Attractive Interactions in *E*2 Reactions: the Origin of the *syn–anti* Duality and the Divergent Stereoselectivity of the Two Competing Pathways

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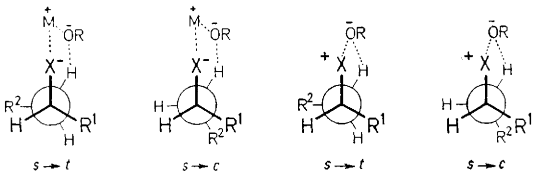
Summary A simple and general explanation for the title phenomena is proposed in terms of ion–dipole or ion–ion interactions between the leaving group and participating base.

It is now well documented[1,2] that two stereochemically distinct *syn*- and *anti*-mechanisms often compete in bimolecular elimination of the type $R^1CHX{\cdot}CH_2R^2 + RO^+M^- \rightarrow$ *cis*- and *trans*-$R^1CH{=}CHR^2$ (R^1, R^2 = alkyl) and exhibit divergent stereoselectivity, the former preferring *trans*-, but the latter *cis*-olefin formation (*syn* → *trans*, *anti* → *cis* dichotomy). Special steric† characteristics of substrates, base, and solvent have been invoked[3a–e] to account for these results. We have shown, however, that the dichotomy may occur, pronouncedly, also in the complete absence[2,4a] of the required steric qualities and predicted[4a] that the operation of some effect which so far escaped notice must therefore be considered.

Recently, we discovered[2,5] that separated as well as contact ions of the participating (alkoxide) base may take part in elimination of simple open-chain derivatives (R^1 = R^2 = Bu) and lead, eventually, to very different steric results depending strongly on the nature of the leaving group. We have found that for the derivatives bearing a leaving group with unshared electron pairs (X = OTs or halide), contact ions are necessary both for promotion of the *syn*-mechanism as well as for preferential *cis*-olefin formation in the *anti*-component; the separated ions of the base utilize here almost exclusively the *anti*-pathway and lead preferentially to *trans*-olefin formation. By contrast, separated alkoxide ions appear to be responsible (at least in a greater part) for the dichotomy in reactions of the derivatives which possess positively charged leaving groups (*e.g.*, X = Me_3N^+); metathesis between the onium salt and metal alkoxide leads always to the formation of a more reactive quaternary alkoxide existing prevalently in the form of separated ions.[6]



Scheme 1

Significantly, attractive interactions may exist between contact ions of the base and leaving groups with unshared electron pairs ($RO^- \cdots M^+ \cdots X^-$), and also between separated alkoxide ions and the positively charged leaving groups ($RO^- \cdots X^+$). On the other hand, repulsion[7] rather than attraction would result from interaction of separated anions and the groups with unshared electron pairs ($RO^- \cdots X^-$). Hence, availability of the attractive interactions may be viewed to distinguish the dichotomous situations and possible modes of their operation in both the *syn*- as well as the *anti*-pathway must therefore be examined.

In the *syn*-pathway, we have already considered[8] such interactions and proposed for the two types of leaving groups (X^- and X^+, respectively) 'cyclic' transition states providing an optimal arrangement for the interacting groups (Scheme 1). In the *anti*-pathway, it is more difficult to imagine such interactions; nonetheless,[9] a reasonable proximity of the interacting groups may be achieved in the transition state, if a somewhat unusual‡ but theoretically sound[10] non-linear approach of the base is taken into account (Scheme 2).

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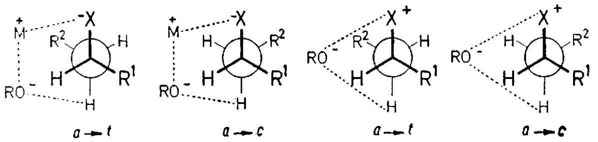
† Non-steric hypotheses were also proposed for the anomalies (ref. 4a,b); these, however, cannot explain the observed relationship between the dichotomy and the nature of the base–solvent combination used.

‡ However, a non-linear approach of base is commonly considered in connection with *E*2*C* mechanism (ref. 1).

A comparison of the Schemes immediately shows that the *syn*-process is able to take a greater benefit from the interactions involved by allowing a closer proximity of the interacting groups; this, obviously, explains well the promotion of the otherwise less advantageous *syn*-mechanism under circumstances favourable for the attractive interactions. Furthermore, it becomes apparent that the transition states proposed may also account, very satisfactorily, for the divergent stereoselectivity of the competing *syn*- and *anti*-mechanisms. In the *syn*-pathway (Scheme 1) the almost linearly approaching base does not interfere with the alkyl portion of the substrates; eclipsing effects preserve therefore the steric control and favour the *trans*-olefin formation. In the *anti*-pathway, on the other hand, the non-linearly[§] approaching base does interfere with the alkyl portion; examination of the alternative arrangements (Scheme 2) reveals that the interference will be considerably more severe in the arrangement leading to *trans*-olefin formation affording thus opportunity for the other (*cis*) isomer to prevail.



Scheme 2

Accordingly, the attractive interactions between the leaving group and participating base are proposed to underlie the anomalies constituting the long-standing problem of the *syn* → *trans*, *anti* → *cis* dichotomy. Other factors, such as already considered,[3,4] may also co-operate in generation of the dichotomy; these, however, are predicted to become self-sufficient only beyond a much higher threshold of structural complexity than has been originally expected.

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[§] It might be argued that the hydrogen isotope effect for the *anti*-pathway with non-linear transition state should be lower than that for the *syn*-pathway (*cf.* ref. 10b). However, it is known (ref. 1,8a) that the degree of C(β)–H bond breaking in the two alternative transition states is different; therefore, it appears unwarranted to expect in the present case any simple relationship between the transition-state geometry and magnitude of the isotope effect.

[1] For review of related data see J. Sicher, *Angew. Chem.*, 1972, **84**, 177; *Angew. Chem. Internat. Edn.*, 1972, **11**, 200.

[2] For more recent data see M. Pánková, M. Svoboda, and J. Závada, *Tetrahedron Letters*, 1972, 2465, and references cited therein.

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[9] M. Schlosser in Houben-Weyl-Müller: Methoden der organischen Chemie, vol. V, Ib, Thieme-Verlag, Stuttgart, 1972, p. 40.

[10] (a) C. A. Coulson in 'Hydrogen Bonding,' ed. D. Hadži, Pergamon Press, London–New York, 1959; (b) R. A. More O'Ferrall, *J. Chem. Soc.* (*B*), 1970, 785.