Tetrahedron Letters,Vol.23,No.12,pp 1285-1288,1982 0040-4039/82/121285-04$03.00/0
Printed in Great Britain

SENSITIZED PHOTOOXYGENATION OF 2,4-HEXADIENOIC ACID ESTERS AND 2,4,6-OCTATRIENOIC ACID ESTERS. UNUSUAL SOLVENT AND TEMPERATURE EFFECTS

Masakatsu Matsumoto and Keiko Kuroda
Sagami Chemical Research Center
Nishi-Ohnuma 4-4-1, Sagamihara, Kanagawa 229
Japan

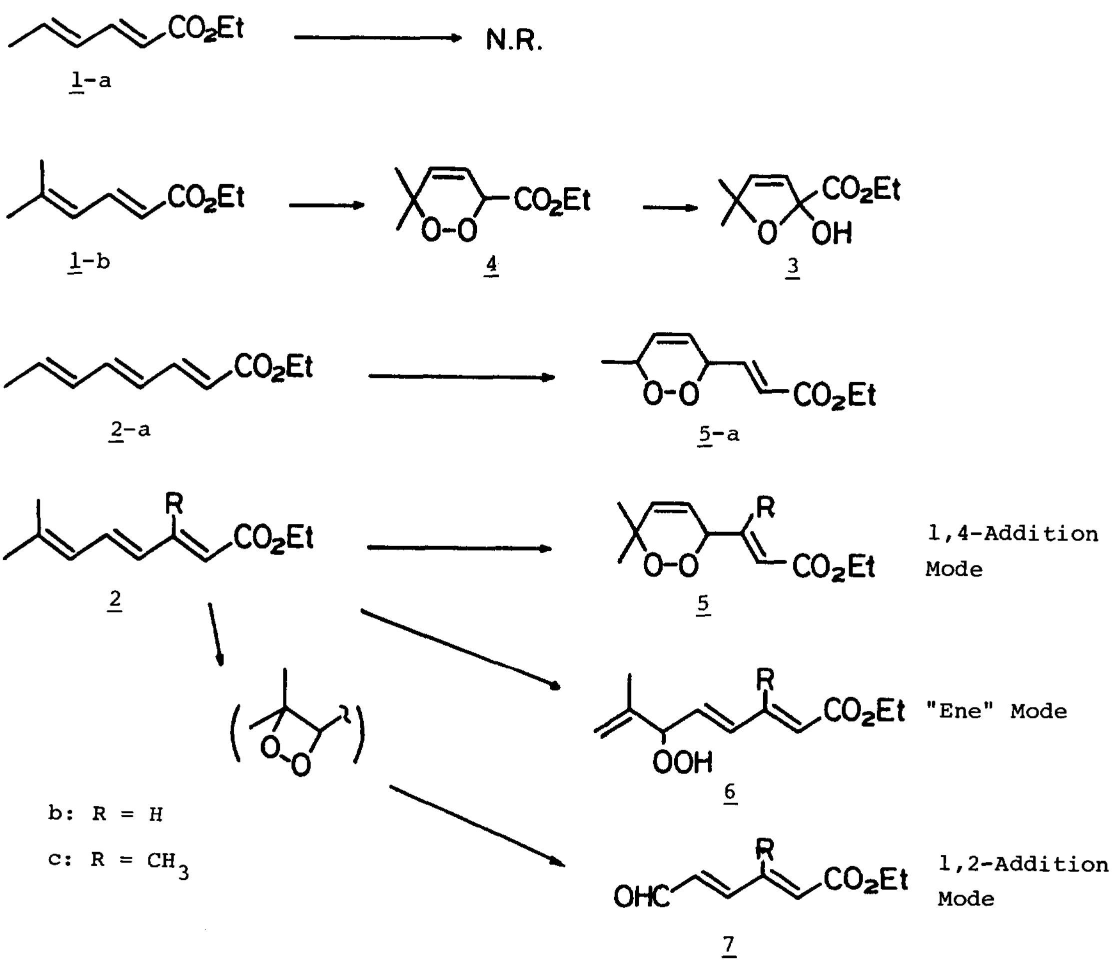
Summary: Sensitized photooxygenation of the title compounds were remarkably affected by the solvent used and the reaction temperature.

Sensitized photooxygenation has intensively been studied and now singlet oxygen is widely used as an oxidant for the selective functionalization of alkenes.[1] Recent successful report[2] on the reaction of singlet oxygen with α,β-unsaturated ketones and lactones constrained to the s-cis conformation stimulated us to investigate the sensitized photooxygenation of acyclic conjugated polyenoic acid esters such as 2,4-hexadienoates (1) and 2,4,6-octatrienoates (2). The purpose of the investigation is to shed light on the reactivity of polyenoates 1 and 2 toward singlet oxygen and to attempt the application of the reaction to organic synthesis. We report here that (i) the conjugated polyenoates 2 are far more reactive toward singlet oxygen than the dienoates 1, (ii) singlet oxygen attacks to a double bond or a conjugated system which is remote from the ester group, (iii) distribution of three reaction modes, i.e., 1,4-addition, 1,2-addition, and "ene" reaction, are remarkably affected by the solvent used and the reaction temperature.

Olefinic esters such as crotonates, senecioates, and sorbates (1-a) were substantially inert to singlet oxygen under our reaction conditions.[3] Whereas (E,E)-5-methyl-2,4-hexadienoic acid ethyl ester (1-b) was reactive; the sensitized photooxygenation of 1-b in CH_2Cl_2 and successive chromatographic purification of the photolysate on silica gel afforded a lactol[4] 3, which might be derived from an initially formed 1,4-endoperoxide 4, in a 57% yield. Thus, the introduction of a methyl group enhanced the reactivity of the dienoates 1 toward singlet oxygen.

In contrast to the dienecarboxylates 1, conjugated trienecarboxylates 2 were far more reactive. The oxygenation of ethyl (E,E,E)-2,4,6-octatrienoate (2-a) under the various conditions gave a 1,4-endoperoxide[5] 5-a in 74 - 88% yield (solvent: CCl_4, $CHCl_3$, CH_2Cl_2, acetone, methanol and acetonitrile; temperature: 5° and -78°C).

On the other hand, the oxygenation of (E,E,E)-7-methyl-2,4,6-octatrienoate 2-b or 2-c gave a mixture of a 1,4-endoperoxide 5, a hydroperoxide 6, and an aldehyde 7. The product distribution was significantly affected by the reaction conditions, as shown in the table. The "ene" reaction and the 1,4-addition occurred mainly in the oxygenation of 2-b and 2-c, and changing



the solvent from methanol, CH_2Cl_2 to CCl_4 increased the ratio of 5 (1,4-addition) to 6 ("ene" reaction) by a factor of 5 (for 2-b) - 19 (for 2-c). A solvent such as CCl_4, which is able to prolong the lifetime of singlet oxygen, has been known to be favorable to the 1,4-cycloaddition of singlet oxygen with acyclic conjugated dienes.[6] Furthermore, it is reasonable that the 1,4-cycloaddition of singlet oxygen occurred more selectively for sterically less crowded 2-a than for 2-b and 2-c, since the 1,4-addition requires a cisoid conformation of acyclic diene system. However, the significant difference noted above has little been observed so far and a reasonable explanation demands detailed investigation on the solvent effects.

The temperature dependence of the oxygenation of 2-b and 2-c in CH_2Cl_2 was also shown in the table. The 1,4-addition mode was scarcely affected by the reaction temperature. On the other hand, the ratio of 6 ("ene" reaction) to 7 (1,2-addition) was varied by a factor of 17 (for 2-b) - 50 (for 2-c) as the reaction temperature was changed from 5° to -78°C. These facts could be accounted for by a possible two-step mechanism through a peroxirane intermediate including its canonical structures.[7]

Table Sensitized Photooxygenation of Trienoate 2-b and 2-c.*

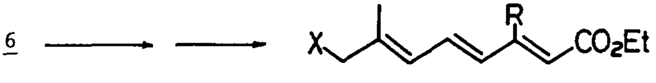
Trienoate	Solvent	Temperature (°C)	1,4-Addition mode (5)	"Ene" mode (6)	1,2-Addition mode (7)
2-b	CH_2Cl_2	5	42	51	7
	CH_2Cl_2	-78	54	14	32
	CCl_4	5	77	19	5
2-c	CH_2Cl_2	5	31	66@	3
	CH_2Cl_2	-78	31	28	41
	CH_3CN#	5	36	64	0
	MeOH#	5	18	82	0
	CCl_4	5	78	19	3

* The conversion of the substrates was more than 70%.

\# Rose Bengal was used as a sensitizer. In these solvents, the oxygenation was very slow and the isomerization of double bond of 2 was observed.

@ Conversion: 80%. Absolute yield: 49%.

The results described here showed that the olefinic esters such as dienoate 1-b and trienoates 2 were easily oxidized in the sensitized photooxygenation and the reaction modes could be controlled by the reaction conditions. The "ene" reaction of 2, followed by a reduction and an allylic rearrangement provided a method to prepare 8-hydroxy- or 8-halooctatrienoates, which are known as the key intermediates of retinoids synthesis.[8]



X=OH or Halogen

References and Notes

1. (a)"Singlet Oxygen", H. H. Wasserman and R. W. Murray, ed., Academic Press, New York, N. Y., 1979; (b) G. Ohloff, Pure Appl. Chem., 43, 481 (1975); (c) M. Matsumoto and K. Kondo, J. Syn. Org. Chem., 35, 188 (1977).
2. H. E. Ensley, R. V. C. Carr, R. S. Martin, and T. E. Pierce, J. Amer. Chem. Soc., 102, 2836 (1980).
3. Unless otherwise stated, the oxygenation was carried out as follows; a solution of the substrate (0.05 - 0.1M) was irradiated together with a catalytic amount of tetraphenylporphine with sodium vapor lamps (National SOI-60, 60W x 8) under an oxygen atmosphere at 5°C.
4. Colorless oil, bp 50°C/0.1torr. NMR(in CCl_4)δ1.27(t, J=7Hz, 3H), 1.28 1.36(two s, 6H), 4.11 (s, 1H), 4.17 (q, J=7Hz, 2H), 5.47, 6.00 (two d, J= 5.5Hz, 2H)ppm. MS(m/z) 186 (M^+, trace), 113 (100), 95 (50), 67 (42). IR(liquid film) 3500, 2990, 1740 and 1633 cm^{-1}.
5. All new compounds reported herein gave satisfactory NMR, IR and MS data. The hydroperoxides 6 were reduced to the corresponding alcohols which gave also satisfactory spectral data. The representative spectral data of the peroxides are as follows.
   5-c: NMR(in CCl_4)δ1.24(t,J=7Hz,3H),1.26(s,6H),2.11(d,J=1Hz,3H),4.06(q,J= 7Hz,2H),4.68(broad s,1H), 5.61-5.97(m,3H)ppm; IR(liquid film) 2990,1720, 1212,1153 cm^{-1}; MS(m/z) 226(M^+, trace),194(34),121(92),43(100).
   6-c: NMR(in CCl_4)δ1.24(t,J=7Hz,3H),1.72(broad s, 3H),2.20(broad s,3H), 4.08(q,J=7Hz,2H),4.72-5.06(m,3H),5.71(broad s,1H),5.94(d of d, J=16 and 7 Hz,1H),6.24(d,J=16Hz,1H),9.15(broad s,1H)ppm; IR(liquid film)3440,1713cm^{-1}; MS(m/z)226(M^+,trace),139(60),43(100).
6. M. Matsumoto and K. Kuroda, Synthetic Comm.,in press.
7. For a review, see A. A. Frimer, Chem. Rev., 79, 359 (1979).
8. For a review, see H. Mayer, W. Bollag, R. Hanni and R. Ruegg, Experientia, 34, 1105 (1978).

(Received in Japan 25 December 1981)