The Absolute Stereochemistry of H–D Exchange in Benzyl Methyl Sulphoxide. The Orgin of the Kinetic Nonequivalence of the Methylene Protons

By SAUL WOLFE and A. RAUK

(*Department of Chemistry, Queen's University, Kingston, Ontario, Canada*)

DIMETHYL SULPHOXIDE[1] and benzyl methyl sulphoxide[2] undergo ready hydrogen–deuterium exchange in D_2O–NaOD. The methylene hydrogens of benzyl methyl sulphoxide exchange at unequal rates,[2] a result which implies the intervention of asymmetric carbanions. In contrast to this work, the results of previous exchange studies[3] have led to the conclusions that α-sulphinyl carbanions are not readily formed[4] and are not asymmetric.[5] Since the previous studies, for solubility reasons, were conducted in mixed solvents or nonaqueous media, it appears that the structure and stability of α-sulphinyl carbanions are strongly influenced by the nature of the solvent. A knowledge of the details of the exchange in D_2O is clearly needed before the relationship between solvent and mechanism can be discussed, and it seemed desirable to try to clarify the stereochemistry of hydrogen exchange in benzyl methyl sulphoxide.

Treatment of (*S*)-benzyl methyl sulphoxide[6] (I; conformationally *a*, *b*, or *c*) $[\alpha]_D$ −54° (chloroform), +96° (ethanol), +133° (D_2O), with 1M-NaOD–D_2O until slightly more than one of the methylene hydrogens had exchanged, and oxidation (H_2O_2 in HOAc) of the resulting α-deuteriobenzyl methyl sulphoxide (II) gave (+)-α-deuteriobenzyl methyl sulphone (III) $[\alpha]_D$ 0·92° (*c*, 3 in $CHCl_3$).

The initial rotation of (I) in 1M-NaOD–D_2O is +127°; the rotation of (II) in the same medium is +128° The rotation of the αα-dideuterio-compound is +125° and that of the pentadeuterio-compound is +122°. Hence there is no loss of asymmetry at sulphur associated with H–D exchange.[5] The conversion of (I) into (III) represents the transfer of asymmetry from sulphur to carbon, and provides direct evidence for the intermediacy of asymmetric carbanions.

The reduction of benzaldehyde with (−)-di-isopinocampheyldeuterioborane[7,8] gave (*S*)-(+)-α-deuteriobenzyl alcohol[9] (IV) $[\alpha]_D$ 0·47° (*c*, 10 in $CHCl_3$) (30% optically pure[10]). Tosylation of (IV), followed by reaction with CH_3SNa, gave (*R*)-α-deuteriobenzyl methyl sulphide (V) which was oxidized (H_2O_2 in HOAc) to (*R*)-α-deuteriobenzyl methyl sulphone (VI) $[\alpha]_D$ −0·30° (*c*, 5 in $CHCl_3$).

This sequence of reactions establishes that the configuration at carbon in (II) is (*S*), *i.e.*, that, considering (*a*), (*b*), and (*c*), H_A is preferentially exchanged.

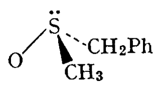
Neglecting solvation effects, the calculated dipole moments of (*a*), (*b*), and (*c*) are: (*a*): 3·84;

(*b*): 3·06; (*c*): 2·29D. [Parameters used:[11] bond lengths: S–O, 1·47; S–CH_3, 1·82; S–C_α–C_{Ar}, 1·525; aromatic C–C, 1·395Å; bond angles: CH_3–S–O = C_α–S–O, 107°; CH_3–S–C_α, 100°; S–C_α–C_{Ar}, 109°28′.]. Since the observed dipole moment is 3·86D (benzene, dioxan),[2] it appears that (*a*) is the predominant conformation in these solvents. The lower dipole moment of *p*-chlorobenzyl methyl sulphoxide (3·66D in benzene[2]) is consistent with this conclusion. Simple conformational considerations, taken together with the dipole moment and the result of extended HMO calculations,[12] indicate that (*c*) is unimportant both in the ground state and in the transition state for the exchange.

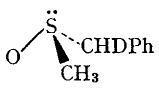
These conclusions do not necessarily hold in NaOD–D_2O, but the situation in this medium can be handled through an analysis of the n.m.r. spectrum. On the assumptions that (i) the lone pair of electrons on the sulphur atom has a shielding effect on a proton which is anticoplanar[13] and (ii) the shielding effect on the S–O bond is greater for the proton which is *gauche* than for the proton which is anticoplanar, it is concluded that in (*a*) H_A is at lower field, and in (*b*) H_B is at lower field. It is assumed that the anisotropic effect of the S=O double bond[11] is similar to that of a carbonyl group. [The effect of a multiple bond on the chemical shift of a proton has been discussed recently by Bhacca and Williams.[14] A study of the temperature- and solvent-dependence of the n.m.r. spectrum of benzyl methyl sulphoxide, which we will publish shortly, has revealed that the energy barrier to free rotation is low, and that the chemical-shift difference between the methylene protons depends only on the relative populations of (*a*), (*b*), and (*c*).]

Since the proton at lower field is exchanged first,[2] and this proton is H_A, then the preferential exchange must occur in conformation (*a*).

It was concluded earlier that the α-sulphinyl carbanion is nearly flat.[2] This requires a transition state for abstraction of H_A in which the H_B–C_α–phenyl angle increases to nearly 120° and the phenyl begins to interact with one of the other groups. These interactions are expected to increase in the order: lons pair < oxygen < methyl, and it is clear that the explanation of the kinetic difference between H_A and H_B cannot ignore these steric effects. In addition, three kinds of electrostatic effects can be discerned which might affect the exchange results: (i) the carbanion is generated *trans* to the lone pair on the sulphur; (ii) a deuteroxide ion is directed to a hydrogen which is *trans* to the polar S–O bond;[15] (iii) a solvated deuteroxide ion is directed *via* hydrogen bonding to a hydrogen which is *gauche* to oxygen and to the lone pair on sulphur.[16]



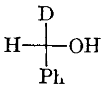
(I)



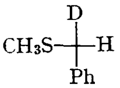
(II)

$Ph{\cdot}CHD{\cdot}SO_2{\cdot}CH_3$

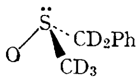
(III)



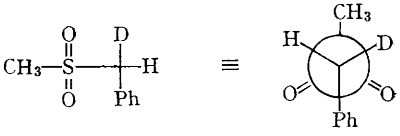
(IV)



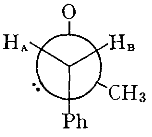
(V)



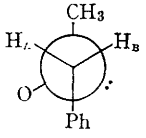
(VII)



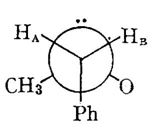
(VI)



(*a*)



(*b*)



(*c*)

Suppose that, despite the n.m.r. analysis given above, H_A is abstracted from (*b*); it would then have to be argued that the repulsion between the incipient carbanion and the lone pair controls the stereochemistry of the exchange since in (*b*) the steric retardation is greater for abstraction of H_A than for H_B. But H_B of (*a*) should then exchange equally readily since the resulting carbanion is in the same electronic environment and there would be little or no kinetic difference between H_A and H_B.[17] Since this is not in accord with the experimental facts, the conformation from which H_A is abstracted cannot be (*b*). All of the data, therefore, point to the abstraction of H_A from (*a*). This is not the result of a steric effect, however, since there would then be little or no rate difference between H_A of (*a*) and H_B of (*b*).[17]

We conclude that an electrostatic effect is responsible for the kinetic nonequivalence of the methylene protons and that an α-sulphinyl carbanion is generated preferentially in NaOD–D_2O by the abstraction of a proton which is situated on the bisector of the oxygen–sulphur–lone pair angle.

(*Received, August* 31*st*, 1966; *Com.* 643.)

---

[1] E. Buncel, E. A. Symons, and A. W. Zabel, *Chem. Comm.*, 1965, 173.

[2] A. Rauk, E. Buncel, R. Y. Moir, and S. Wolfe, *J. Amer. Chem. Soc.*, 1965, **87**, 5498.

[3] Summarized by D. J. Cram in "Fundamentals of Carbanion Chemistry", Academic Press, New York, 1965.

[4] W. E. Doering and A. K. Hoffman, *J. Amer. Chem. Soc.*, 1955, **77**, 521; R. L. Shriner, H. C. Struck, and W. J. Jorison, *ibid.*, 1930, **52**, 2060.

[5] D. J. Cram and S. H. Pine, *J. Amer. Chem. Soc.*, 1963, **85**, 1096.

[6] K. Mislow, M. M. Green, and M. Raban, *J. Amer. Chem. Soc.*, 1965, **87**, 2761.

[7] H. C. Brown and D. B. Bigley, *J. Amer. Chem. Soc.*, 1961, **83**, 3166.

[8] S. Wolfe and A. Rauk, *Canad. J. Chem.*, in the press.

[9] A. Streitweiser, Jr., J. R. Wolfe, Jr., and W. D. Schaeffer, *Tetrahedron*, 1959, **6**, 338.

[10] V. E. Althouse, D. M. Feigl, W. A. Sanderson, and H. S. Mosher, *J. Amer. Chem. Soc.*, 1966, **88**, 3595.

[11] C. W. N. Cumper, J. F. Read, and A. I. Vogel, *J. Chem. Soc.*, 1965, 5323; see also "Tables of Interatomic Distances", *Chem. Soc. Special Publ.*, No. 11, 1958.

[12] S. Wolfe, A. Rauk, and I. G. Csizmadia, to be published.

[13] J. B. Lambert and R. G. Keske, *J. Amer. Chem. Soc.*, 1966, **88**, 620.

[14] N. S. Bhacca and D. H. Williams, "Applications of NMR Spectroscopy in Organic Chemistry", Holden-Day, San Francisco, 1964, p. 28.

[15] D. J. Cram and A. S. Wingrove, *J. Amer. Chem. Soc.*, 1963, **85**, 1100.

[16] E. J. Corey and T. H. Lowry, *Tetrahedron Letters*, 1965, 793.

[17] The conclusion that the reaction would occur equally well from (*a*) and (*b*) follows from the Curtin–Hammett principle. See: E. L. Eliel, N. L. Allinger, S. J. Angyal, and G. A. Morrison, "Conformational Analysis", Interscience, New York, 1965, p. 28, for a discussion.