemiacetal form could also be present in solution complicating NMR spectra.

For compound **3** simple NMR or mass spectroscopic analysis did not enable us to assign its structure so a single crystal X-ray diffraction study was necessary‡ The molecular structure§ (Fig. 1) of compound **3** shows two five-membered rings namely a butenolide and an hemiacetal. The lactone ring adopts a planar structure with the oxygen atoms of the carbonyl group in the plane. The pentagonal hemiacetal ring adopts an envelope form where the O(5), C(5), C(6) and C(1) atoms are in the plane and the C(8) atom at the top of the fold. The C(2)–C(1)–C(8)–O(4) torsion angle (−55°) and the distances of the O(4) and H(4) atoms from the lactonic plane (d = −1.100 and −1.853 Å, respectively) indicates that the O(1) and O(4) atoms are in a non-eclipsed arrangement. No intramolecular hydrogen bonding is observed. The crystal structure is stabilized by a network of two strong intermolecular hydrogen bonds where the O(1), O(4) and H(4) atoms are participating [O(1)···H(4) 2.06 Å and O(1)···H(4)–O(4) 160.58°].



Scheme 3 Possible mechanism for G_3 rearrangement

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† GC–MS analysis on a HP-S971A apparatus, column HP1 25 m × 0.2 mm × 0.3 μm; T_{oven} = 150 °C, T_{inj} = 180 °C, T_{det} = 220 °C; t_r **2** = 3.04 min t_r **2′** = 4.85 min; m/z 224, 209, 181, 154, 139, 71, 59 and 43.

‡ *Crystal data*: $C_{14}H_{20}O_5$, M = 268.31, white crystal orthorhombic, space group $P2_12_12_1$, a = 6.542, b = 11.681, c = 18.841 Å, V = 1439.7 Å^3, Z = 4, F(000) = 576. Data collected on a CAD4 Enraf-Nonius diffractometer at room temperature using graphite monochromated Mo-Kα radiation. 3541 unique reflections were collected in the range $0 \leqslant \theta \leqslant 30°$. The data were corrected for Lorentz polarization but absorption effects were ignored. The structure was solved by direct methods and refined (difference Fourier synthesis; full-matrix least-squares) using 1526 reflections with $I > 2\sigma(I)$. The final residuals were R = 0.0546 and R_w = 0.0608. All hydrogen atoms are refined and inserted at calculated positions except for H(4) which was only refined. Atomic coordinates, bond lengths and angles, and thermal parameters have been deposited at the Cambridge Crystallographic Data Centre. See Notice to Authors, Issue No. 1.

§ We thank Dr J. Jaud at the Centre d'élaboration des matériaux et d'études structurales for X-ray data determination.

Compounds **2** and **3** are formed from **1** *via* a rearrangement with decarboxylation or a simple rearrangement process. A possible mechanism of this reaction is outlined in Scheme 3.

The Ru^{II} catalysed rearrangement of cyclic peroxide G_3 shows a very good selectivity yielding only two compounds where the butenolide **3** predominates (yield 70%).

Investigation of this mechanism and use of analogous cyclic peroxides for this reaction are planned and should be of interest since butenolides are found frequently in a large number of natural products and may possess various biological activities.[12,13]

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