

MECHANISTIC DICHOTOMY IN CYCLOALKENE FORMATION :
SIMULTANEOUS OPERATION OF ANTI- AND SYN-MECHANISMS IN
BIMOLECULAR ELIMINATION[†]

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Studies on rates of cis- and trans-cycloalkene formation from cycloalkyl 'onium salts (1) have led us to postulate that two different mechanisms are simultaneously operative in bimolecular eliminations leading to cis- and trans-cycloolefins, respectively. We now present direct evidence in support of this view.

We have investigated the course of the elimination reactions of 1,1,4,4-tetramethyl-7-cyclodecyltrimethylammonium chloride (2) (I) and its cis-8-d₁ and trans-8-d₁ deuterated derivatives (II and III, respectively) with potassium methoxide in methanol; and also of 1,1,4,4-tetramethyl-7-cyclodecyl tosylate (IV) and its cis-8-d₁ and trans-8-d₁ deuterated derivatives (V and VI) with potassium

[†]This is the third of a series of papers on the mechanism of elimination reactions; for previous paper see preceding note (1).

tert.butoxide in dimethylformamide (DMF) (cf. Table 1). One reason for the choice of the 1,1,4,4-tetramethylcyclodecane derivatives for this purpose is that in this system the two pairs of gem.-dimethyl groups act as positional "markers" ; another is that 1,1,4,4-tetramethylcyclodecane presumably represents a cyclodecane system of stabilised conformation (2).



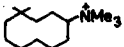
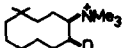
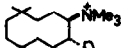
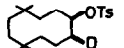
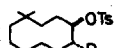

Appropriately deuterium labeled 1,1,4,4-tetramethylcyclodecan-7-ols were synthesised from the olefin cis-VII (2) by deuteroboration, and by reaction of the epoxide corresponding to cis-VII with $\text{LiAlD}_4 - \text{AlCl}_3$ (3). Labeled cyclodecylamines were obtained from the deuterated tosylates V and VI by reaction with sodium azide in dimethyl sulfoxide (complete inversion), followed by reduction of the azide with LiAlH_4 or by deuteroboration of cis-VII and decomposition of the adduct with chloramine (4); the amines were converted into the quaternary salts I - III in the usual manner.

The composition of the olefin fractions formed in the bimolecular elimination reactions⁺ (runs 1 - 6) is given in Table 1. From the composition of the olefins formed from the 'onium compound I (run 1), relative to that formed from the deuterated derivatives II and III (runs 2 and 3), respectively, one can calculate the deuterium isotope effects, $k_{\text{H}}/k_{\text{D}}$, on the formation of the olefins trans-VII and cis-VII (see Table 1). The same procedure gives the $k_{\text{H}}/k_{\text{D}}$ values for the tosylate eliminations.

⁺The possibility of incursion of an E_1 -process in the reaction of the tosylates IV - VI (runs 4¹- 6) is excluded by the fact that the composition of the olefins obtained on solvolysis of IV in DMF alone (run 7) differs very greatly from that obtained in the reaction with base (run 4); the same conclusion follows from a study of the olefin composition in dependence on potassium tert.butoxide concentration.

TABLE 1

Olefins Formed in Reactions of Quaternary Salts I - III
and Tosylates IV - VI

Conditions	Run	Substrate	VII 		VIII 			
			%	$\frac{k_H}{k_D}$ ^c	%	$\frac{k_H}{k_D}$ ^c	%	%
MeOK in MeOH ^a (140°C)	1	I 	48.9	-	5.92	-	36.7	8.48
	2	II 	47.3	<u>1.1</u>	5.91	<u>1.0</u>	38.3	8.59
	3	III 	34.4	<u>2.3</u>	3.24	<u>2.8</u>	51.2	11.2
t-BuOK in DMF ^b (50°C)	4	IV 	47.4	-	37.1	-	3.80	11.7
	5	V 	47.6	<u>1.0</u>	36.7	<u>1.0</u>	4.00	11.6
	6	VI 	34.5	<u>3.8</u>	25.4	<u>4.0</u>	9.70	30.3
Solvoly- sis DMF ^c (100°C)	7	IV	73.6	-	1.25	-	15.4	9.83

^aSix hours, 0.61 mmole of the quaternary salts (chlorides) I - III and 30 mmole potassium methoxide in 15 ml methanol at 140°C under nitrogen in sealed tubes.

^bThirty minutes, 0.69 mmole of tosylates IV - VI and 10 mmole potassium tert.butoxide in 10 ml dimethylformamide at 50°C under nitrogen in sealed tubes.

^cThe kinetic isotope effects were evaluated as shown for the calculation of k_H/k_D for the formation of trans-VII from III:

$$(k_H/k_D) = \frac{(\% \text{ trans VII from I})/(\% \text{ trans VIII from I})}{(\% \text{ trans VII from III})/(\% \text{ trans VIII from III})}$$

The values of k_H/k_D thus found were corrected for the deuterium content of the substrates, i.e. 12 % d_0 for III and V and 6 % d_0 for II and VI; the content of d_2 species was estimated as 0.5 - 1.0 %.

As the values of k_H/k_D reveal, there is a marked isotope effect in the formation of both trans-VII and cis-VII from the trans-deuterium labeled compounds III and VI (runs 3 and 6), but there is no isotope effect in the corresponding formation of either trans-VII or cis-VII from the cis-deuterium labeled compounds II and V (runs 2 and 5).

These facts show that one and the same hydrogen (or deuterium) atom is involved in the formation of both the olefins, trans-VII and cis-VII. Since the hydrogen atom being removed is configurationally trans to the group eliminated (NMe_3 or OTs^-), it follows that the olefin trans-VII must have arisen by a syn-mechanism and the olefin cis-VII by an anti-mechanism⁺ (cf. Scheme 1 in preceding note (1)).

In agreement with the proposal made in the previous note (1) two mechanism thus actually proceed side by side : the generally accepted (5,6) anti-mechanism, and a syn-

⁺ This conclusion is fully supported by a mass spectroscopic examination (kindly performed by Dr L. Dolejš) of the olefins trans-VII and cis-VII formed from the cis- as well as the trans-deuterium labeled tosylates V and VI (runs 5 and 6). The olefin cis-VII as well as the olefin trans-VII formed from the trans-deuterium labeled tosylate VI were found to have lost essentially all their deuterium, whereas the same two olefins formed from the cis-deuterated tosylate were found to have retained all their deuterium.

mechanism, previously thought to be operative only in very special cases (7-10).

We believe that syn-eliminations, as well as the simultaneous operation of anti- and syn-mechanisms leading, respectively, to cis- and trans-olefin from one single substrate, may well be encountered more generally in bimolecular eliminations, though possibly not in so pronounced or clear-cut a manner as in the present case. Previous mechanistic conclusions (e.g. ref. 11-13) based on the ratios of cis to trans olefin formed in elimination reactions may hence have to be reconsidered in the light of this. In such cases, the cis to trans olefin ratio will depend 1) on the intrinsic energetics of the two competing mechanisms (syn and anti elimination), and 2) on the relative aptitudes of the particular system (including the base and solvent) to adopt transition state conformations leading to cis- or trans-olefin formation by the syn and/or the anti-processes. Four, rather than two, energy profiles will therefore have to be considered.

Preferred, or exclusive, trans-cycloalkene formation in bimolecular eliminations in the medium rings is an interesting open problem of long standing. As a result of the present findings the problem has taken on a different form, trans-olefin formation in the medium rings being a consequence of syn-elimination, even in the bimolecular reactions which have hitherto been considered to involve anti-elimination exclusively (5,14,15). The fact that syn-eliminations (e.g. the amine oxide eliminat-

ion) preferentially give the trans-cycloalkene is well known (15); an explanation of this feature requires a complex conformational discussion which cannot be attempted within the scope of the present note.

More detailed studies on various aspects of these problems are in progress and the results will be reported shortly.

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