Tetrahedron Letters No. 38, pp 3309 - 3312, 1977. Pergamon Press. Printed in Great Britain.

THE PHOTOLYSIS OF SOME POLYCYCLIC CYCLOBUTANONE TOSYLHYDRAZONE SALTS IN METHANOL: THE GENERATION AND DECOMPOSITION OF EPIMERIC CYCLOBUTYL DIAZONIUM IONS

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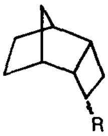
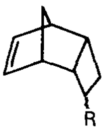
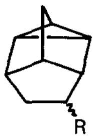
(Received in USA 26 May 1977; received in UK for publication 28 July 1977)

Over the years there has been considerable interest in the nature of the intermediate produced via solvolysis of cyclobutyl systems. Current feeling is that this process is best described by a concerted, symmetry allowed disrotatory ring opening proceeding from the side opposite to the leaving group to generate a cyclopropylcarbinyl species.[1] This suggestion has received additional support recently by a study of the solvolysis of a series of strained, fused-ring cyclobutyl derivatives (e.g., 1b, c and 2b, c) which showed both large rate differences as well as unique product distributions as a function of the configuration of the starting material.[2]







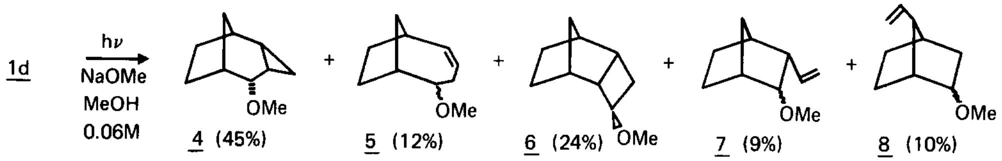
1a R- = O
b -endo-Tos
c -exo-Tos
d - = NNHTos
e -endo-NH_2
f -endo-$NNOCO_2Et$

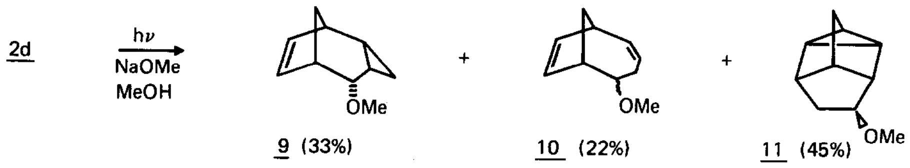
2a R- = O
b -endo-Tos
c -exo-Tos
d - = NNHTos

3a R- = O
b -exo-OH
c -exo-OAc

Since photolysis of ketone tosylhydrazone salts in protic media provides a convenient in situ source of diazonium ions,[3] the irradiation of the tosylhydrazone derivatives 1d and 2d in NaOMe-MeOH was carried out in an attempt to generate the corresponding epimeric cyclobutyl diazonium ions to examine both the stereoselectivity of their decomposition as well as the tendency toward equilibration in basic media.

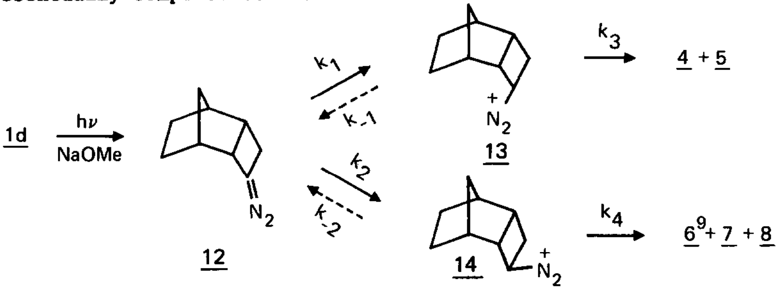
Irradiation of 1d in NaOMe-MeOH (7 hr, 25°, 450 Hg watt lamp, Pyrafilter, produced a rather complex mixture of seven products.[5] Products 4 and 5, resulting from the opening of the strained 2-5 bond in the starting material, are produced in ca. the same relative ratio as in the solvolysis of the tosylate 1b in anhydrous methanol, possibly suggesting a common intermediate. However, the generation of olefins 7 and 8 requires the cleavage of the peripheral 4-5 bond, a process not previously detected in the solvolysis of 1b. In this respect it should be noted that the formation of products resulting from 4-5 bond cleavage are, in fact, the major ones associated with the solvolysis of the corresponding epimeric tosylate 1c which produces <7% of material from rearrangement of the more strained 2-5 bond.[2] Furthermore, the stereospecific formation of the unrearranged cyclobutyl ether 6 was unique to the photolysis, since no products of this type were ever observed in the solvolysis of either 1b or 1c.





When the unsaturated derivative 2d was photolyzed under the same conditions, the product distribution was as shown above. Again, the ratio of 9/10 was the same as previously observed in the solvolysis of the endo tosylate 2b in buffered methanol. The structure of the unusual tetracyclic product 11 was verified by synthesis from the corresponding exo-alcohol 3b produced by the Meerwein-Pondorf-Verley reduction of the known ketone 3a.[6] This material presumably arises by initial cleavage of the 4-5-bond and intramolecular cyclization involving the two double bonds. A similar product 3c was isolated (85%) from the solvolysis of the exo-tosylate 2c in buffered acetic acid, (120°).

A tentative mechanism which rationalizes the apparent lack of bond selectivity in the photolysis reactions relative to the corresponding solvolyses is shown below for 1d.[7] Subsequent results which are reported in Table I provide some additional support for this mechanism and bear on the question of the possible equilibration of 13 and 14 via 12. It should be noted that the product composition from the photolysis of 1d is essentially unchanged over a wide range of base concentrations.[8] This suggests that the cyclobutyl ether 6 is probably not arising via the traditional S_{N-2} displacement on the incipient diazonium ion. This seems reasonable since the displacement center is both secondary and cyclobutyl and hence resistant to direct nucleophilic displacement.[9] Furthermore, this product invariance implys that if the equilibration of 13 and 14 is significant under the reaction conditions (i.e., k-1 and k-2 > k_3 and k_4), it must be essentially complete even at low concentrations of sodium methoxide.



In an effort to generate the diazonium ion 13 stereospecifically under conditions which are assuredly nonequilibrating, the corresponding endo amine 1a[10] was prepared and diazotized using sodium nitrate-aqueous perchloric acid.[11] The alcohols thus produced were quantitatively methylated[12] to facilitate the subsequent analysis. Under these conditions, the ethers 4 and

5 were the only isolable materials from solvent capture, and no products resulting from either the cleavage of the 4-5-bond (i.e., 7 or 8) or from direct displacement without rearrangement could be detected. Thus, even the highly reactive diazonium ion 13 generated in situ undergoes a highly selective cleavage of the more strained 2-5-bond which in this case is able to open in the preferred disrotatory fashion to yield the observed products.

To test the configurational stability of 13 under potentially equilibrating conditions, the nitrosourethane derivative 1f[13] was prepared and decomposed in base. In the weakly basic media, $NaHCO_3$-MeOH, the products of 2-5-bond cleavage (4 and 5) again predominated, and the yields of 6, 7 and 8 were reduced to a very low level (Table I). The results were essentially the same when 1d decomposed in 1M NaOMe-MeOH at 0°. The slightly increased amounts of 6, 7 and 8 produced under these conditions were still far less than those observed for the photolysis of 1d under comparable conditions. In order to answer the question of whether 13 and 14 were equilibrating and to further assure that significant quantities of 4 and 5 were not arising directly from 14 via this route, 1f was decomposed in 1M NaOMe-MeOD. The ethers 4 and 5 were produced in this manner were isolated and found to be <15%d_1. This low deuterium incorporation assures that 4 and 5 are produced predominately from 13 prior to any significant equilibration.[15] On the other hand, the isolation of 6 from this reaction mixture and mass spectral analysis showed that it was 85% d_1, further assuring that 13 generated directly from 1f is not the primary source via simple direct displacement.

Conditions		Products (%)				
		4	5	6	7	8
1d	NaOMe - 1M	48[b]	13	[75][a] 24	7	8
1e	$NaNO_2$-$HClO_4$[c]	86	14	[50] –	–	–
1f	$NaHCO_3$-MeOH	78	13	[87] 5	2	2
	NaOMe -1M	72	14	[85] 8	3	3

a. Total Yield; b. Relative Yield; c. Converted to Methyl Ethers for Analysis

On the basis of this evidence, it seems reasonable that the photochemical decomposition of 1d or 2d in NaOMe-MeOH leads to isomeric cyclobutyl diazonium ions via protonation of the initially formed diazo compounds. These ions appear to decompose rapidly without significant equilibration each to unique product mixtures with relatively little crossover. This distinct regioselectivity for rearrangement as a function of the stereochemistry of the diazonium ion is reminiscent of that observed in the solvolysis of 1b, c and 2b, c.[2]

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4. a. Prepared from the ketone 1a using a p-toluenesulfonyl hydrazide in absolute ethanol; b. R. D. Miller, D. L. Dolce and U. Y. Merritt, J. Org. Chem., 41, 1221 (1976).
5. Spectral data in accord with the proposed structures have been obtained. We thank Prof. Kirmse for providing the spectral data of 4 for comparison.
6. P. K. Freeman, D. M. Balis and D. J. Brown, J. Org. Chem., 33, 2211 (1968).
7. a. The protonation of polycyclic diazo compounds produced by photolysis of tosylhydrazone salts to give isomeric diazonium ions has been suggested previously; b. W. Kirmse, Angew Chemie Int. Ed., 15, 251 (1976) and references cited therein.
8. The base concentrations were varied from using the performed sodium salt of the tosylhydrazone in dry methanol to 1M NaOMe in the same solvent.
9. The source of the exo methyl ether 6 is somewhat uncertain. It could conceivably arise directly from a tight yet sterically unencumbered ion pair resulting from the protonation of 12 from the exo side by methanol. This concept of a tight ion pair as the source of 6 would explain why the relative yield is uninfluenced by the bulk properties of the media. Alternatively 6 could arise via a carbene produced directly from the diazo compound 12. While it seems unlikely that this decomposition would be competitive with protonation of a secondary dialkyl diazo compound,[7b] it cannot be conclusively ruled out at this time.
10. The amine was prepared by catalytic hydrogenation of the corresponding oxime of the ketone 1a over PtO_2 in ethanol (4 atm).
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13. W. W. Hartman and M. R. Brethen, Org. Syn. Coll. Vol. II, 278, (1943). The nitrosation was performed using N_2O_4 in ether.[14]
14. R. A. Moss, J. Org. Chem., 31, 1082 (1966).
15. Even this low deuterium incorporation does not necessarily have to arise via isomerization of 10 to 14 under the reaction conditions, since small amounts of 12 could be produced directly from the nitrosourethane 1f in a competing reaction.[14] The appearance of a transient very pale organic color during the reaction may be indicative of this competition.