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POLARITY EFFECTS ON THE RATE OF SOLVOLYSIS OF 4-SUBSTITUTED CYCLOHEXYL TOSYLATES[1]

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THE greater reactivity, in solvolysis, of axial tosylates compared with equatorial tosylates is well known.[2] As the *cis* isomer of 4-alkylcyclohexyl tosylates contains a much higher proportion of the conformer with the axial tosylate moiety, the *cis* isomer reacts more rapidly than the *trans* isomer.

In continuing our studies[3-6] on the effects of polar

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[1] Studies of Configuration. XII. Previous paper: D. S. Noyce and L. J. Dolby, *J. Org. Chem.* **26**, 3619 (1961). Supported in part by grants from the National Science Foundation (NSF G-5921 and 13125).

[2] S. Winstein and H. J. Holness, *J. Am. Chem. Soc.* **77**, 4935 (1955).

[3] D. S. Noyce and B. R. Thomas, *ibid.* **79**, 755 (1957).

[4] D. S. Noyce, B. R. Thomas and B. N. Bastian, *ibid.* **82**, 885 (1960).

[5] D. S. Noyce and B. N. Bastian, *ibid.* **82**,1246 (1960).

[6] D. S. Noyce and H. I. Weingarten, *ibid.* **79**, 3103 (1957).

substituents on the reactivity of cyclohexyl systems, we have observed a striking inversion of reactivity in several 4-substituted cyclohexyl tosylates.

Our new data are summarized in Table I.

TABLE I

Rates of Solvolysis in Acetic Acid at 90°

Substituted Tosylate[a]	m.p.	k x 10^5, sec.$^{-1}$	k_{trans}/k_{cis}
trans-4-Chlorocyclohexyl	76-77°	2.85	2.36
cis-4-Chlorocyclohexyl	66-67°	1.21	
trans-4-Bromocyclohexyl	85-86°	2.43	2.01
cis-4-Bromocyclohexyl	79-80°	1.21	
trans-4-Cyanocyclohexyl	95-96°	0.932	1.13
cis-4-Cyanocyclohexyl	105-106°	0.814	

(a) Satisfactory analyses have been obtained for all new compounds.

In all three pairs, the trans isomer reacts more rapidly than the cis isomer, with the rate ratio k_{trans}/k_{cis} varying from 2.36 to 1.13. These results clearly demonstrate that substituents in the 4-position of the cyclohexane ring which have a substantial dipole cause a marked perturbation in the "normal" reactivity ratio between the cis and trans isomer.

Though the faster rate of solvolysis of trans-4-methoxycyclohexyl tosylate[3,4] is due in large measure to the transannular participation which we have demonstrated,[5] nevertheless, the unassisted rate of solvolysis appears to be as large as the rate of solvolysis of cis-4-methoxycyclohexyl tosylate.[4] In the present studies we have shown that participation is not responsible for the increased rate of reaction. For example, the product composition from trans-4-chlorocyclohexyl tosylate (I) is 84% 4-chlorocyclohexene, 15% cis-4-chlorocyclohexyl acetate, II, and 1.3% trans-4-chlorocyclohexyl acetate, III, i.e., a "normal" product distribution.

We ascribe the measured rate results to a combination of two factors: (1) the interaction of the two dipoles in the ground state of the substrate, resulting in a striking increase in the proportion of the axial-axial conformer present in the trans isomer;[7] (2) the influence of the geometrical position of the dipole of the substituent group in relation to the developing charges in the transition state (a direct field effect).

With regard to the first of these two factors, several lines of evidence substantiate this conclusion. The infrared mull spectrum for trans-4-chlorocyclohexyl tosylate is much simpler than the solution spectrum (in CS_2) in the 13 - 16 micron region. Pronounced bands at 13.43 and 14.60 microns appear in the solution spectrum. In trans-4-chlorocyclohexanol and in trans-4-chlorocyclohexyl acetate two bands appear in the carbon-chlorine stretching region, at 13.40 and 13.68

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[7] In trans-1,4-dichlorocyclohexane, Kozima and Yoshino (J. Am. Chem. Soc. 75, 166 (1953)) have shown that the diaxial conformer predominates in solution in a variety of solvents, including ethanol and ether. Similar, less extensive results were reported for trans-1,4-dibromocyclohexane.

microns in the former, at 13.30 and 13.94 in the latter. The bands in III assigned to the equatorial and axial carbon-chlorine stretching modes, respectively, have an intensity ratio of 7:3, indicating that a substantial fraction of III is in the a,a conformation.

With regard to the second factor, we have previously indicated the probable importance of this term (the direct field effect) in aiding the interpretation of the rate ratio for cis and trans-3-methoxycarbonylcyclohexyl tosylate.[6] The differences due to polarity terms in dissociation of carboxylic acids is well exemplified by the work of Siegel and Morse;[8] cis-3-bromocyclohexanecarboxylic acid is a stronger acid than trans-3-bromocyclohexanecarboxylic acid. In effect, the distance from the carboxylate to the equatorial or axial bromo, and consequently the direct electrostatic interaction between the two groups is sufficiently different to account for a two-fold difference in ionization constant. More recently, Combe and Henbest[9] have reported results showing the increased proportion of cis-4-chlorocyclohexanol obtained on borohydride reduction of the ketone.[10] They suggest that such an electrostatic interaction between a dipole and the charges developed

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[8] S. Siegel and J. G. Morse, J. Am. Chem. Soc. 75, 3857, (1953).

[9] M. G. Combe and H. B. Henbest, Tetrahedron Letters No. 12 404 (1961).

[10] Cf. also, D. S. Noyce, G. L. Woo and B. R. Thomas, J. Org. Chem. 25, 260 (1960); B. N. Bastian, thesis, University of California, June (1960).

at the transition state of the reduction is responsible for the altered isomer ratio.

The present results indicate clearly that the perturbed ground state conformation population is an important factor affecting the reactivity ratios of substituted cyclohexyl compounds bearing strongly polar substituents. The present results cannot be satisfactorily interpreted if only the e,e conformation for the trans isomer is considered. This suggestion also resolves the quandary expressed by Mori.[11]

We are presently investigating reactivity ratios in appropriately substituted cyclohexanes of frozen conformation.

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[11] N. Mori, Bull. Chem. Soc. Japan **33**, 1332 (1960); **34**, 110 (1961).