

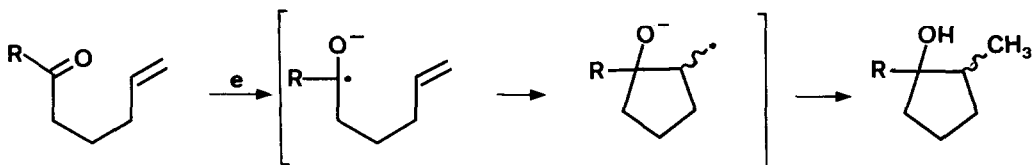
PHOTOREDUCTIVE CYCLIZATION OF δ,ϵ -UNSATURATED KETONES

D. BELOTTI, J. COSSY*, J.P. PETE and C. PORTELLA *

Laboratoire des Réarrangements thermiques et photochimiques, UA CNRS 459,
UER Sciences. 51062 REIMS Cédex, FRANCE

Abstract. δ,ϵ -unsaturated ketones are efficiently photoreduced in HMPA or tertiary amines. Cyclization to cyclopentanols is the only observed reaction.

The photoreduction of phenyl ketones in the presence of tertiary amines is a well known reaction, involving an electron transfer in the first step (1). Similarly, ketones and even esters are photoreduced in Hexamethylphosphotriamide (HMPA). The metal reduction (3) or electrochemical reduction (4) of carbonyl compounds involves the same radical anion intermediate, which cyclizes in the 5-exo-mode to cyclopentanol derivatives, when the molecule contains a δ,ϵ -unsaturation (scheme I).



Scheme I

To our knowledge, such cyclization reactions have not yet been described from radical anions produced photochemically. We report here that substituted cyclopentanols are efficiently obtained when the reduction step consists of a photochemically induced electron transfer from HMPA or triethylamine.

UV irradiation (254 nm) of an acetonitrile solution of 2-(1-buten-4 yl)-cyclopentanone 1 containing triethylamine as electron donor gave the cyclized product 5 in 50% yield (5). This yield increased to 81% when compound 1 was irradiated in HMPA. Hence this medium was used to study the behavior of several other unsaturated ketones. Reactions reported in scheme II were conducted according to the following procedure :

Typical procedure

A solution of ketone 1 (3.5×10^{-3} mole) in HMPA (65 cm^3 ; $5 \times 10^{-2} \text{ M}$) was degassed by Argon bubbling and irradiated in 3 quartz tubes (i.d. = 1 cm) by 12 low pressure mercury lamps (Philips TUV 15). Irradiation was stopped after 120 minutes when TLC analysis of an aliquot indicated complete disappearance of the starting material. Ether (100 cm^3) and 2M HCl (200 cm^3) were successively added to the ice cold HMPA solution. Aqueous layer was extracted twice more time with 100 cm^3 ether. Organic layer was washed, dried over magnesium sulfate and ether was distilled. Flash chromatography of the crude product yielded pure bicyclic alcohol 5 (81%), the structure was checked by M.S. Infrared and NMR spectrometry.

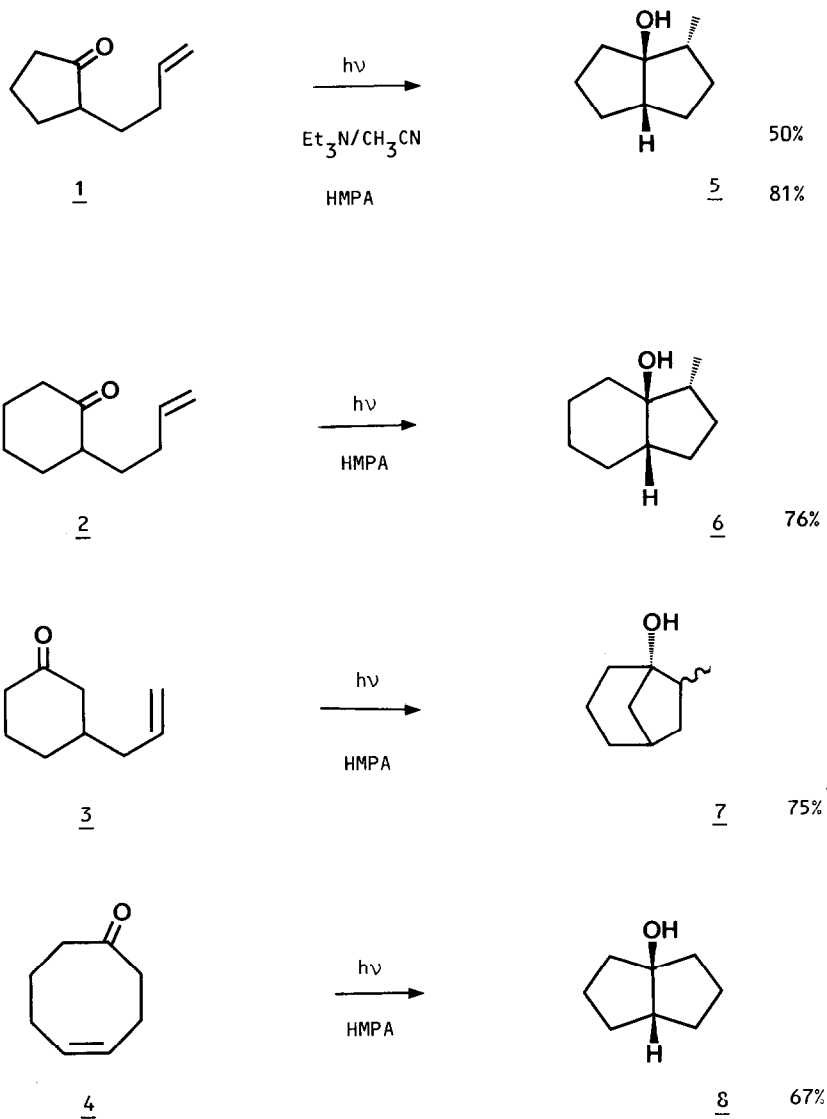
As shown in scheme II, the photoreductive cyclization of cyclic ketones 1-4 in HMPA produced the corresponding cyclopentanols in high yield. In the case of δ, ϵ -alkenyl ketones 1 and 2, the cyclization is highly stereoselective: alcohols 5 and 6 respectively are the only isolable products, as previously reported in the electroreductive cyclization of similar unsaturated ketones (4a). This stereoselectivity is well explained by a repulsive electrostatic interaction in the transition state (4a, 5). In contrast to 2-alkenyl ketones, the photocyclization of 3-allyl cyclohexanone 3 is not significantly stereoselective, probably because, for this compound, the electrostatic factors are balanced by steric interactions in a more strained transition state.

This photochemical synthesis of polycyclic cyclopentanols can be compared favourably with the previous chemical or electrochemical methods. The similar yields and stereochemistry indicate that the selectivity depends more on the intermediate and transition state than on the method which is used to produce them.

The photochemical production of the intermediate radical anion presents several features which make this method an advantageous complement to others: (i) the reaction can be conducted under very mild conditions and in neutral medium; (ii) the electron transfer process is controlled by the production of excited states whereas reducing agents are often used in excess in other methods; (iii) the final product is formed by abstraction of a hydrogen atom from the solvent by the cyclized radical.

Generalization of this approach to various unsaturated ketones and detailed discussion of the results will be reported in a forthcoming paper.

Scheme II a/b/



a/ Yields refer to pure isolated products, for total conversion of starting material

b/ All products have been fully characterized from their NMR, IR and mass spectra (detailed description will be reported in a full paper)

c/ Two isomers were isolated in 45 and 30% yield. Their stereochemistry is not yet established.

References

1. a) S.G. Cohen, *Chem. Rev.*, 73, 141 (1973)
b) R.W. Yip, R.O. Loutfy, Y.L. Chow and L.K. Magdzinski, *Can. J. Chem.*, 50, 3426 (1972)
c) A.H. Parola, A.W. Rose and S.G. Cohen, *J. Am. Chem. Soc.*, 97, 6202 (1975)
d) J.D. Simon and K.S. Peters, *J. Am. Chem. Soc.*, 104, 6542 (1982).
2. C. Portella, H. Deshayes, J.P. Pete and D. Scholler, *Tetrahedron*, 40, 3635 (1984).
3. a) M. Eakin, J. Martin and W. Parker, *J.C.S. Chem. Commun.*, 206 (1965)
b) G. Stork, R.K. Boeckmann Jr., D.F. Taber, W.C. Still and J. Singh, *J. Am. Chem. Soc.*, 101, 7107 (1979)
c) M. Bertrand, P. Teisseire and G. Pelerin, *Tetrahedron Lett.*, 21, 2051 and 2055 (1980)
d) S.K. Pradhan, S.R. Kadam, J.N. Kolhe, T.V. Radhakrishnan, S.V. Sohani and V.B. Thaker, *J. Org. Chem.*, 46, 2622 (1981)
e) E.J. Corey and S.G. Pyne, *Tetrahedron Lett.*, 24, 2821 (1983).
4. a) T. Shono, I. Nishiguchi, H. Ohmizu and M. Mitani, *J. Am. Chem. Soc.*, 100, 545 (1978)
b) G. Pattenden and G.M. Robertson, *Tetrahedron Lett.*, 24, 4617 (1983).
5. A solution of ketone 1 (0.72×10^{-3} mole) and Et_3N (5 equiv.) in acetonitrile (20 cm^3) was irradiated until complete disappearance of starting ketone on TLC. Acetonitrile and Et_3N were distilled and the crude purified by preparative TLC.
6. A.L.J. Beckwith, *Tetrahedron*, 37, 3073 (1981).

(Received in France 17 July 1985)