Tetrahedron Letters,Vol.28,No.47,pp 5933-5936,1987
Printed in Great Britain

0040-4039/87 $3.00 + .00
Pergamon Journals Ltd.

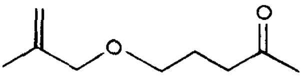
THE PATERNÒ-BÜCHI REACTION AS A ROUTE TO MEDIUM-RING ETHERS AND ACETALS

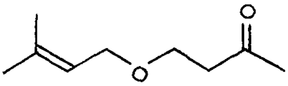
Howard A.J. Carless*, John Beanland and Samson Mwesigye-Kibende
Department of Chemistry, Birkbeck College, Malet Street, London WC1E 7HX

Summary: Photochemical reactions of the vinyloxyketones (3) give a regioselective intramolecular cycloaddition to afford oxetanes (4); the latter react stereospecifically with methanol to yield medium-ring acetals (5).

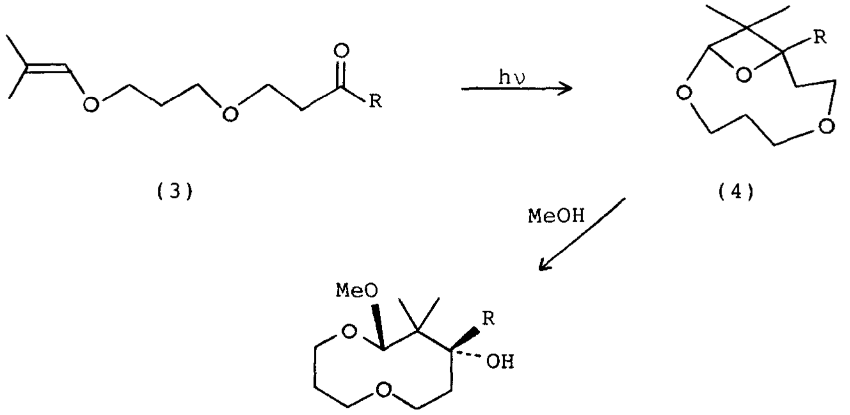
There has been considerable recent interest in the use of the [2+2] cycloaddition of carbonyl compounds to alkenes (Paternò-Büchi reaction) as a synthetic method.[1,2] The work of Schreiber,[3] and of others,[4] has shown the efficiency and versatility of the photocycloaddition involving vinyl ethers or furans as alkenes. We now describe examples in which intramolecular photocycloaddition of simple acyclic molecules has led to the synthesis of medium-ring bicyclic ethers. Moreover, the high reactivity of the oxetane-containing acetal products enables a facile reaction with nucleophiles to give monocyclic dioxacycloalkanols.

Although intramolecular examples of the Paternò-Büchi reaction are known, they generally involve attack on double bonds situated γδ or δε to the carbonyl group. In the case of carbonyl/alkene reactants which are further removed, as in (1)[5] and (2),[6] intramolecular hydrogen abstraction from the γ or δ position becomes the dominant photochemical process. However, the photocycloaddition of carbonyl compounds with vinyl ethers is a much more efficient process than that with alkenes, and we report the first applications of such an approach to the formation of eight- to eleven-membered rings.


(1)


(2)

U.v. irradiation of the ketone (3a)[7] in benzene solution led to a single major photoproduct, present in 85% yield by examination of the ^{1}H and ^{13}C n.m.r. spectra of the crude material. This sensitive compound could be purified by distillation (56% isolated yield) or by column chromatography on silica gel (40-45%), and was assigned the structure of the bicyclic oxetane acetal (4a).[8] Alternatively, the oxetane (4a) reacted with methanol in the presence of traces of acid (CF_3CO_2H) to generate a single stereoisomer (5a) of the cyclic acetal in quantitative yield. The crude photoproduct also contained minor components of which the tetrahydrofuranols (6) arising by δ-hydrogen abstraction[6] were isolated (6%).

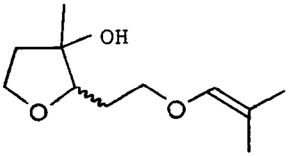


(3)

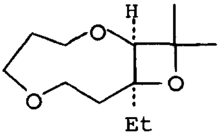
(4)

(5) a; R = Me
b; R = Et

A similar irradiation of the ethyl ketone (3b) gave a crude product whose ^{1}H and ^{13}C n.m.r. spectra suggested it to be *ca.* 90% of a single compound, *viz.* the oxetane (4b), which was subsequently isolated in 29% yield by column chromatography. The 2-alkoxyoxetane (4b) reacted cleanly with methanol to yield the medium-ring acetal (5b). A stable minor adduct isolated in 4% yield by chromatography of the crude irradiation product from (3b) was the alternative 3-alkoxyoxetane cycloaddition isomer (7).

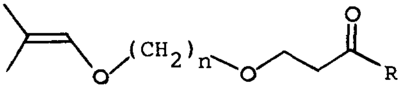


(6)

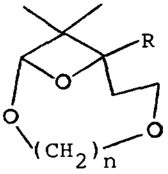


(7)

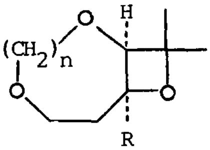
Photochemical reaction of the shorter-chain ketones (8) and (9) gave a high yield (*ca*. 80%) of intramolecular adducts, but with little regioselectivity: the 2-alkoxyoxetane (10) and 3-alkoxyoxetane (11) products were formed in ratios of 1:1 and 1:1.2, respectively. The oxetanes (10) could be trapped, either before or after separation from (11), by reaction with nucleophiles such as methanol in the presence of traces of acid, to give single stereoisomers of (12). A particularly convenient set of conditions for carrying out this transformation (which allowed n.m.r. monitoring) was to dissolve the material containing (10) in deuteriochloroform, adding two equivalents of methanol, and leaving the solution exposed to daylight for 2-3 days, thereby generating sufficient DCl to cause quantitative conversion to (12).



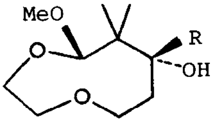
(8) n = 2, R = Me
(9) n = 2, R = Et
(13) n = 4, R = Me



(10) n = 2, R = Me or Et
(14) n = 4, R = Me



(11) n = 2, R = Me or Et
(15) n = 4, R = Me



(12) R = Me or Et

δ-Hydrogen abstraction was more prevalent in the photochemistry of the longer-chain ketone (13), which gave an easily separable mixture of the corresponding tetrahydrofuranols (55%) and the intramolecular cycloadducts (45%). Column chromatography allowed the isolation of the eleven-membered ring oxetane (14) and its isomer (15), formed in the ratio 1:0.9.

References and Notes:

1. G. Jones, II, *Org. Photochem.*, 1981, *5*, 1.
2. H.A.J. Carless, in "Synthetic Organic Photochemistry", ed. W.M. Horspool, Plenum Press, New York, 1984, p.425.
3. S.L. Schreiber, *Science*, 1985, *227*, 857; S.L. Schreiber and K. Satake, *J. Am. Chem. Soc.*, 1984, *106*, 4186; S.L. Schreiber and A.H. Hoveyda, *ibid.*, 1984, *106*, 7200.
4. T. Kozluk and A. Zamojski, *Tetrahedron*, 1983, *39*, 805; H.A.J. Carless and G.K. Fekarurhobo, *J. Chem. Soc., Chem. Commun.*, 1984, 667; A. Nehrings, H.-D. Scharf and J. Runsink, *Angew. Chem., Int. Ed. Engl.*, 1985, *24*, 877: J. Mattay, J. Gersdorf and K. Buchkremer, *Chem. Ber.*, 1987, *120*, 307.
5. H.A.J. Carless and G.K. Fekarurhobo, *Tetrahedron Lett.*, 1984, *25*, 5943.
6. H.A.J. Carless and D.J. Haywood, *J. Chem. Soc., Chem. Commun.*, 1980, 657.
7. Compounds (3a) and (3b) were prepared from propane-1,3-diol, *via* the monomethallyl ether [Na, $CH_2=C(Me)CH_2Cl$], BF_3-catalysed addition to methyl vinyl ketone or ethyl vinyl ketone, respectively, and rhodium(I)-catalysed isomerisation to the 2-methylpropenyl ether (E.J. Corey and J.W. Suggs, *J. Org. Chem.*, 1973, *38*, 3224). Irradiations were carried out as 0.5-1.0% solutions in benzene under nitrogen, using quartz apparatus and a 450 W medium-pressure mercury arc lamp.
8. N.m.r. data: 9,11,11-trimethyl-2,6,10-trioxabicyclo[7.1.1]undecane (4a) ^1H (200 MHz, C_6D_6) δ 4.78 (1 H, s, 1-H), 3.88 (1 H,ddd, $\underline{J}$ 2.5, 6 and 11 Hz, 7-H), 3.8-3.5 (5 H, m, 3-H, 5-H and 7-H), 2.41 (1 H, ddd, $\underline{J}$ 2.5, 9 and 15 Hz, 8-H), 1.68 (2 H, m, 4-H), 1.10 (1 H, ddd, $\underline{J}$ 1.7, 6 and 15 Hz, 8-H), 1.07, 1.06 and 1.03 (each 3 H, s, Me); $\delta_C(C_6D_6)$ 107.4 (C-1) 86.6 (C-9),67.4 and 67.1 (C-3 and C-5), 64.1 (C-7), 44.4 (C-11), 36.9 (C-8), 31.2 (C-4), 25.1, 23.3 and 17.1 (3 x Me) p.p.m.; (5a) ^1H (200 MHz, C_6D_6) δ 4.38 (1 H, s, $C\underline{H}OMe$), 4.11 (1 H, bs, OH), 3.92 [1 H, dt, $\underline{J}$ 2, 11.5 and 11.5 Hz, $C\underline{H}_2CH_2C(Me)OH$], 3.70 (1 H, ddd, $\underline{J}$ 2.5, 6 and 10 Hz, CH_2O), 3.44 (1 H, ddd, $\underline{J}$ 4.5, 9.5 and 14 Hz, CH_2O), 3.35 (2 H, m, CH_2O), 3.26 [1 H, ddd, $\underline{J}$ 3, 4.5 and 11.5 Hz, $C\underline{H}_2CH_2C(Me)OH$], 3.24 (3 H, s, OMe), 2.83 [1 H, ddd, $\underline{J}$ 3, 11.5 and 15 Hz, $C\underline{H}_2C(Me)OH$], 1.6-1.25 (2 H, m $OCH_2C\underline{H}_2CH_2O$), 1.18, 1.15 and 1.05 (each 3 H, s, Me), and 0.94 [1 H, ddd, $\underline{J}$ 2, 4.5 and 15 Hz, $C\underline{H}_2C(Me)OH$]; $\delta_C(C_6D_6)$ 112.3 ($\underline{C}$-OMe), 76.3 (C-OH), 68.1 and 67.6 (2 x CH_2O), 63.7 [$\underline{C}H_2CH_2C(Me)OH$], 58.0 (OMe), 47.2 ($\underline{C}Me_2$), 34.7 [$\underline{C}H_2C(Me)OH$], 27.8 ($CH_2\underline{C}H_2CH_2$), 27.9, 22.0 and 16.9 (3 x Me) p.p.m.

Acknowledgement: We thank the S.E.R.C. for support of this work.

(Received in UK 15 September 1987)