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A GENERAL OCCURENCE OF THE SYN-ANTI ELIMINATION DICHOTOMY UNDER ION-PAIRING CONDITIONS :

INESSENTIALITY OF STERIC REQUIREMENTS OF THE LEAVING GROUP[1]

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It is now well documented[2,3] that two stereochemically distinct syn- and anti-processes may operate, side by side, in bimolecular elimination. Also, it is known that, when the tendency towards the dual reaction mode is rather pronounced, the competing syn- and anti-mechanisms may exhibit "divergent" stereoselectivity, the former leading preferentially to trans-, but the latter to cis-olefin formation. In such cases we speak about syn-anti dichotomy[2].

We gave an ample evidence that the syn-anti dichotomy is the usual rather than an exceptional reaction mode in eliminations of medium and large-ring onium salts[2d,4], tosylates[2c] and bromides[2b]. Also, we as well as others demonstrated a very general occurence of the dichotomy in elimination of the open-chain quaternary ammonium bases[2d-f,3a]. By contrast, an incomplete evidence available suggested a relatively rare, if any, occurence of the dichotomy in reactions of the corresponding acyclic tosylates[4] or bromides[5].

For these intriguing results, Saunders and his coworkers presented a conformational explanation[3] postulating that steric hindrance in trans-olefin formation by anti-elimination is the main cause of the dichotomy: by a slowing down the rate of the anti⟶trans pathway, it gives the anti⟶cis and/or the syn⟶trans pathways the opportunity to predominate. According to the hypothesis[3a], it is the ring structure, which enforces such a situation in the cyclic systems (Scheme 1,A): therefore, the syn-anti dichotomy is observed with a number of different leaving groups. In acyclic derivatives, on the other hand, it is the bulk of the leaving group which is believed to enforce it, by pushing the alkyl residues into the base approach shielding position (Scheme 1,B). Consequently, the dichotomy in open-chain systems was predicted[3a] to be of importance only with quaternary ammonium salts, whereas "there should be much less tendency towards the syn-anti dichotomy with poor leaving groups that are not bulky (such as fluorine)". Concerning the role of other factors which had been shown[2a-c] to be very important for the dichotomy, the American authors concluded[3b]: "While the strength and steric requirements of the base, and a solvent system which favors ion pairing may all create conditions favorable to syn elimination, they are not alone sufficient to cause it".

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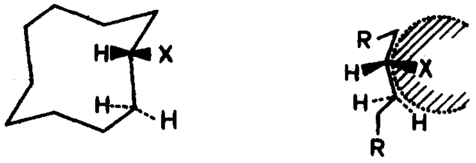

A B

Scheme 1

Now, we wish to report an evidence that under ion-pairing conditions[2b,6] the syn-anti dichotomy occurs, very pronouncedly, also in reactions of simple open-chain derivatives which do not possess a bulky leaving group. We have made a detailed study of the elimination behaviour of 5-decyl fluoride (I, X = F) and the corresponding chloride (I, X = Cl) in two base-solvent combinations differing greatly in the ion-pairing ability (potassium tert-butoxide in dimethyl sulphoxide and in benzene, respectively). The procedure consisted of the determination of deuterium content of the cis- and trans--5-decene (II), obtained from the reaction of the threo- and erythro-6-deuterio-derivatives of I (X = F and Cl). The labelled halides were prepared (with inversion of configuration) from the appropriately deuterated alcohols (erythro- and threo-6-D-I; X = OH) by the known stereospecific procedures[7,8] (Scheme 2).

$Bu.CHX.CH_2.Bu$ $Bu.CH{=}CH.Bu$
I cis- and trans-II

$$\text{I, X = F} \xleftarrow[\text{ether}]{Et_2NCF_2.CHFCl} \text{I, X = OH} \xrightarrow{CCl_4,\ PPh_3} \text{I, X = Cl}$$

Scheme 2

The determination of the deuterium content in the olefins produced as well as the subsequent evaluation of the contributions of the syn- and anti-pathways to trans- and cis-5-decene formation from the parent (unlabelled) halides I was carried out by the standard procedures described by us previously[2d] in an analogous study of the corresponding ´onium compound and tosylate I(X = $\overset{+}{N}Me_3$ and OTs, respectively). The results from the two closely related studies are compared in the Table 1.

It follows from the data of the Table that the steric course of the reactions is greatly dependent on the ion-pairing ability[2b,6] of the solvent used. In the ion-pairs dissociating solvent dimethyl sulphoxide, the steric outcome is consistent with the Saunders´ prediction: in the reactions of the halides (and also of the tosylate), the contribution of syn-elimination is small and the prevailing anti-pathway leads preferentially to trans-olefin formation. Indeed, the dichotomous syn ⟶ trans, anti ⟶ cis reaction

TABLE 1 Contributions[a] of the syn- and anti-Pathway to the trans- and cis-5-Decene Formation from Reaction of the Unlabelled 5-Decyl Derivatives I (X = F, Cl, OTs, $\overset{+}{N}Me_3$) with 0.5M Potassium tert-Butoxide in Two Different Solvents

X	trans-5-Decene			cis-5-Decene			%syn
	$k_{s\rightarrow t}$	$k_{a\rightarrow t}$	%syn	$k_{a\rightarrow c}$	$k_{s\rightarrow c}$	%anti	overall
				Dimethyl Sulphoxide			
F^b	<16	>66	<20	~ 14	<4	>80	<20
Cl^c	5.2	80.6	6	12.1	2.1	85.2	7.3
OTs^d	2.8	73.2	3.7	22.6	1.4	94.2	4.2
$\overset{+}{N}Me_3{}^d$	74.7	5.3	93.4	18.8	1.2	94	75.9
				Benzene			
F^b	>81	<9	>90	~ 9	<1	>90	>80
Cl^e	34	20.8	62	40.7	4.5	90	38.5
OTs^d	12.4	33.6	27	50.4	3.6	93.4	16
$\overset{+}{N}Me_3{}^d$	82.4	7.6	91.6	8.2	1.8	82	84.2

[a] Expressed as the relative rate constants of the corresponding processes syn → trans ($k_{s\rightarrow t}$), anti → trans ($k_{a\rightarrow t}$), anti → cis ($k_{a\rightarrow c}$), syn → cis ($k_{s\rightarrow c}$); $k_{s\rightarrow t} + k_{a\rightarrow t} + k_{a\rightarrow c} + k_{s\rightarrow c} = 100$.

[b] Although the reaction was interrupted after about 50% completion, a subsequent isomerisation of the olefin produced could not be completely suppressed. In a blank experiment, the less stable cis-olefin underwent about 10% isomerisation under conditions used in the elimination runs (20 hrs at 40°C in the solvent dimethyl sulphoxide; 25 hrs at 140°C in the solvent benzene). Therefore, the data given are less accurate. [c] 2 hrs at 40°C. [d] Data from ref. 2d. [e] 20 hrs at 100°C.

mode is here operative only for the quaternary ammonium compound I with the most bulky leaving group ($X = \overset{+}{N}Me_3$).

On the other hand, an entirely different situation exists in the ion-pairs supporting solvent benzene. It is immediately apparent that the contribution of syn-elimination in the reaction of the fluoride I as well as the chloride I is considerable and represents for the former derivative the principal process. Comparing the derivatives summarised in the Table, it may be seen that the contributions of the syn-pathway are equally pronouncedly represented in the reaction of the derivative with the least and the most bulky leaving group (I, X = F, and I, $X = \overset{+}{N}Me_3$, respectively). Noteworthy enough, the proportion of syn-elimination decreases, significantly, on going from the least bulky fluoride to bulkier chloride, and further still, to tosyloxy leaving group[9].

Even more importantly, all the derivatives exhibit, in the reaction in benzene, the "divergent" pattern of stereoselectivity, stigmatizing the syn-anti dichotomy. Thus, in the reaction of the two halides, as well as the tosylate and the quaternary ammonium chloride, the syn-pathway leads predominantly to the trans-olefin formation ($k_{s \rightarrow t} > k_{s \rightarrow c}$), whereas the anti-pathway affords preferentially the corresponding cis-isomer ($k_{a \rightarrow c} > k_{a \rightarrow t}$).

These findings establish that the syn-anti dichotomy in open-chain systems is by no means a privilege of the derivatives possessing a bulky leaving group. The view that steric hindrance in the anti ⟶ trans pathway is the necessary condition[3b] for the dichotomy must therefore be definitely abandoned: in the open-chain systems investigated, the steric requirements of the leaving group, claimed to be the main cause of the hindrance[3a], appear to be entirely inessential for the occurence of the dichotomy.

By contrast, the ion-pairing ability of the base-solvent combination used, believed formerly[3b] to be only of secondary importance, appears to be very essential for the dichotomy: the present evidence suggests strongly that it constitutes the sufficient condition for generation of the dichotomy.

Accordingly, these findings necessitate a complete re-examination of the current views[2d,3] on the origin of the dichotomy; we shall deal with the problem in the papers to be published shortly.

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