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STRUCTURE AND SPECTRA OF DISELENIDES FROM A SELENIUM DIOXIDE OXIDATION[1]

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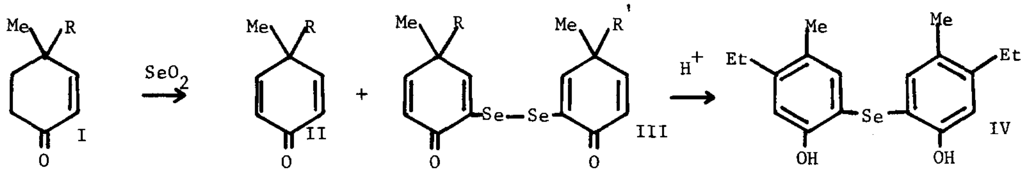
Selenium dioxide is used as a common oxidant to introduce oxygen functionality at an enolic or allylic position. Complex mixtures of selenium-containing by-products are often formed, but are seldom characterized. The most common products seem to be selenate esters, and a few have been well characterized.[3]

We wish to report that oxidation of 4,4-dimethylcyclohexenone (Ia) with SeO_2 in refluxing t-BuOH gives, in addition to 70% of the dienone IIa,[4] a 14% yield of the diselenide IIIa, mp 155-157°. 4-Methyl-4-ethylcyclohexenone (Ib) gives IIb[4] and the analogous diselenide IIIb, mp 141-143° in comparable yield. Diselenides have been reported during the synthesis of a few steroidal dienones, but have not been completely characterized,[5] and o-dimethoxybenzene gives rise to bis-(3,4-dimethoxyphenyl) diselenide[6] with SeO_2, although the reaction does not appear to be general. Diselenides are commonly synthesized by quite different procedures.[7]



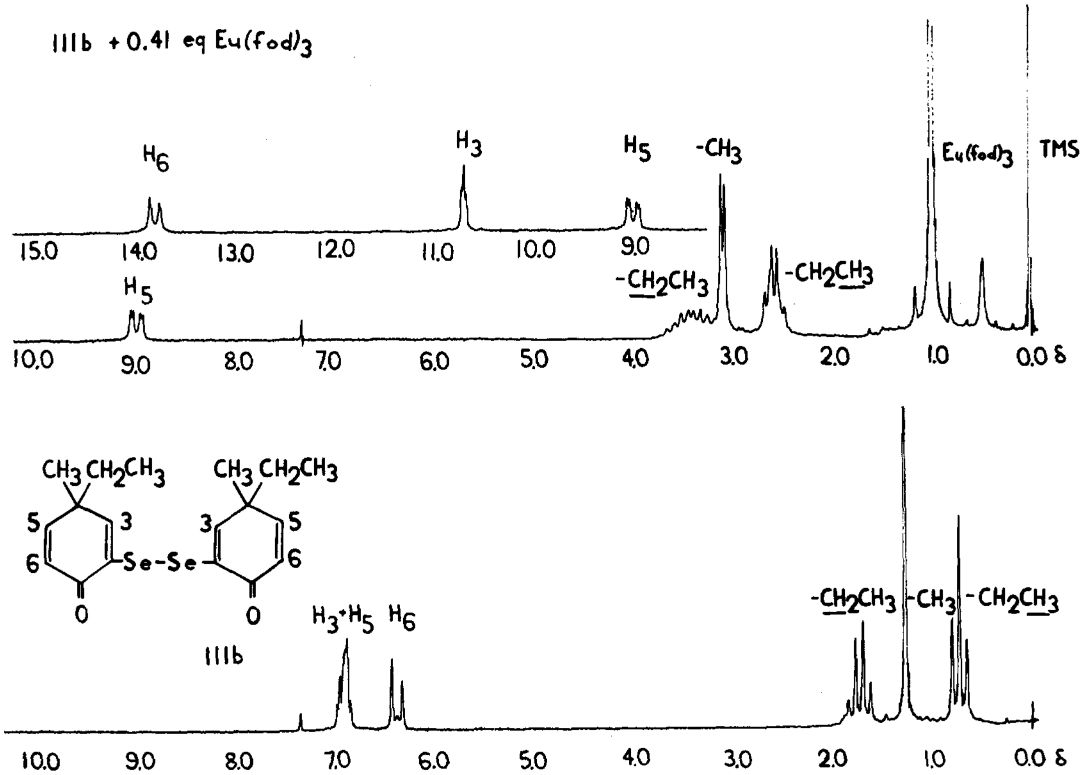
I, II a. R = Me
b. R = Et

III a. R = R' = Me
b. R = R' = Et
c. R = Me, R' = Et

The UV, IR, and NMR spectra of IIIa and IIIb are consistent with structures containing the intact cyclohexadienone moiety. The elemental analysis and mass spectrum of IIIb are consistent with the formula $C_{18}H_{22}O_2Se_2$. The main fragmentation pattern showed a family of peaks at m/e 434 to 422 (parent), 299 to 287 ($P-C_9H_{11}O$), 217 to 211 ($P-C_9H_{11}OSe$), 135 ($C_9H_{11}O$), as well as smaller peaks below 280, some partially overlapping the reported ones, due to other fragmentations. The relative intensities of the parent peaks match calculated isotopic abundances. This data requires a symmetrical structure with an Se-Se bond, which can be placed in the 2 or 3 position.

The diselenide IIIb in CF_3COOH rapidly undergoes dienone-phenol rearrangement with Se extrusion[8] and ethyl migration.[9] The main product, mp 150-152°, is assigned structure IV on the basis of its NMR and mass spectra. In particular, two singlets in its NMR spectrum at δ6.34 and 6.78 must be caused by aromatic protons <u>para</u> to each other, thus requiring the diselenide linkage in IIIb to be located in the 2-position.

FIGURE I



The NMR spectrum of the diselenide IIIb is reproduced in Figure I. Addition of the paramagnetic shift reagent, Eu(fod)$_3$,[10] resolved the three vinyl signals. The ΔEu values[11] observed (H_3 = 7.7, H_5 = 4.5, H_6 = 17.9, Me = 3.7, Et = 3.5 ppm) allow the assignments given in Figure I. The observed ΔEu values give the best fit to a simplified form[12] of the

McConnell-Robertson equation, when the Eu atom is placed in the plane of the ring, ca. 2.8 Å from the carbonyl oxygen and 3.9 Å from the Se atom. Although several assumptions are inherent in the treatment, the data suggest that the preferred pseudo contact interaction of the Eu is with both the oxygen and selenium. The observed multiplicities of the vinyl signals require long range W coupling[13] (J = 2Hz) between H_3 and H_5, and this was verified by double resonance experiments. However, irradiation of the H_5 signal caused the H_3 signal to collapse to two sharp lines separated by ca. 2Hz, and the signal was unaffected by irradiation elsewhere in the spectrum. Also, the methyl and ethyl[14] groups showed two sets of signals in the shifted spectrum (at 100 MHz but not resolved at 60 MHz) which were unaffected in the double resonance experiments. Thus the shift reagent has revealed the presence of two similar species in equal concentrations. The tetramethyl compound IIIa, however, showed only the expected pattern for a single species.

Since IIIb (but not IIIa) contains a chiral center in each ring, our sample must contain equal quantities of a dl- and a meso-isomer, even though its mp is fairly sharp. However, with the chiral centers so far removed from each other, it seemed surprising that the signals for the two forms could be resolved, even with the shift reagent, so experimental verification was obtained by synthesis of a compound (IIIc) containing the chiral center in only one ring.

Oxidation of a 1:1 mixture of Ia and Ib gave a diselenide fraction containing IIIa, IIIb, and IIIc in a ratio of ca. 1:1:2 (mass spectral analysis of parent peaks). The crossover product IIIc was partially purified by preparative high pressure liquid chromatography on a C-18 reverse phase column (35:65 acetone-water) and was shown to be essentially free of IIIb. Its NMR spectrum in the presence of $Eu(fod)_3$ showed the expected pattern[14] for a single ethyl group (other signals were obscured by the presence of IIIa and the dimethyl portion of IIIc). This demonstrates that the shift reagent is resolving the dl and meso forms of IIIb.

The mechanism of formation of the diselenides remains speculative, but must involve dimerization of a dienone selenium radical as the final step, since the crossover product IIIc is formed in statistical amount. The diselenides must represent an alternative pathway to the normal course[15] of the oxidation, since the ratio of dienone to diselenide formed is independent of the amount of SeO_2 used. Further studies on the scope and limitations of this reaction are in progress.

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