Tetrahedron Letters No. 14, pp. 1189-1192, 1970. Pergamon Press. Printed in Great Britain.

STEREOCHEMISTRY OF NUCLEOPHILIC ATTACK IN THE SOLVOLYSES OF *cis*- AND *trans*-2-METHYLCYCLOBUTYLCARBINYL DERIVATIVES

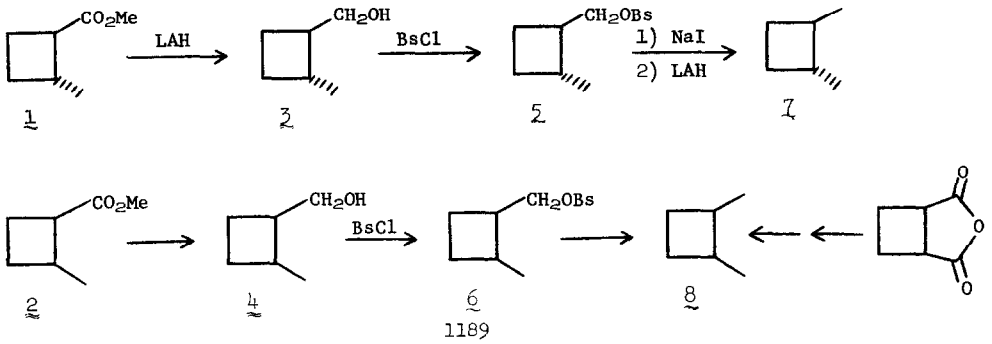
Joseph J. Gajewski, Ronald L. Lyle, and Robert P. Gajewski

Department of Chemistry, Indiana University
Bloomington, Indiana 47401
Contribution No. 1756

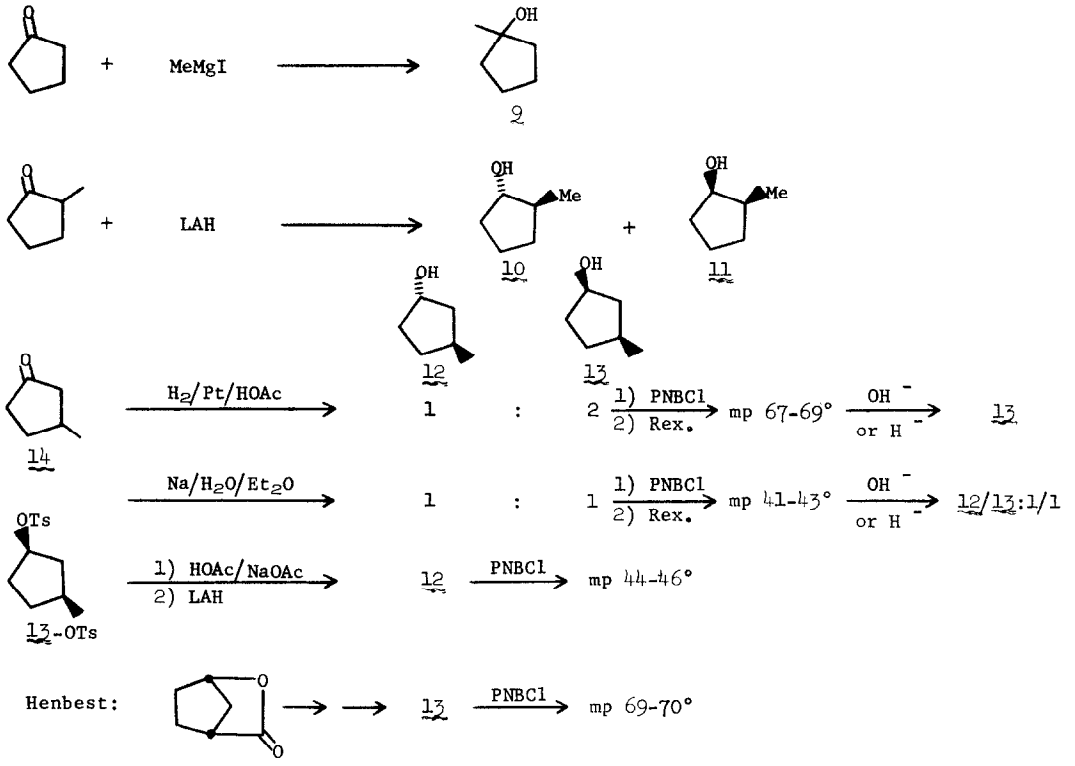
(Received in USA 30 January 1970; received in UK for publication 24 February 1970)

Despite the fact that cyclobutylcarbinyl arenesulfonates solvolyze 10^2-10^3 times faster than appropriate models indicating carbon participation in the ionization,[1] the nature of the product-forming intermediate has yet to be investigated in the parent system. We wish to report on the stereochemistry of nucleophilic attack on the rearranged cation derived from the cyclobutylcarbinyl system and indicate that net retention of configuration of the migration origin is the result in acetolysis and formolysis.

The starting materials were prepared by a modification of Cason's procedure for cyclobutane carboxylic acid.[2] The *trans*- and *cis*-2-methylcarbomethoxycyclobutanes, 1 and 2, were separated by preparative vpc. Ester 2 had similar spectroscopic properties to the reduction product of 2-methyl-1-carbomethoxycyclobut-1-ene which was assigned the *cis*-configuration by Gassman.[3] Verification of the stereochemistry was provided upon reduction of 1 and 2 to the alcohols 3 and 4 followed by reaction with brosyl chloride to give 5 and 6, then reaction with sodium iodide to give the iodides which were reduced with lithium aluminum hydride to the hydrocarbons 7 and 8. *cis*-1,2-Dimethylcyclobutane, 8, was prepared independently from cyclobutane-1,2-dicarboxylic acid anhydride by a similar route, thus confirming the assigned structures.



Authentic samples of anticipated products 9, 10,[4] and 11[4] from the solvolyses were prepared without event; however, the crucial trans- and cis-3-methylcyclopentanols, 12 and 13, deserve comment. Hydrogenation of 3-methylcyclopentanone, 14, gave a 1:2 mixture of 12 and 13 which could be separated only by capillary vpc; however, recrystallization of the p-nitrobenzoates gave a material, mp 67-69°,[5] which upon saponification gave a 1:9 mixture of 12 and 13. The cis stereochemistry of this alcohol seemed secure since Henbest[6] prepared this alcohol from the lactone of 3-hydroxy-1-cyclopentane carboxylic acid, and its p-nitrobenzoate melted at 69-70°. Sodium in moist ether reduction of 14 gave a 1:1 mixture of 12 and 13, and recrystallization of the p-nitrobenzoates gave p-nitrobenzoate, mp 42-43.5°, which was assigned[5] the trans stereochemistry, 12-OPNB; however, saponification gave a 1:1 mixture of 12 and 13. The p-nitrobenzoate of 12 when produced from 13-OTs by buffered acetolysis (see below) followed by cleavage had a mp 44-46°. Thus, the stereochemical assignments are secure.



Acetolyses of the brosylates 5 and 6 were conducted in the presence of a slight excess of sodium acetate at 89° for the length of time necessary to cause disappearance of the S – O

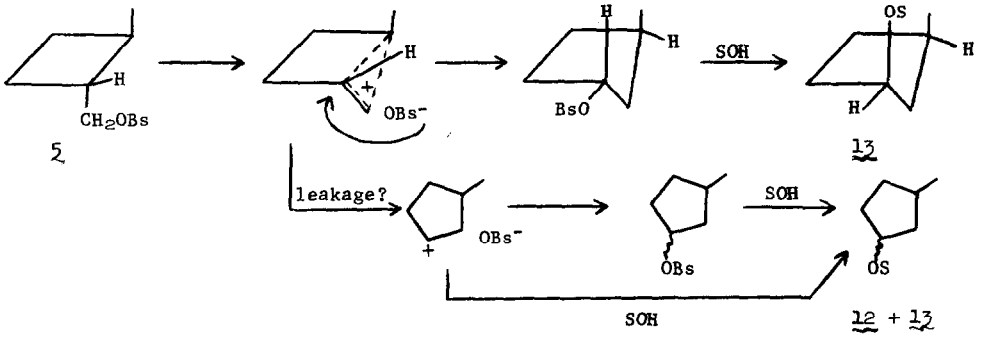
stretching modes in the ir. The distribution of acetate products is given in the table. All of the acetate products were stable under these conditions, and the tosylate of 13 gave exclusively 12-OAc under these conditions, and a 1:1 mixture of 12- and 13-OTs gave a 1:1 mixture of 12- and 13-OAc upon acetolysis. Formolyses of 5 and 6 were conducted in a 9:1 mixture (by volume) of formic acid and pyridine at 50°.

Table I. Product Distributions from Solvolyses of cis- and trans-2-Methylcyclobutylcarbinyl Brosylates

			9	10	11	12	13	3	4	unk
5	HOAc/NaOAc	89°	16	6	-	24	39	7	-	8
5	HCOOH/pyr.	50°	24	3	-	21	36	6	-	9
6	HOAc/NaOAc	89°	47	6	-	19	11	-	3	14
6	HCOOH/pyr.	50°	53*	6	-	18	11	-	*	11

*4-OCHO is included with 9-OCHO.

The observation of net retention at the migration origin in the 3-methylcyclopentyl product, 12 and 13, stands in contrast to previous observations of vicinal shifts in solvolyses[7] with the exception of cases where a second rearrangement can and does occur as in the nopinyl system.[8] In the simple cyclopentyl cation no second rearrangement save for a hydride shift appears possible, and this alternative seems unlikely because no such shift is observed in the solvolysis of 12- or 13-OTs. Conformationally isomeric classical cations also appear unlikely since steric effects should govern the direction of nucleophilic attack, and inspection of molecular models suggests that inversion at the migration origin would be expected. A "memory effect" similar to that proposed by Berson[9] might be invoked, but the effect was suggested with regard to intramolecular trapping of rearranged carbonium ions and not to solvent trapping. We propose that the solvolyses of 5 and 6 involve partially specific internal return to rearranged cyclopentyl brosylates, reactions which should give inversion at C-1;[7] subsequent rapid solvolysis would proceed with inversion at C-1 resulting in net retention at C-1 in the



solvolysis product. The lack of complete stereospecificity might be attributed to "leakage" to a classical cyclopentyl cation. Internal return with rearrangement has been noted with other cyclobutylcarbinyl derivatives; however, in each of these the subsequent solvolysis of the rearranged arenesulfonate has been relatively slow due to the nature of the system, e.g., 1-norbornyl from bicyclo[2.2.0]hexane-1-methyl derivatives.[10]

In general, internal return in the solvolyses of non-rearranging secondary systems is much faster than the formation of solvent-separated ion pairs,[11] and the results with 5 and 6 are not inconsistent with these observations. Indeed, we suggest that Wagner-Meerwein shifts that do not proceed via relatively stable mesomeric ions in poorly ionizing solvents will be accompanied by net retention at the migration origin due to subsequent solvolysis with inversion, where possible, of rearranged arenesulfonates, halides, etc., which themselves are formed with inversion.

It is remarkable that in the case of 5 and 6, the specificity in the formation of 12 and 13 is relatively independent of solvent. Just why this is so is unclear in light of Winstein's work.[11] However, the facts that bicyclo[2.2.0]hexane-1-methanol p-nitrobenzoate does not equilibrate oxygens on rearrangement to the 1-norbornyl p-nitrobenzoate[10b] and that optically active 3-phenyl-2-butyl tosylate undergoes oxygen scrambling slower than return to starting material or to the opposite enantiomer[12] suggest a molecular pathway for internal return as well as an ionic one. The efficiency of the former may well be less sensitive to solvent than the latter. Unclear in the solvolyses of 5 and 6 as well is the exclusive formation of 10 over 11 although steric effects may play an important role here.

References

1. K. B. Wiberg and B. A. Hess, J. Amer. Chem. Soc., 88, 4433 (1966).
2. J. Cason and H. Rapoport, "Laboratory Text in Organic Chemistry," Prentice-Hall, Inc., Englewood Cliffs, N. J., 1962, p 407.
3. P. G. Gassman and K. T. Manfield, J. Org. Chem., 32, 915 (1967).
4. J. B. Umland and M. I. Jefraim, J. Amer. Chem. Soc., 78, 2788 (1956).
5. M. Godchot, G. Cauquil, and R. Calas, Bull. Soc. Chim. Fr., 6, 1353 (1939).
6. H. B. Henbest and J. J. McCullough, Proc. Chem. Soc., 74 (1962).
7. C. K. Ingold, "Structure and Mechanism in Organic Chemistry," 2nd ed, Cornell University Press, Ithaca, N. Y., 1969, p 762.
8. E. C. Friedrich and S. Winstein, J. Amer. Chem. Soc., 86, 2722 (1964); P. von R. Schleyer, W. E. Watts, and C. Cupas, ibid., 86, 2723 (1964); see also ref 1.
9. J. A. Berson, et al., ibid., 91, 5550, 5567, 5580, 5594, 5601 (1969).
10. (a) K. B. Wiberg and B. R. Lorry, ibid., 85, 3188 (1963); (b) W. G. Dauben and J. L. Chitwood, J. Org. Chem., 34, 726 (1968) and references contained therein.
11. A. F. Diaz, I. Lazdins, and S. Winstein, J. Amer. Chem. Soc., 90, 1904 (1968) and references contained therein.
12. H. L. Goering and R. W. Thies, ibid., 90, 2967, 2969 (1968).