Photochemical Cyclisation of β-Allyloxy-Carbonyl Compounds: Synthesis of 2-Alkenyl-3-hydroxytetrahydrofurans

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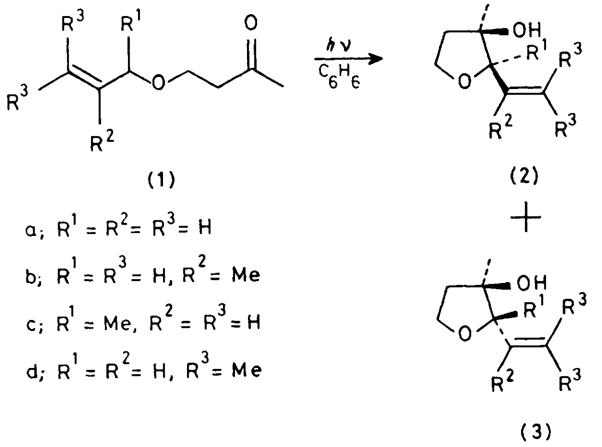
Summary The β-allyloxy-ketones (**1**) and (**6**) undergo cyclisation on u.v. irradiation to yield the 2-alkenyl-3-hydroxytetrahydrofurans (**2**), (**3**), and (**7**)—(**10**); similar cyclisation of the aldehyde (**12**) has been used in a dihydrofuran-3(2*H*)-one synthesis.

Photochemical excitation of alkyl ketones generally causes intramolecular hydrogen-atom abstraction from the γ-carbon atom by the carbonyl-group, resulting in chain cleavage and some cyclisation to cyclobutanols.[1] Introduction of an alkoxy group into the β- or δ-position of the alkyl chain activates the δ-hydrogens towards abstraction, so that excitation results in competitive abstraction involving a 7-membered ring.[2] We now report that u.v. irradiation of β-allyloxy-ketones and -aldehydes leads, by δ-hydrogen abstraction, to a useful, high-yield synthesis of the 2-alkenyl-3-hydroxytetrahydrofuran ring. Tetrahydrofurans with this substitution pattern occur in mycotoxins such as citreoviridin[3] and asteltoxin,[4] whilst syntheses of 2-substituted tetrahydrofurans allow approaches to the polyether antibiotics.[5]



(1)

(2)

(3)

a; $R^1 = R^2 = R^3 = H$

b; $R^1 = R^3 = H, R^2 = Me$

c; $R^1 = Me, R^2 = R^3 = H$

d; $R^1 = R^2 = H, R^3 = Me$

Irradiation of a solution of the ketone (**1a**)† (1 g) in benzene (15 ml) using quartz apparatus and a 450 W medium-pressure mercury arc lamp led to an efficient conversion into the hydroxytetrahydrofurans (**2a**) and (**3a**) in the ratio 1·4:1 and in high yield (94%). The reaction appeared general, in that u.v. irradiation of the ketone (**1b**) led to the tetrahydrofurans (**2b**) and (**3b**) (ratio 1·65:1, 85%), whilst the ketone (**1c**) gave (**2c**) and (**3c**) (ratio 0·6:1, 80%), and the ketone (**1d**) gave (**2d**) and (**3d**) (ratio 1·5:1, 88%). The photoproducts (**2**) and (**3**)

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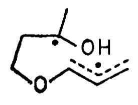
† The starting ketones were accessible from reaction of the corresponding allylic alcohol with methyl vinyl ketone, catalysed by boron trifluoride–ether; see N. A. Milas, E. Sakal, J. T. Plati, J. T. Rivers, J. K. Gladding, F. X. Grossi, Z. Weiss, M. A. Campbell, and H. F. Wright, *J. Am. Chem. Soc.*, 1948, **70**, 1597.

were easily separable by preparative g.l.c. and their structures clearly shown by their ^1H and ^{13}C n.m.r. spectra.‡



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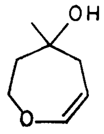
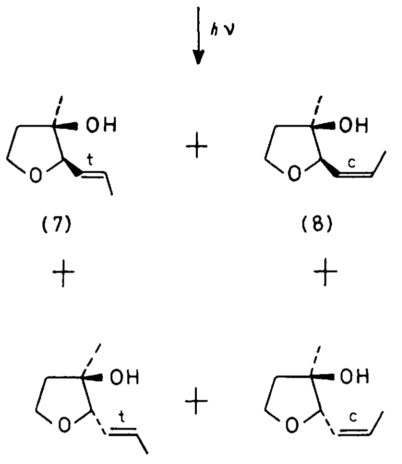


(5)

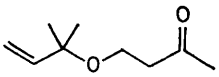
Reaction presumably occurs by hydrogen abstraction to give a biradical, such as (**4**) [derived from (**1a**)], followed by its cyclisation, the δ-hydrogen atom is activated both by being α to oxygen and by being allylic. No ring expanded products [*e.g.* (**5**)] were detected, which might be formed by rebonding the ketyl radical centre to the other end of the allylic radical, as found, for example, in the u.v. irradiation of hept-6-en-2-one.[6] Moreover, the photochemical reaction is highly selective in maintaining the geometry about the alkenyl bond upon cyclisation, as shown by experiments involving the β-butenyloxy-ketone (**6**). Irradiation of (**6**) (*trans*:*cis*, 3:1) gave a mixture which was separated into the four isomeric tetrahydrofuranols (**7**)—(**10**) (ratios 2:1·4:1·3:1). An irradiation of *cis*-(**6**) gave mainly (>94%) the isomers (**8**) and (**10**) containing the *cis*-propenyl unit. Similarly, irradiation of *trans*-(**6**) led predominantly (>93%) to the isomers (**7**) and (**9**). These results suggest restricted rotation about the allyl radical end of a biradical, such as (**4**), during its lifetime before cyclisation.[7]

$MeCH{=}CHCH_2OCH_2CH_2COMe$

(6)

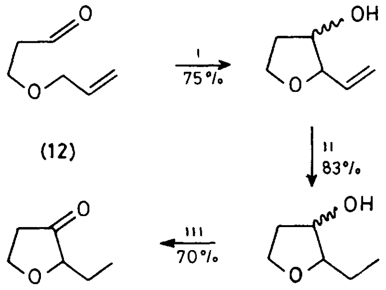


(7) (8) (9) (10)



(11)

Irradiation of the ketone (**11**) under similar conditions led to its slow disappearance, with only minor volatile products being detected. This suggests that intramolecular addition of the carbonyl group to the alkenyl bond is unlikely to be a competitive reaction in the present examples.[8]



(12)

(13)

SCHEME Reagents i, *h*ν, 0·5% in C_6H_6, ii, H_2, Rh on Al_2O_3, iii, pyridinium chlorochromate. Yields given for each reaction.

This photochemical cyclisation can also be applied to aldehydes and hence provides a useful synthetic route to the dihydrofuran-3(2*H*)-ones, some of which are of interest as flavouring components.[9] Thus, the Scheme shows that u.v. irradiation of the aldehyde (**12**), followed by hydrogenation and oxidation, can lead to (**13**) in an acceptable yield.[10]

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‡ Further evidence for the relative stereochemistry of (**2b**) and (**3b**) was obtained by conversion of each into the isomeric acetates and the examination of their ^1H n.m.r. spectra: isomer (**3b**) on acetylation showed a significant downfield shift (0·2 p.p.m.) for the 2-H signal.

[1] J. A. Barltrop and J. D. Coyle, 'Excited States in Organic Chemistry,' Wiley, London, 1975.

[2] J. D. Coyle, R. V. Peterson, and J. Heicklen, *J. Am. Chem. Soc.*, 1964, **86**, 3850, P. Yates and J. M. Pal, *Chem. Commun.*, 1970, 553, L. M. Stephenson and J. L. Parlett, *J. Org. Chem.*, 1971, **36**, 1093, P. J. Wagner, P. A. Kelso, A. E. Kemppainen, and R. G. Zepp, *J. Am. Chem. Soc.*, 1972, **94**, 7500.

[3] N. Sakabe, T. Goto, and Y. Hirata, *Tetrahedron Lett.*, 1964, 1825.

[4] G. J. Kruger, P. S. Steyn, R. Vleggaar, and C. J. Rabie, *J. Chem. Soc., Chem. Commun.*, 1979, 441.

[5] For recent examples, see T. F. Tam and B. Fraser-Reid, *Can. J. Chem.*, 1979, **57**, 2818, R. E. Ireland and D. Habich, *Tetrahedron Lett.*, 1980, 1389.

[6] N. C. Yang, A. Morduchowitz, and D. D. H. Yang, *J. Am. Chem. Soc.*, 1963, **85**, 1017.

[7] The rotational barrier in allyl radicals is significant: P. J. Krusic, P. Meakin, and B. E. Smart, *J. Am. Chem. Soc.*, 1974, **96**, 6211.

[8] *Cf.* H. Morrison, *Acc. Chem. Res.*, 1979, **12**, 383.

[9] H. G. Maier, *Angew. Chem., Int. Ed. Engl.*, 1970, **9**, 917.

[10] A previous six-step route to (**13**) involved the cyclisation of an allenic alcohol: S. Hoff, L. Brandsma, and J. F. Arens, *Recl. Trav. Chim. Pays-Bas*, 1969, **88**, 609.