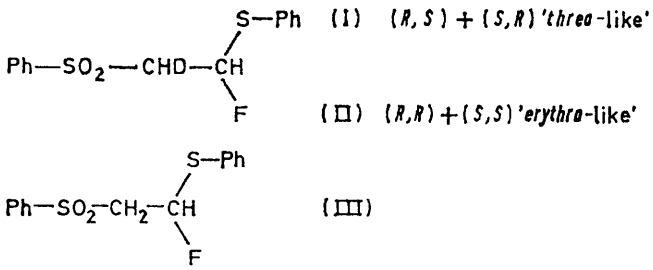
The *syn–anti* Dual Pattern in Elimination from Fluorosulphonylethanes promoted by Phenoxide and t-Butoxide Ions

By **Vito Fiandanese, Giuseppe Marchese, Francesco Naso,*** and **Oronzo Sciacovelli,** Istituti Chimici, Facolta' di Scienze, Universita' di Bari, via Amendola 173, 70126 Bari, Italy

The stereochemical course of elimination, promoted by phenoxide and t-butoxide ions, from the diastereoisomeric 1-deuterio-2-fluoro-2-phenylthioethyl phenyl sulphones (I) and (II) has been studied. The reactions with phenoxide ion show an almost completely *syn*-stereospecific course, but a small contribution from the *anti*-pathway is present. The importance of the latter process is dramatically increased when a macrocyclic ether is added to the reaction solutions. Using t-butoxide ions in t-butyl alcohol or in benzene–t-butyl alcohol [80:20 (v:v)] as solvent the *anti*-pathway can predominate. The observations are briefly discussed in light of current views concerning elimination reactions.

BASE-promoted 1,2-eliminations usually proceed most readily *via* an antiperiplanar transition state.[1] However, several cases are known in which the *syn*-pathway can compete effectively with the *anti*-counterpart.[1,2]

Recently we reported a rather unusual stereochemical course (complete *syn*-stereospecificity) for the reactions



of the diastereoisomeric 1-deuterio-2-fluoro-2-phenylthioethyl phenyl sulphones (I) and (II) with triethylamine in benzene.[3] An extension of our work to the oxygen bases seemed warranted and this paper deals with the results obtained using phenoxide and t-butoxide ions.

RESULTS AND DISCUSSION

The dehydrofluorination of the undeuteriated compound (III) with potassium phenoxide in dioxan, with potassium t-butoxide in t-butyl alcohol or with sodium t-butoxide in benzene–t-butyl alcohol [80 : 20 (v : v)] at 25—30° was found to reach completion practically upon mixing. *trans*-Phenyl 2-phenylthiovinyl sulphone [4] (IV) was formed in a quantitative yield. The isomeric *cis*-olefin [4] was not detected among the products and it was shown that under the reaction conditions *cis–trans*-isomerization did not occur.

Due to the presence of the sulphone function and to the nature of the leaving group the intervention of an *E*1 component is unexpected in the above reactions. In-

[1] C. K. Ingold, *Proc. Chem. Soc.*, 1962, 265; D. V. Banthorpe, in ' Studies on Chemical Structure and Reactivity,' ed. J. H. Ridd, Methuen, London, 1966, ch. 3; J. F. Bunnett, in ' Survey of Progress in Chemistry,' ed. A. F. Scott, Academic Press, New York, vol. 5, 1969; D. J. McLennan, *Quart. Rev.*, 1967, **21**, 490; R. W. Alder, R. Baker, and J. M. Brown, ' Mechanism in Organic Chemistry,' Wiley-Interscience, London, 1971, ch. 3.

[2] For a comprehensive review on the *syn–anti* dichotomy see J. Sicher, *Angew. Chem. Internat. Edn.*, 1972, **11**, 201 and references therein.

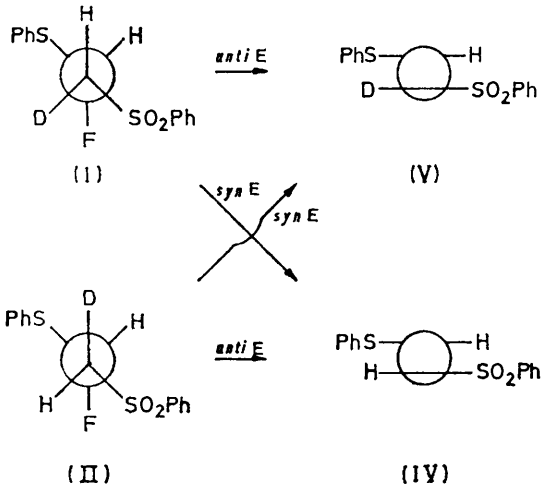
[3] V. Fiandanese, G. Marchese, and F. Naso, *Chem. Comm.*, 1972, 250.

[4] G. Modena and F. Montanari, *Gazzetta*, 1956, **86**, 432; F. Montanari, *ibid.*, p. 120.

deed, when the promoting base was absent no significant reaction took place over 10 h.

The deuterio-derivatives (I) and (II) which, considering the two sulphur groups as ' similar ' substituents, may be called ' *threo* ' and ' *erythro* ' respectively, reacted under the above conditions yielding mixtures of olefin (IV) and the corresponding labelled compound (V).

According to the Scheme *anti*-elimination involves retention of deuterium in the reaction of the '*threo*'-isomer and loss of deuterium in the reaction of the ' *erythro* '-counterpart. Opposite considerations are valid for the *syn*-course.



SCHEME

The data of Table 1 show that when the phenoxide ion in dioxan is the promoting base the *syn*-pathway largely

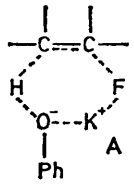
TABLE 1

Stereochemical course of the reactions of compounds (I) and (II) with phenoxide ion in dioxan at 25°

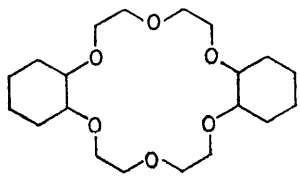
Substrate [a]	Base [b]	*anti*-Elimination (%)	*syn*-Elimination (%)
(I)	PhO⁻K⁺	13	87
(I)	PhO⁻K⁺–crown ether [c]	58	42
(I)	PhO⁻K⁺ [d]–crown ether [c]	58	42
(II)	PhO⁻K⁺	4	96
(II)	PhO⁻K⁺–crown ether [c]	50	50

[a] Concentration of substrate $1{\cdot}30 \times 10^{-2}$M. [b] Concentration of base $1{\cdot}25 \times 10^{-2}$M. [c] Concentration of macrocyclic ether $2{\cdot}10 \times 10^{-2}$M. [d] Externally added phenol ($6{\cdot}5 \times 10^{-3}$M) present.

prevails and only a small contribution of the *anti*-route is observed. In order to explain the importance of the *syn*-mode of elimination a ' pseudocyclic ' transition state A can be advocated.[5] This hypothesis is strongly supported by the effect of the addition of the macrocyclic ether (VI), dicyclohexyl-18-crown-6, to the reacting mixtures. This and similar compounds are



known to cause ion-pair separation of alkali and alkaline earth cations [6] thus making the intervention of transition states of the type A for the phenoxide base more difficult in elimination reactions.[5] The contribution



(VI)

of the *anti*-pathway is dramatically increased when the crown ether is present and as a result a non-stereospecific course is observed. The possibility that during these runs the isotopic composition of the starting or of the final material could be modified by H–D exchange with the phenol which is produced is easily refuted by the fact that when phenol is added to the reacting solutions no variation is observed in the stereochemical course. Therefore, the changes observed when the macrocyclic ether is present are not due to an artefact and we conclude that the base–leaving group interaction is important in favouring the *syn*-course.

The results obtained using potassium t-butoxide in t-butyl alcohol are reported in Table 2. However, in this case H–D exchange with the solvent appeared to be a complicating factor. Indeed, when the reaction of compound (III) was performed in Bu^tOD a high incorporation of deuterium (*ca.* 95%) was observed in the final product. Furthermore, when the deuterio-olefin (V) was dissolved in solution of Bu^tO^- in Bu^tOH complete loss of the isotopic label was observed after a few seconds. Consequently, the data concerning the Bu^tO^-–Bu^tOH base–solvent pair have to be considered as limiting values.

When sodium t-butoxide was dissolved in benzene containing a small amount of t-butyl alcohol to increase the solubility, a system was obtained in which the exchange reaction appeared to be of little importance. In fact, when the undeuteriated material (III) was allowed to react with $Bu^tO^-Na^+$ in C_6H_6–Bu^tOD [80 : 20 (v : v)] the olefin produced showed deuteriation only to a small (*ca.* 3%) extent. Therefore, the data of Table 2 for

[5] M. Svoboda, J. Hapala, and J. Závada, *Tetrahedron Letters*, 1972, 265; J. Závada, M. Svoboda, and M. Pánková, *ibid.*, p. 711; R. A. Bartsch and K. E. Wiegers, *ibid.*, p. 3819; D. H. Hunter and D. J. Shearing, *J. Amer. Chem. Soc.*, 1971, **93**, 2348.

[6] (*a*) C. J. Pedersen and H. K. Frensdorff, *Angew. Chem. Internat. Edn.*, 1972, **11**, 16, and references therein; (*b*) L. M. Thomassen, T. Ellingsen, and J. Ugelstad, *Acta Chem. Scand.*, 1971, **25**, 3024; (*c*) R. N. Greene, *Tetrahedron Letters*, 1972, 1793; (*d*) M. J. Maskornick, *ibid.*, p. 1797.

benzene–alcohol as solvent should represent closely the actual *syn–anti* distribution. Only small variations in the percentage of the two competing pathways were observed when crown ether (VI) was added to the base solutions. Also, the result of the deuterium incorporation experiment did not change when the crown-complexed species was used.

We have observed that for the benzene–alcohol system the *anti*-pathway can predominate. Also, the deuterium isotope effect [1] plays an important role in determining the extent of the two competing pathways. In the '*threo*'-isomer the *syn*-process involving the loss of the heavier atom is slowed down with respect to the *anti*-counterpart. The reverse occurs for the '*erythro*'-compound. Finally, the lack of any significant crown-ether effect suggests that ion pairing and consequently base–leaving group interactions cannot be considered as the sole factor responsible for the *syn*-contribution which, to a greater or smaller extent, is observed in every experiment performed.

Undoubtedly, according to current views,[1,2,7] considerable importance has to be given to the high degree of carbanionic character involved in these reactions. This can be easily appreciated by comparison with the stereochemical course of elimination from other sulphones. In fact, *threo*- and *erythro*-2-X-3-arylsulphonylbutanes [8] (X = *p*-bromophenylsulphonate or iodide), where the combination of electron-repelling methyl substituents and good leaving groups could cause a shift towards a (more) concerted mechanism, have been found to follow an *anti*-stereospecific pathway.[8]

Besides the base–leaving group interactions and degree of carbanionic character, there is a third factor which could play an important role in systems of the type investigated here. In principle, the reactivity of the two diastereotopic hydrogens of the methylene group could be intrinsically different.[9] Furthermore, such a difference could be enhanced by the highly hindered rotation of the C–C bond.[10] Nevertheless, due to the complexity of the substrates we have investigated it is rather difficult to reach a safe conclusion on which one of the two hydrogens should be more sensitive to attack by the base and, consequently, on which one of the two stereochemical pathways should accrue advantage from such a situation.[11]

TABLE 2

Stereochemical course in the reactions of compounds (I) and (II) with t-butoxide ion

Substrate [a]	Base [b]	Solvent	*t*/°C	*anti*-Elimination (%)	*syn*-Elimination (%)
(I)	$Bu^tO^-K^+$	Bu^tOH	30	≥41	≤59
(II)	$Bu^tO^-K^+$	Bu^tOH	30	≤69	≥31
(I)	$Bu^tO^-Na^+$	C_6H_6–Bu^tOH (80 : 20)	25	77	23
(II)	$Bu^tO^-Na^+$	C_6H_6–Bu^tOH (80 : 20)	25	33	67
(I)	$Bu^tO^-Na^+$–crown ether [c]	C_6H_6–Bu^tOH (80 : 20)	25	79	21
(II)	$Bu^tO^-Na^+$–crown ether [c]	C_6H_6–Bu^tOH (80 : 20)	25	38	62

[a] Concentration of substrate was 2.95×10^{-3}M. [b] Concentration of base was 2.90×10^{-3}M. [c] Concentration of macrocyclic ether was 4.40×10^{-3}M.

EXPERIMENTAL

N.m.r. spectra were recorded with a Varian HA 100 spectrometer. I.r. spectra were taken with a Perkin-Elmer model 256 instrument.

Substrates.—'*threo*'- and '*erythro*'-1-Deuterio-2-fluoro-2-phenylthioethyl phenyl sulphones (I) and (II) and the undeuteriated compound (III), all with m.p. 75—76° (from ethanol) were prepared by a previously described procedure.[10a]

Solvents and Bases.—Solvents were purified by conventional methods.[12] t-Butyl [^{2}H]alcohol [13] and phenoxide ion solutions [6b] were obtained by known procedures. Dicyclohexyl-18-crown-6 ether was a commercial sample (Aldrich) purified by means of column chromatography.

Stereochemical Experiments.—The experiments were performed under the conditions indicated in the Tables. The deuterium content of the olefin produced was determined by means of n.m.r. analysis. In hexadeuterioacetone the olefinic part of the molecule ($-S-CH_A=CH_B-SO_2-$) shows a doublet at τ 3·8 (J 15 Hz) for H_B, whereas the doublet at τ 2·1 for H_A was partially covered by the aromatic multiplet. Therefore, since a comparison of the integral for the aromatic protons and H_A with the integral for H_B would have involved a large error, a known amount of *sym*-tetrachloroethane [τ 3·5 (s)] was added as a standard. Control experiments showed that the error in the extent of

[7] Nguyen Trong Anh, *Chem. Comm.*, 1968, 1089.

[8] F. G. Bordwell and P. S. Landis, *J. Amer. Chem. Soc.*, 1957, **79**, 1593; P. S. Skell and J. H. McNamara, *ibid.*, p. 85. See also S. J. Cristol and P. Pappas, *J. Org. Chem.*, 1963, **28**, 2066.

[9] J. Sicher, J. Závada, and M. Pánková, *Chem. Comm.*, 1968, 1147. For studies on systems involving the sulphoxide group as a chiral centre see S. Wolfe and A. Rauk, *Chem. Comm.*, 1966, 778; E. Bullock, J. M. W. Scott, and P. D. Golding, *ibid.*, 1967, 168; M. Nishio, *ibid.*, 1968, 562; M. Cinquini, S. Colonna, and F. Montanari, *ibid.*, 1969, 607; R. R. Fraser and F. J. Schuber, *ibid.*, p. 397; J. E. Baldwin, R. E. Hackler, and R. M. Scott, *ibid.*, p. 1415; B. J. Hutchinson, K. K. Andersen, and A. R. Katritzky, *J. Amer. Chem. Soc.*, 1969, **91**, 3839; T. Durst, R. R. Fraser, M. R. McClory, R. B. Swingle, R. Viau, and Y. Y. Wigfield, *Canad. J. Chem.*, 1970, **48**, 2148; see also G. Barbarella, A. Garbesi, and A. Fava, *Helv. Chim. Acta*, 1971, **54**, 341.

[10] (*a*) G. Marchese, F. Naso, L. Schenetti, and O. Sciacovelli, *Chimica e Industria*, 1971, **53**, 843; (*b*) G. Marchese, F. Naso, and O. Sciacovelli, *ibid.*, 1972, **54**, 265.

[11] For theoretical calculations on the conformational preference of the fluoroethyl anion, see J. A. Jafri and R. G. Jesaitis, *Tetrahedron*, 1972, **28**, 3363, and references therein. For conformational studies on species containing adjacent electron pairs and/or polar bonds see S. Wolfe, *Accounts Chem. Res.*, 1972, **5**, 102; S. Wolfe, L. M. Tel, J. H. Liang, and I. G. Csizmadia, *J. Amer. Chem. Soc.*, 1972, **94**, 1361; S. Wolfe, A. Rauk, L. M. Tel, and I. G. Csizmadia, *J. Chem. Soc.* (*B*), 1971, 136 and references therein.

[12] J. A. Riddick and W. B. Bunger in 'Techniques of Chemistry,' ed. A. Weissberger, Wiley-Interscience, New York, vol. 2, 1970.

[13] D. J. Cram and B. Rickborn, *J. Amer. Chem. Soc.*, 1961, **83**, 2178.

deuteriation was not higher than $\pm 2\%$. In some cases the n.m.r. analysis was also complemented with an i.r. analysis (for CS_2 solutions) based on a comparison of the absorption of the bands at 935 cm^{-1} [present in (IV)] and 965 cm^{-1} [present in (V)].

Hydrogen–Deuterium Exchange Experiments.—The experiments were performed and followed in a way similar to that used for the stereochemical investigation.

cis–trans *Isomerization Experiments.*—The experiments were performed by dissolving *cis*-phenyl 2-phenylthiovinyl sulphone in solutions of the bases used for the stereochemical investigation and analysing the mixtures by means of t.l.c. and g.l.c.

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