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SOLVOLYSIS OF t-BUTYL SUBSTITUTED CYCLOBUTYL TOSYLATES[1]

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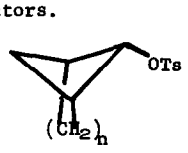
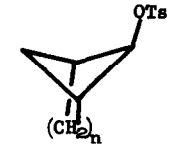
Rigidly held cyclobutyl tosylates show a remarkable dependence of solvolysis rates on the conformation of the leaving group.[3] Thus, in both the bicyclo[2.1.1]pentyl and bicyclo[3.1.1]-hexyl series, the equatorial isomers (1) are strongly accelerated and the axial isomers (3) strongly decelerated, relative to the behavior of the parent compound (2).[3] The deceleration observed for 3 is attributed to the unfavorable geometry which precludes the most favorable concerted ring contraction process to a cyclopropyl carbinyl cation, a process facilitated in 1. The acceleration of 1 over 2 can be attributed to a combination of steric (relief of ring strain) and electronic (rearrangement to a secondary, rather than to a primary, cyclopropylcarbinyl cation) factors.



n = 2,3

1

2

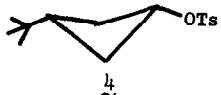


n = 2,3

3

	1	2	3
k_{rel} HOAc, 25°	1,000	1	0.0003

The use of t-butyl groups as conformational anchors on the cyclobutane ring leads to quite different results, initially surprising, but explicable on the basis of mechanistic features of the solvolysis of cyclobutane compounds.[3-6] The rates of solvolysis (Table 1) of the 3-t-butyl substituted cyclobutyl tosylates 4 and 5[7] clearly do not parallel those of the bridged compounds



4

2

5a

5b

	4	2	5a ⇌ 5b
k_{rel}, 60% acetone, 50°	0.008	1	0.14

1 and 3. The t-butyl group fails to act as an effective conformation lock,[11] and ionization of the trans tosylate 5 probably occurs via the conformer with an axial t-butyl group 5b. The transition state for 5 suffers, relative to that of the parent compound 2, from unfavorable interactions involving the t-butyl group; hence, the small rate decrease observed for 4. Similarly, the large rate deceleration of the cis tosylate 4 is a consequence of ionization with participation which produces increased steric t-butyl-methylene interactions in the transition state which resembles the cis-2-t-butylcyclopropylcarbinyl cation.

TABLE 1 Conductometric Solvolysis Rates in 60% Aqueous Acetone

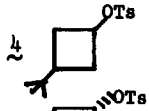
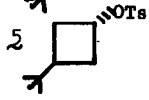
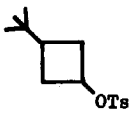
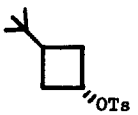
	T	k (sec^{-1})	$\Delta H^{\ddagger}$	$\Delta S^{\ddagger}$	k_{rel} (50°)
2 	25.2	4.61×10^{-5}			
	50.1	8.55×10^{-4}	21.9	-4.9	1.00
4 	50.1	7.03×10^{-6}			
	76.1	1.08×10^{-4}	22.7	-12.1	0.008
5 	50.1	1.23×10^{-4}			
	76.2	1.32×10^{-3}	19.8	-15.3	0.14

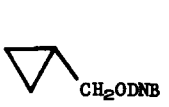
TABLE 2 Product Distributions from Solvolyses in 60% Aqueous Acetone at 100°.[a]

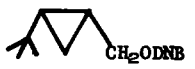
	2-OH	10-OH	11-OH	7-OH	12-OH	4-OH	6-OH	
4 	2	60	13	--	3	9 (no trans)	13	b,c
6 	2	57	15	--	3	2 (no trans)	21	b,c
5 	1	16	6	76	--	--	--	b,d
7 	1	5	25	68	--	--	--	b,c

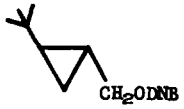
[a] The numbers in the table refer to the distribution of the alcohols shown; the solvolysis product usually included about 10-20% of unidentified material (mostly nonalcoholic hydrocarbons). [b] No internal return was found. [c] Buffered with 2,6-lutidine. [d] Buffered with $CaCO_3$.

Table 2 presents the product distributions resulting from solvolysis of cis- and trans-3-t-butylcyclobutyl tosylates (4 and 5) and of the related cis- and trans-2-t-butylcyclopropylcarbinyl dinitrobenzoates (6 and 7).[12] Despite the use of different leaving groups the cis (4 and 6) and trans (5 and 7) pairs of derivatives each yield nearly identical product mixtures. This provides strong evidence for common intermediates in the solvolysis of cyclobutyl and cyclopropylcarbinyl derivatives of the same stereochemistry. The absence of crossover between the cis and trans series demonstrates that the initial ionization and any subsequent rearrangements between the various possible cationic species are all stereospecific.[5,16]

The similarity in rates of the cyclopropylcarbinyl derivatives 6 and 7, with the expected[17] enhancement over the parent 8, indicates that these compounds ionize with very little molecular rearrangement. Taken together with the cyclobutyl results these data suggest that ionization of

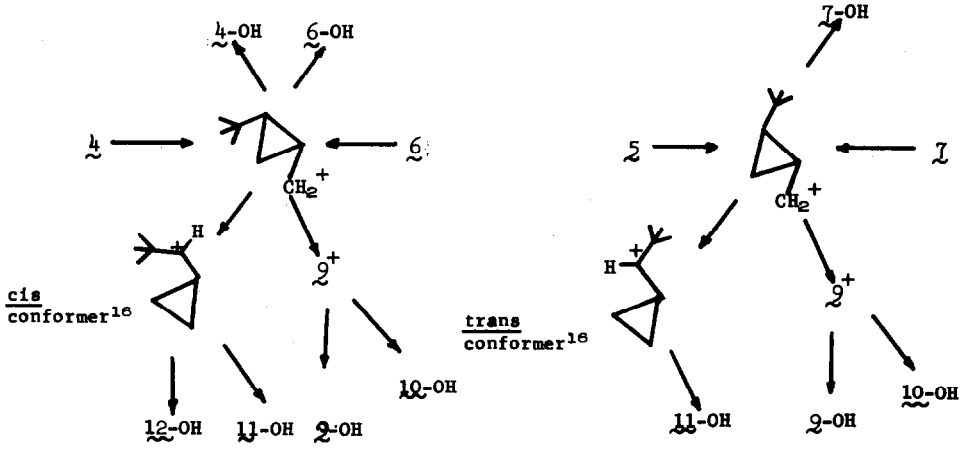






	8[15]	6	7[15]
k (100°, 60% acetone)	4.3×10^{-7}	1.62×10^{-5}	9.7×10^{-6}
k_{rel}	1	38	23

both the cyclobutyl and cyclopropylcarbinyl derivatives proceeds directly and stereospecifically to a cyclopropylcarbinyl cation or ion pair. On this basis it is possible to describe the formation of the various products according to the following scheme:



References

1. Supported by grants from the National Science Foundation and the Petroleum Research Fund, administered by the American Chemical Society.
2. (a) NATO Postdoctoral Fellow, 1967-1968. (b) NIH Postdoctoral Fellow, 1968-1970.
3. K. B. Wiberg and B. A. Hess, Jr., J. Am. Chem. Soc., 89, 3015 (1967); K. B. Wiberg and R. Fenoglio, Tetrahedron Letters, 1273 (1963).
4. J. D. Roberts and V. C. Chambers, JACS, 73, 5034 (1951) and other papers in the same series.
5. I. Lillien, G. F. Reynolds and L. Handloser, Tetrahedron Letters, 3475 (1968); K. B. Wiberg and G. L. Nelson, private communication; Y. E. Rhodes, private communication.
6. I. Lillien and L. Handloser, Tetrahedron Letters, 1035 (1969).
7. Reduction of 3-t-butylcyclobutanone[8] with lithium aluminum hydride afforded the cis-alcohol 4-OH. Displacement of the tosylate 4 with tetraethylammonium acetate[9] in acetone gave the acetate of the trans-alcohol 5-OH, and the free alcohol resulted from treatment of the acetate with lithium aluminum hydride. The nmr features of the alcohols correspond with literature stereochemical assignments of related compounds.[10]
8. J. Salaun and J. Conia, Bull. Soc., Chim. Fr., 3730 (1968).
9. A. C. Cope, D. L. Nealy, P. Scheiner, and G. Wood, J. Am. Chem. Soc., 87, 3130 (1965).
10. I. Lillien and R. A. Doughty, ibid., 89, 155 (1967).
11. Conformational alkyl ΔG values in the cyclobutyl system are considerably less than in the cyclohexyl system: G. M. Lampman, K. E. Apt, E. J. Martin and L. E. Wangen, J. Org. Chem., 32, 3950 (1967); N. L. Allinger, J. A. Hirsch, M. A. Miller, I. J. Tyminski and F. A. Van-Catledge, J. Am. Chem. Soc., 90, 1199 (1968).
12. Cis-2-t-butylcyclopropylcarbinol (6-OH) was formed by Simmons-Smith reaction[13] of cis-4,4-dimethylpent-2-ene ,[14] and the trans isomer[15] was prepared by the reaction of ethyl diazoacetate with 3,3-dimethylbutene followed by reduction of the ester with lithium aluminum hydride.
13. W. G. Dauben and G. H. Berezin, ibid., 85, 468 (1963).
14. L. F. Hatch, H. D. Weiss and T. P. Li, J. Org. Chem., 26, 61 (1961).
15. G. W. Van Dine, Ph. D. Thesis, Princeton University.
16. K. B. Wiberg and G. Szeimies, J. Am. Chem. Soc., 90, 4195 (1968); K. Wiberg, private communication; Z. Majerski, to be published.
17. P. v. R. Schleyer and G. W. Van Dine, ibid., 88, 2321 (1966).