Tetrahedron Letters, Vol.27, No.4, pp 509-512, 1986 0040-4039/86 $3.00 + .00
Printed in Great Britain

PHOTOINDUCED REACTIONS OF 3β-ACETOXYCHOLESTA-5,7-DIENE, 3β-ACETOXYCHOLEST-5-ENE, TETRAPHENYLCYCLOPENTADIENE AND 1,1-DIPHENYLETHYLENE WITH OXYGEN IN THE PRESENCE OF PHENYLSELENENYL BROMIDE

Richard K. Haynes * and Audrey E. Hilliker
Department of Organic Chemistry, Univesity of Sydney, Sydney NSW 2006, Australia

Summary: Whereas PhSeBr under irradiation with O_2 in CH_2Cl_2 at -78° acts as a photoxygenation catalyst to convert 3 β-acetoxycholesta-5,7-diene and tetraphenylcyclopentadiene into the corresponding endoperoxides, and 3β-acetoxycholest-5-ene into 3β-acetoxycholest-5-en-7-one and the corresponding alcohols, it reacts with 1,1-diphenylethylene to give mainly a bromohydrin; bromine radicals arising by photodissociation of the PhSeBr are implicated as the active intermediates.

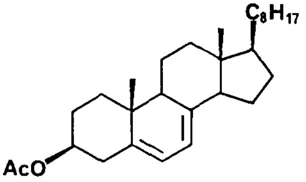
The Lewis acid-catalysed conversion of conjugated dienes into endoperoxides in the presence of O_2 is subject to autoinhibition arising from deactivation of the catalyst by its complexation with the product; the extent of inhibition is dependent upon the strength of the Lewis acid.[1-3] Metal halide Lewis acids are also unsuitable as catalysts for the oxygenation of substrates containing Lewis basic sites other than the diene systems; thus $Ph_3C^+BF_4^-$ or I_2 may be used for oxygenation of tetraphenylcyclopentadiene, whereas $AlCl_3$, $FeCl_3$ etc. are largely ineffective.[2] Consequently, in seeking to extend the range of catalysts where such complexation is unlikely to be a problem, we considered that electrophilic divalent selenium compounds, like iodine, could act as selective oxygenation catalysts, providing that electrophilic addition of such compounds to the substrate did not intervene. We describe here preliminary results of the oxygenation of 3β-acetoxycholesta-5,7-diene <u>2</u>, 1,2,3,4-tetraphenylcyclopentadiene <u>4</u>, 1,1-diphenylethylene <u>6</u>, and 3β-acetoxycholest-5-ene (cholesteryl acetate) <u>9</u> in the presence of PhSeBr <u>1</u>. Whereas <u>9</u> has been reported to be inert towards O_2 in the presence of $Ph_3C^+BF_4^-$,[3] the first three substrates yield the corresponding endoperoxides <u>3</u>[1] and <u>5</u>[2], and 3,3,6,6-tetraphenyl-1,2-dioxane[4] in the presence of Lewis acids and O_2 at -78°.

Irradiation (Tungsten lamp, 600 W) of <u>2</u> in CH_2Cl_2 (50 ml) (0.25 mmol) and <u>1</u> (0.28 eq, added as 0.07 eq lots in CH_2Cl_2 each 60 min) during 3 h under dry O_2 at -78° in a Pyrex flask gave, after aqueous bicarbonate quench, 3 (50 %) and unchanged 2 only. The catalyst was recovered as PhSeSePh (59%); products arising from addition of 1 to 2 were not found. Similarly, 4 with 1 (0.4 eq, added portionwise as above) during 4 h under irradiation at -78° gave 5 (41%), unchanged 4 (23%) and PhSeSePh (62%). Irradiation of mixtures of 2 and PhSeCl or PhSeSePh under O_2 did not result in oxygenation of 2. When, in order to enhance the electrophilic nature of the catalyst,[5] a reaction involving 2 and 1 was run in the presence of excess $AgPF_6$ or $AgOSO_2CF_3$, oxygenation was considerably slower; after 3 h, 3 (19%) and unchanged 2 (68%) were obtained. Remarkably, a control experiment involving irradiation of 2 (0.25 mmol) with a suspension of AgBr (2.0 eq) under the above conditions during 3 h also gave 3 (14%) and unchanged 2. Furthermore, 3 was obtained in 44% yield when 2 (0.3 mmol) in CH_2Cl_2 containing *N*-bromosuccinimide (0.2 eq) at -78° was irradiated under O_2 during 80 min.

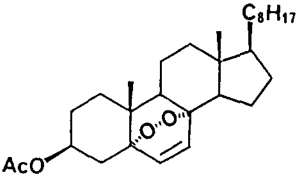
The ethylene 6 (1.0 mmol) with 1 (0.43 eq, added portionwise) under the usual conditions during 4 h gave benzophenone (3 %), the bromohydrin 7 (30 %), the hydroxyselenide 8 (5 %), unchanged 6 (30 %) and PhSeSePh (10 %).[6,7] The products were not formed from 6 and 1 under O_2 in the dark, or under N_2 with irradiation in CH_2Cl_2 at -78°, when 6 was recovered unchanged. The presence of excess $AgPF_6$ (with respect to 1) in irradiated solutions of 6 and 1 under O_2 at -78° almost entirely suppressed formation of 7 and 8. By contrast, cholesteryl acetate 9 (0.4 mmol) in CH_2Cl_2 (50 mL) containing 1 (0.28 eq, added as 0.04 eq lots each 40 min) during 4 h under the above conditions gave the enone 10 (10 %), the α and β-epimers of the alcohol 11 (α: β = 66:34, 12 %), unchanged 9 (72 %) and PhSeSePh (92 %). In the presence of $AgPF_6$ or $AgOSO_2CF_3$, oxygenation of 9 was again inhibited. No oxygenated or other products were obtained from 9 under irradiation in the presence of O_2 and PhSeCl or PhSeSePh.[7] Use of $Ph_3C^+BF_4^-$ (0.5 eq, added portionwise as above) in place of 1 during 4 h under irradiation at -78° gave 10 (21%), 11 (α:β = 54:46, 12 %) and unchanged 9 (49 %). Also recovered was benzophenone (78 %) and triphenylcarbinol. Irradiation of $Ph_3C^+BF_4^-$ alone under O_2 in CH_2Cl_2 at -78° also gave benzophenone (70 %).[8]

Thus, whereas 1 does induce endoperoxide formation from 2 and 4, it is much less effective than is I_2 or other Lewis acids.[1,2] Indeed, the general inhibition of the reactions by $AgPF_6$ or $AgOSO_2CF_3$, the nature of the products formed from 6, and the fact that irradiated NBS also induces endoperoxide formation from 2, together suggest that the active oxygenating agent is not 1, but rather are bromine radicals which presumably arise by photodissociation of 1. The bromine radicals then initiate the oxygenation of 2 and 4 by oxidizing these dienes to cation radicals, which react with O_2 as has been discussed elsewhere.[1,2] Bromohydrin formation is accounted for through addition of $Br^{\bullet}$ to 6, and reaction of the derived radical with O_2 and the other product of the photodissociation process, $PhSe^{\bullet}$. The hypothetical peroxide 12 so formed upon aqueous treatment delivers 7 (Scheme 1).[9-11] The small amount of 8 may arise by reversible addition of the feebly electrophilic $PhSe^{\bullet}$[12] to 6, with subsequent reactions proceeding analogously to those of Scheme 1. The products from 9 correspond to those normally formed from autoxidation of cholesterol, and arise by decomposition of the 7α- and 7β-hydroperoxides, the primary products of the autoxidation.[13] In the present instance, an allylic radical from 9 may be generated by initial formation of an alkene cation radical, followed by proton loss from C7.[14] Reaction of the radical with oxygen, back-electron-transfer, and reprotonation will generate the hydroperoxide precursors of 10 and 11.[15]

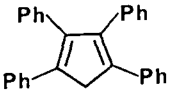
Acknowledgement: We thank the Australian Research Grants Scheme for financial support.



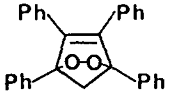
2



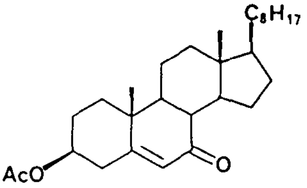
3



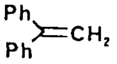
4



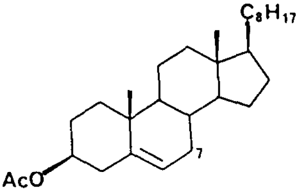
5



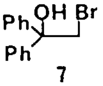
10



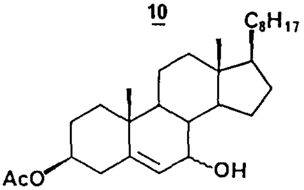
6



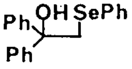
9



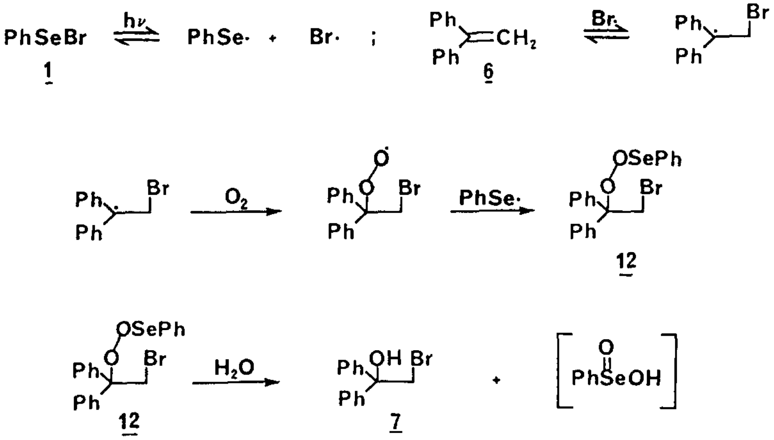
7



11



8



Scheme I

References and Notes

(1) Haynes, R.K. Aust.J.Chem. 1978, 31, 121; Haynes, R.K. Aust.J.Chem. 1978, 31, 131.

(2) Haynes, R.K.; Peters, J.M.; Wilmot, I.D. Aust.J.Chem. 1980, 33, 2653.

(3) Barton, D.H.R.; Haynes, R.K.; Leclerc, G.; Magnus, P.R.; Menzies, I.D. J.Chem.Soc., Perkin Trans. I 1975, 2055.

(4) Haynes, R.K.; Probert, M.K.S.; Wilmot, I.D. Aust.J.Chem. 1978, 31, 1737.

(5) Schmid, G.H.; Garratt, D.G. Tetrahedron Lett. 1975, 3991.

(6) Polar products were formed but not characterized. NBS (1.2 eq.) and 6 (18.5 mmol) in aqueous THF at 0° also gave 7 (95 %) cf. Grant, D.W.; Shilton, R. J.Chem.Soc., Perkin Trans. I 1974, 135. 6 (1 mmol) and 1 (2.1 eq) in THF: H_2O (3:1) at 20° for 12 h gave 8, m.p. 88-89°, (81 %, based on reacting 6), unchanged 6 (57 %) and PhSeSePh (52 %).

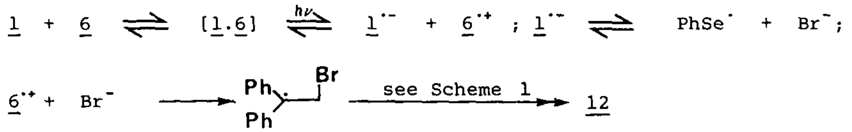
(7) Cholesteryl acetate is inert to electrophilic addition by divalent selenium reagents: Sharpless, K.B.; Lauer, R.F. J.Org.Chem. 1974, 39, 429.

(8) Cf. van Tamelin, E.F.; Cole, T.M. J.Am.Chem.Soc. 1971, 93, 6158. 9 is inert to O_2 upon protracted irradiation in the presence of benzophenone.

(9) PhSeBr is not known as a source of electrophilic bromine. Addition of arylselenenyl halides to alkenes normally involves selenium as the electrophile: Garratt, D.G.; Schmid, G.H. Can.J.Chem. 1974, 52, 3599; Clive, D.L.J. Tetrahedron 1978, 34, 1049; Ho, P.-T.; Kolt, R.J. Can.J.Chem. 1982, 60, 663; Liotta, D. Acc.Chem.Res. 1984, 17, 28.

(10) Phenylselenenyl peroxides related to 12 appear to be unknown. For the preparation of a hydrolytically unstable phenylseleninyl peroxide, see Bloodworth, A.J.; Lapham, D.J. J.Chem.Soc., Perkin Trans. I 1983, 471.

(11) Alternatively, photoinduced electron transfer within a charge transfer complex[1,4] of 1 and 6 produces a radical-ion pair, the radical anion of which undergoes reversible dissociation to PhSe and Br$^-$. Reaction of the latter with $6^{\cdot +}$ produces a neutral radical whose reaction with O_2 and PhSe$^\cdot$ will also lead to 12 (Scheme i, below). However, the formation of halogen free products of oxygenation from 2, 4 or 9 is not compatible with this type of process.



Scheme i

(12) Ito, O. J.Am.Chem.Soc 1983, 105, 850.

(13) Teng, J.L.; Kulig, M.J.; Smith, L.L. J.Org.Chem. 1973, 38, 119; Smith, L.L.; Kulig, M.J. J.Am.Chem.Soc. 1978, 100, 6206.

(14) For possible cases of proton loss from cation radicals, see ref. 3 and Gassmann, P.G.; Singleton, D.A. J.Am.Chem.Soc. 1984, 106, 6085.

(15) Such a mechanism is presumed to operate when $Ph_3\overset{+}{C}\,\overset{-}{BF_4}$ is used as catalyst. For 1, generation of an allylic radical through abstraction of a hydrogen atom from C7 in 9 by Br$^\cdot$ must also be considered. Irradiation of 9 in the presence of O_2 and NBS leads exclusively to 10: Friedman, M.; Goradetsky, M.; Mazur, Y. Chem.Commun. 1971, 874.

(Received in UK 22 October 1985)