Conformations of Certain Acyclic Sulfoxide Alcohols

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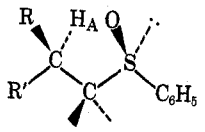
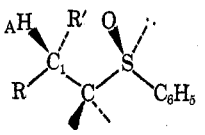
The nmr parameters of the four isomeric 1,2-diphenyl-2-phenylsulfinyl-1-ethanols are compared to the respective sulfides and sulfones. The greatest steric change occurs in going to the sulfoxide indicating that the sulfur oxygen is relatively more space demanding than the nonbonded pair. Hydroxyl splittings due to internal hydrogen bonding are discussed, and it is shown that the intramolecular hydrogen bond to the sulfoxide is less stable than the intermolecular hydrogen bond to DMSO. An instance of large long-range coupling to hydroxyl is given.

In several six-membered rings containing the sulfoxide group, the oxygen function has been shown to preferentially occupy the axial orientation.[1-6] However, the possibility that oxygen is less space demanding than the nonbonded pair at sulfur does not seem reasonable. The opinion has been expressed that an attractive interaction exists between the axial oxygen and the axial hydrogens at C-3 and C-5.[2] This viewpoint has been supported by calculations of conformer energies by the Westheimer method.[7] Recently, however, Johnson and Siegl reported a preference by sulfinyl oxygen for the pseudoequatorial position in a four-ring sulfoxide.[8]

In acyclic sulfoxides, such as **1**, molecular models suggest a preference by the *S*-phenyl group for the position shown, because of the acute C–S–phenyl bond angle (*ca.* 96°).[9] In studies of acyclic molecules, 1,3 interactions, similar to 1,3-diaxial interactions in a cyclohexane system, are usually very unfavorable.[10,11] Thus, an attractive interaction between oxygen and the C-1 hydrogen in conformer **1′** and/or a repulsive interaction between oxygen and R in conformer **1**, should stabilize **1′** compared to **1**.



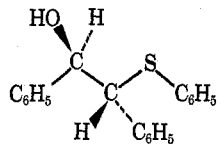
1



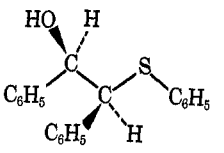
1′

The purpose of the present work is to study the conformational preferences of a series of sulfur-containing alcohols, with consideration given to the preferred orientation of major groups at sulfur. The compounds of interest (Chart I) include the isomeric sulfides **2** and **3**, which have only nonbonded electrons at sulfur, the four isomeric sulfoxides **4–7**, and the sulfones **8** and **9** which have two oxygens at sulfur. The structures shown (Chart I) imply predominant conformation as well as configuration at carbon. Configuration (not conformation) is implied for **5–7** at sulfur. In addition, the simpler alcohols **10** and **11** as well as **12** will be concidered briefly. The synthesis of compounds **2–9** will be covered in a later paper.

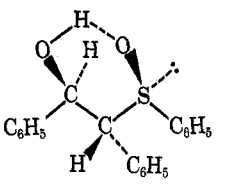
CHART I



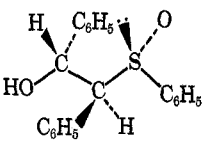
2 (threo)



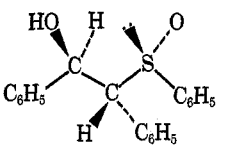
3 (erythro)



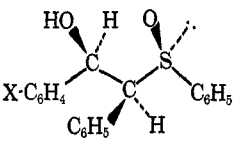
4 (threo)



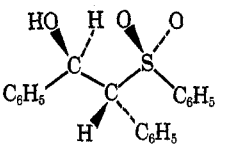
6 (erythro)



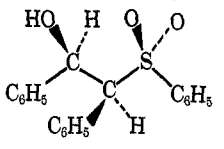
5 (threo)



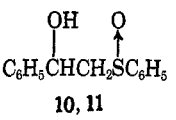
7 (erythro) **a**, X = H **b**, X = Cl



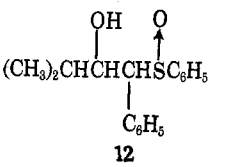
8 (threo)



9 (erythro)



10, 11



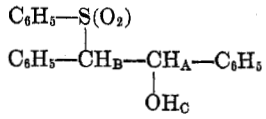
12

As Chapman and King[12] have shown, exchange of the hydroxyl proton is slowed in dimethyl sulfoxide (DMSO) solution due to strong hydrogen bonding. The slow exchange permits observation of couplings to the hydroxyl proton. Thus, in **1**, if R is hydroxyl, hydrogen bonded to the sulfinyl oxygen, a doublet hydroxyl resonance should be observed in chloroform. In any other conformation at sulfur, such coupling would be much less probable. Admittedly the possibility of a strong intramolecular hydrogen bond would

(1) J. C. Martin and J. Uebel, *J. Amer. Chem. Soc.*, **86**, 2936 (1964).
(2) C. R. Johnson and D. McCants, Jr., *ibid.*, **86**, 2935 (1964); **87**, 110 (1965).
(3) H. M. M. Shearer, *J. Chem. Soc.*, 1394 (1959).
(4) P. B. D. de la Mare, D. J. Millen, J. G. Tillett, and D. Watson, *ibid.*, 1619 (1963).
(5) C. Y. Chen and R. J. W. LeFevre, *Aust. J. Chem.*, **1**, 917 (1963).
(6) D. G. Hellier, J. G. Tillett, H. F. Van Woerden, and R. F. M. White, *Chem. Ind. (London)*, 1958 (1963).
(7) N. L. Allinger, J. A. Hirsch, and M. A. Miller, and I. Tyminski, *J. Amer. Chem. Soc.*, **91**, 337 (1969).
(8) C. R. Johnson and W. O. Siegl, *ibid.*, **91**, 2796 (1969).
(9) D. Martin, A. Weise, and H. J. Niclas, *Angew. Chem., Int. Ed. Engl.* **6**, 318 (1967).
(10) A. Dempster, K. Price, and N. Sheppard, *Chem. Commun.*, 1457 (1968).
(11) C. A. Kingsbury and D. C. Best, *J. Org. Chem.*, **33**, 3252 (1968).
(12) O. L. Chapman and R. W. King, *J. Amer. Chem. Soc.*, **86**, 1256 (1964).

TABLE I

NMR CHEMICAL SHIFTS AND COUPLING CONSTANTS



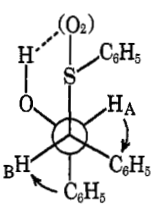
Compd	Mp, °C	Chemical shifts, ppm: H_A (CDCl₃)	H_B (CDCl₃)	H_A (TFA)	H_B (TFA)	J_{AB} (J_{AC}) in Hz, CDCl₃: 10%	5%	2.5%	1.3%	J_{AB} (J_{AC}) in Hz, DMSO
Sulfide										
2, threo[b]	76	4.94	4.35			8.6	8.6 (*ca.* 2.0)	8.6 (*ca.* 2.0)	8.7 (*ca.* 2.0)	6.0
3, erythro[b]	92	5.04	4.44				6.1 (3.8)	6.2 (3.6)	5.8 (*ca.* 3.0)	6.3 (4.8)
Sulfoxide										
4, threo	129	5.64	3.94	5.97	4.68	9.5	9.5 (1.8)	9.6 (1.8)	9.7	9.2 (4.2)
5, threo	196	5.62	3.95	5.91	4.61	*a*	*a*	10.2	~10.2	10.6 (5.0)
6, erythro	156	5.55	3.66	5.70	4.37	8.2	8.3	8.2	8.2	8.1 (5.2)
7b, erythro	196	5.87	3.68	5.97	4.48	*a*	2.9 (4.7)	2.8 (4.5)	2.8 (4.3)	3.1 (5.3)
Sulfone										
8, threo	118	5.70	4.46				9.9 (1.8)	10.0 (1.8)	9.8 (1.8)	10.1 (*ca.* 4.5)
9, erythro	135	6.03	4.19				2.5	2.5	2.7	3.4 (4.8)

[a] Insoluble. [b] These data are similar to those reported by D. J. Pasto, C. Cumbo, and J. Fraser, *J. Amer. Chem. Soc.*, **88**, 2194 (1966).

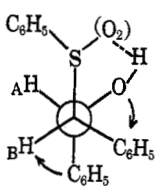
seem to make this study a special case; however, see the ensuing discussion.

The conformation of the carbon skeleton is approximated from the nmr coupling constants J_{AB}. Large values of J_{AB} (*ca.* 10–13 Hz) are taken as indicative of predominately trans protons. Small values for J_{AB} (*ca.* 1–3 Hz) reflect generally gauche protons, and intermediate values are indicative of weighted means of the above conformations.[13–15] The nmr data are recorded in Table I for **2**–**9**.

The threo sulfide **2**, J_{AB} = 8.6 Hz, preferentially occupies a conformation such as **13**, which facilitates hydrogen bonding.[16,17] The infrared hydroxyl absorption



13 (threo isomers)



14 (erythro isomers)

of **2** shows a more intense and stronger intramolecular hydrogen bonding ($\Delta\nu$ *ca.* 95 cm^{-1}) than is observed for the erythro compound **3** ($\Delta\nu$ *ca.* 35 cm^{-1}). As others have noted, deviation from a dihedral angle of 60° takes place to relieve the phenyl–phenyl interaction.[18–21] This internal rotation strengthens the hydrogen bond in the threo isomers **13** but weakens it for the erythro isomers **14**. The erythro sulfide **3**, $J_{AB} \sim$ 6 Hz, is conformationally mixed to a larger extent than the threo isomer **2**, J_{AB} = 8.6 Hz. However, the hydroxyl resonance is a doublet for both isomers at low concentrations in deuteriochloroform. The magnitude of the H_A–C–O–H_C coupling varies with the dihedral angle[22] similar to the relationship given by Karplus.[13] For **2** the magnitude of J_{AC} (*ca.* 2 Hz) is in accord with intramolecular hydrogen bonding. The larger value observed for **3** (3.6 Hz) is consistent with considerable rotational averaging. In DMSO solutions, hydrogen bonding to solvent occurs, resulting in still larger values for J_{AC}.

Moving from the sulfides to the sulfoxides, conformer **13** becomes still more highly populated for the threo isomers. Conformer **14** is clearly predominant for *erythro*-**7** (J_{AB} = 2.9 Hz), but **6** (J_{AB} = 8.3 Hz) prefers a conformer with trans protons. This observation was unexpected since in other examples the two erythro and the two threo isomers have occupied similar conformations.[11]

In *threo*-**4** a strong intramolecular hydrogen bond is present. The hydroxyl resonance is a doublet, J_{AC} = 1.8 Hz. This resonance (δ 5.88) does not shift upfield upon dilution, unlike those of **2**, **3**, and **5**–**7**. The infrared spectrum shows a very weak "free" hydroxyl absorption at 3580 cm^{-1}, and a broad, but concentration independent, absorption at *ca.* 3350 cm^{-1}. Structure **4** then completely describes the conformation at carbon and sulfur.

The second threo isomer **5** differs from **4** in the configuration at sulfur. No hydroxyl splitting is observed in the nmr spectrum. The infrared spectrum now shows a sizable free hydroxyl absorption in addition to the broad but concentration-dependent peak at 3350 cm^{-1}. The latter persists at low concentrations, however, and is considered to be a combination of the inter- and intramolecularly bound hydroxyl absorptions.[23] The apparent molecular weight (Table II) is indicative of some external association, possibly dimerization, even at low concentrations, unlike **4** which is monomeric. This technique, however, is less sensitive to external association than spectral techniques.[24]

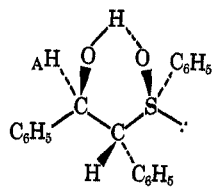
(13) M. Karplus, *J. Amer. Chem. Soc.*, **85**, 2870 (1963).
(14) R. J. Abraham and G. Gatti, *J. Chem. Soc. B*, 961 (1969).
(15) E. Garbisch, Jr., and M. Griffith, *J. Amer. Chem. Soc.*, **90**, 6543 (1968).
(16) (a) H. Szmant and J. J. Rigau, *J. Org. Chem.*, **31**, 2288 (1966); (b) R. J. Abraham and W. A. Thomas, *J. Chem. Soc.*, 335 (1965).
(17) P. Schleyer and R. West, *J. Amer. Chem. Soc.*, **81**, 3164 (1959).
(18) (a) L. P. Kuhn, *ibid.*, **80**, 5950 (1958); (b) J. Sicher, M. Cherest, Y. Gault, and H. Felkin, *Collect. Czech. Chem. Commun.*, **28**, 72 (1963); (c) L. P. Kuhn, R. Schleyer, W. Baitinger, Jr., and L. Eberson, *J. Amer. Chem. Soc.*, **86**, 650 (1964).
(19) J. B. Hyne, *Can. J. Chem.*, **39**, 2536 (1961), and related papers.
(20) M. E. Munk, M. Meilahn, and P. Franklin, *J. Org. Chem.*, **33**, 3480 (1968).
(21) H. Bodot, J. Fediere, Guy Pozard, and L. Pujol, *Bull. Soc. Chim. Fr.*, 2260 (1968).
(22) R. R. Fraser, M. Kaufman, P. Marand, and G. Govil, *Can. J. Chem.*, **47**, 403 (1969).
(23) A. L. Ternay and D. M. Chasar, *J. Org. Chem.*, **33**, 2237 (1968).
(24) M. Davies, "Hydrogen Bonding," D. Hadzi, Ed., Pergamon Press, New York, N. Y., 1959, p 393.

TABLE II
OSMOMETRIC APPARENT MOLECULAR WEIGHTS IN CHLOROFORM (CONCENTRATION, MG/ML)

Compd	Formula wt	Apparent molecular wt
4	322	310 (28.5),[a] 322 (0.7)
5	322	360 (10.8), 335 (0.7)
6	322	332 (14.1), 320 (0.7)
7a	322	328 (0.7)
7b	356.5	364 (5.50)
10	246	253 (25.0), 257 (12.5)
11	246	273 (25.3), 268 (17.6)

[a] Concentration in mg/ml; to convert to the same units used for the nmr studies (percentages), divide by 10.

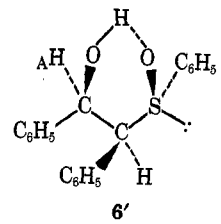
If conformer **5** were highly populated, the anisotropy of the sulfinyl group would be expected to deshield H_A by *ca.* 0.4 ppm.[23,25] On the other hand, if the alternate conformer **5′** were highly populated, H_A should be shielded by the *S*-phenyl by *ca.* 0.5 ppm.[11] The latter conformation permits hydrogen bonding but places the *S*-phenyl in a rather unfavorable conformation. Only



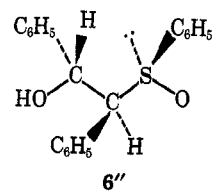
5′

a small shielding effect (0.02 ppm) is observed in comparison to the rigid structure **4** (Table I). The small change is believed to be due to population of both **5** and **5′** with cancellation of shielding and deshielding effects.

In the low-melting erythro isomer **6**, the predominant conformation prohibits both intramolecular association and dimerization. Accordingly, the infrared spectrum exhibits a strong "free" hydroxyl absorption and a relatively weak bonded hydroxyl absorption. The apparent molecular weight is close to that of the monomer. If the alternate conformation **6′** is considered, in which hydrogen bonding is possible, H_A would again be shielded by *S*-phenyl. Substantial shielding of H_A (δ 5.55) is indeed noted in comparison to the isomeric sulfoxide **7a** (δ 5.85). The vicinal coupling constant (J_{AB} = 8.6 Hz) is consistent with mostly **6** (or possibly **6″**), but some of the gauche H_A–H_B conformer **6′** is also present.



6′



6″

The fourth sulfoxide **7a** is extremely insoluble and therefore the more tractable para chloro analog **7b** was studied. The vicinal coupling constant, J_{AB} = 2.9 Hz, indicates gauche protons, and hydroxyl splitting is observed. However, the magnitude of J_{AC} (*ca.* 5 Hz) in chloroform is almost as large as that in DMSO, where external association exists. The hydroxyl coupling constant and chemical shift are concentration dependent (Table I). The apparent molecular weight indicates some external association, even at low concentration, which suggests that dimerization may compete with intramolecular association. Any intramolecular hydrogen bond would be weakened by partial internal rotation as in structure **14**. The infrared spectrum also indicates a substantial "free" hydroxyl absorption (Figure 1).

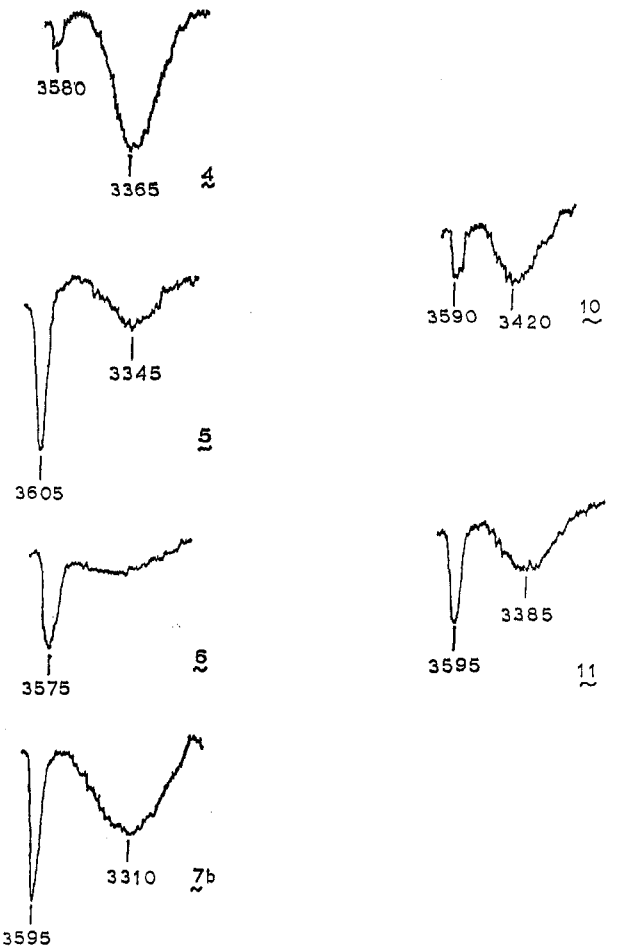


Figure 1.—The hydroxyl region of the infrared spectra of **4–7**, **10**, and **11**, taken at 0.5% concentration for **4–7**, 0.4% for **10**, and 0.44% for **11**. The solvent is deuteriochloroform.

In certain sulfoxides, Nishio has shown that the deshielding effect of trifluoroacetic acid (TFA), compared to carbon tetrachloride, was most pronounced for protons gauche to the sulfinyl oxygen and trans to the lone pair.[26] However, the four sulfoxides **4–7** were rather similar in their response to TFA compared to deuteriochloroform (Table I). In these cases, the partially protonated sulfinyl oxygen functions may occupy different conformations than the unprotonated species. Our interest in this technique was also chilled by observations on phenyl benzyl sulfoxide, which, in our hands, showed equivalent protons in either solvent.

Considering next the sulfones **8** and **9**, the J_{AB} values, 9.9 Hz and 2.5 Hz, are indicative of considerable conformational purity, on the same order as the sulfoxides **4**, **5**, and **7**. The infrared spectrum again shows

(25) (a) R. D. Cooper, P. DeMarco, N. Cheng, and N. Jones, *J. Amer. Chem. Soc.*, **91**, 1408 (1969); (b) C. R. Johnson and W. O. Siegl, *Tetrahedron Lett.*, 1879 (1969).

(26) (a) M. Nishio, *Chem. Commun.*, 564 (1968); (b) *ibid.*, 51 (1969). (c) For revised findings, see M. Nishio, *ibid.*, 1485 (1970).

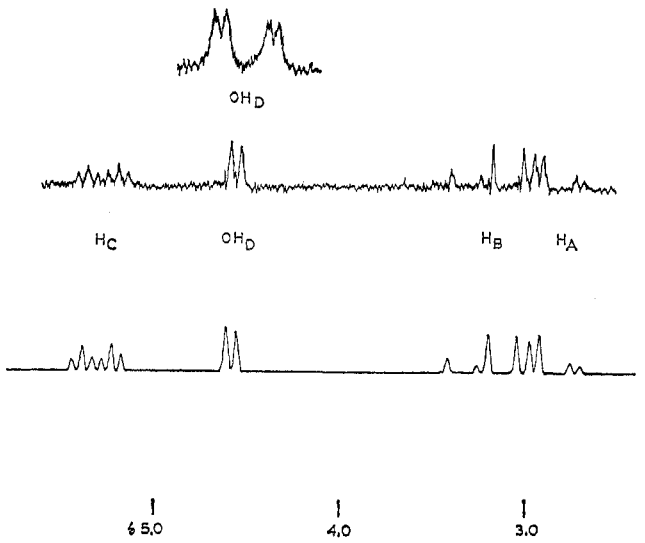


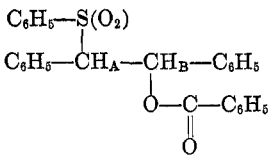
Figure 2.—Partial nmr spectrum of **11** showing the hydroxyl multiplet. The uppermost trace is a 100-Hz expansion of the hydroxyl multiplet. The lower trace is the computer simulation of the spectrum.

stronger hydrogen bonding for the threo isomer ($\Delta\nu$ 85 cm^{-1}), and hydroxyl splitting is observed for this isomer[27,28] ($\Delta\nu$ is *ca.* 45 cm^{-1} for the erythro isomer). The chemical shift of H_A of the sulfoxides **4**–**7** is rather similar to that of the sulfones **8** and **9**, but 0.5–0.9 ppm downfield from H_A of the sulfides **2** and **3**. The single sulfoxide oxygen appears to be almost as strongly deshielding as the two sulfone oxygens.[25] The general similarity of the chemical shifts of H_A in **4**–**7** suggests that the sulfinyl oxygen may be close enough in space to deshield H_A in conformers such as **1**, as well as in **1′**.

Returning to the question of the spatial requirements of the sulfinyl oxygen, sulfoxides **4** and **7** prefer the hydrogen-bonded conformation (although the bond probably is weak in **7**). The conformational preference at sulfur in *threo*-**5** is rather difficult to assess. However, it is clear that no strong preference for a hydrogen-bonded conformation exists, but whether this is due to the stability of a conformer such as **5** (in which the sulfinyl oxygen may attract H_A) or due to the instability of the hydrogen-bonded conformations is not known. The similarity of the conformation at carbon in **4** and **5** suggests that the orientation of the oxygen is not of overwhelming importance.[23,26c] With **6**, the high degree of shielding of H_A and H_B is not consistent with pure conformer **6** (or even considering an admixture of *ca.* 30% **6′**). Molecular models suggest the importance of a group of skewed conformations (one such conformation results from a partial internal rotation from **6** toward **6′**, another from **6** toward **6″**). Models suggest that H_A and H_B spend a great deal of their time over the face of the *S*-phenyl group and are thus shielded. The order of increasing general conformational purity, sulfides < sulfoxides ≤ sulfones, is similar to that usually observed upon increasing the size of one group.[29] This increase must be due to the presence of the oxygens, although the diminished C–S–phenyl angle is also a factor. The shape of the oxygens (or of the nonbonded pair at sulfur) may vary with the compound.[30–32]

In spite of the reputation of the sulfoxide group as a powerful hydrogen bond acceptor,[12,33] it is clear that this factor does not dominate the choice of conformation (*vide supra*). Thus, moving to DMSO as solvent results in a considerable change in the chemical shift (except for **4**) and coupling constant of the hydroxyl proton, which suggests that bonding to DMSO replaces intramolecular bonding. The esters of several of these compounds populate generally the same set of conformations as the parent alcohols (Table III).

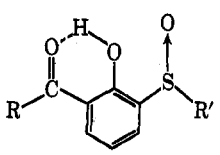
TABLE III
NMR CHEMICAL SHIFTS AND COUPLING CONSTANTS



	Chemical shifts in $CHCl_3$, ppm		Coupling constants, J_{AB} (in Hz)
	H_A	H_B	
threo-**2** OBz	4.74	6.38	7.6
erythro-**3** OBz	4.58	6.28	5.9
erythro-**7a** OBz[a]	3.98	6.98	3.3
erythro-**6a** OBz	4.02	6.76	8.7
threo-**8** OBz	4.93	6.92	10.1

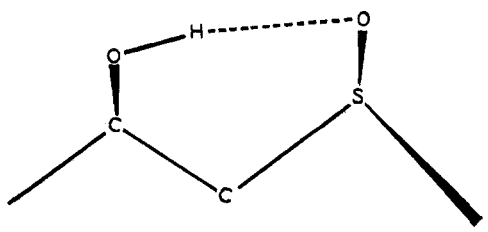
[a] The threo sulfoxide benzoates were inseparable, but coupling constants of 9.6 and 10.8 Hz were determined.

Some precedent for the weakness of the intramolecular hydrogen bond exists in the work of Chua and Hoyer,[34] who showed a preference to bonding to carbonyl over sulfoxide in **15**.



15

As the scale drawing in structure a indicates, the oxygen–oxygen distance (*ca.* 2.9 Å) is close to optimum for hydrogen bonding, and the O—H---O angle is nearly optimum, but the S—O---H angle (<90°) is very unfavorable.[21c]



a

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(31) P. Haake, W. B. Miller, and D. A. Tyssee, *J. Amer. Chem. Soc.*, **86**, 3577 (1964).
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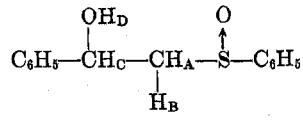
(33) I. Kolthoff, M. Chantooni, and S. Bhowmik, *ibid.*, **90**, 23 (1968).
(34) M. Chua and H. Hoyer, *Z. Naturforsch., B*, 416 (1968).

TABLE IV

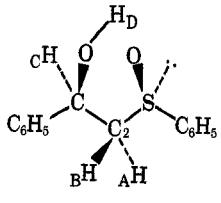
NMR CHEMICAL SHIFTS AND COUPLING CONSTANT IN 2-PHENYLSULFINYL-1-PHENYL-1-ETHANOL (10 AND 11)



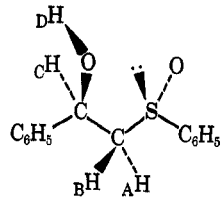
	Chemical shifts, ppm				Coupling constants, Hz				
	H_A	H_B	H_C	H_D	J_{AB}	J_{AC}	J_{BC}	J_{CD}	Other
				10% $CDCl_3$					
10	2.96	3.25	5.34	4.21	−13.2	3.3	9.6	~2.0	
11	2.79	3.21	5.30	4.58	−13.1	2.4	10.1	3.3	J_{AD} = 0.7
				5% Trifluoroacetic Acid-$CDCl_3$[b]					
10	3.41	3.95	5.36		−13.5	4.3	9.0		
11	3.51	3.55	5.49		−13.1	~1[a]	~11[a]		
				10% Benzene					
10	2.63	3.08	5.36		−12.8	3.2	9.3		
11	2.60	2.94	5.25		−12.4	2.0	10.4		

[a] Due to virtual degeneracy these coupling constants could not be determined with accuracy. [b] Equal volumes of each solvent.

In order to assess the effect of steric hindrance at C-2, the simple sulfoxides **10** and **11** were studied. The nmr data are recorded in Table IV and Figure 2. In **10**,



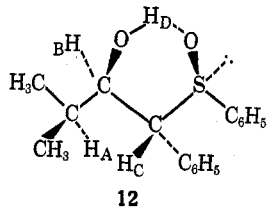
10



11

H_B is seen to be the more sensitive to TFA,[26] whereas proton H_A is the more sensitive in **11**. Both isomers show hydroxyl splitting, but that of **10** is more consistent with strong intramolecular association. The infrared spectra of both isomers show free hydroxyl absorptions at *ca.* 3595 cm^{-1} (CCl_4) but that of **10** is noticeably weaker (Figure 1). The bonded hydroxyl absorptions (*ca.* 3400 cm^{-1}) are somewhat concentration dependent but persist at low concentrations. The apparent molecular weights show **11** to be somewhat more externally associated (Table II). Thus the phenyl group at C-2 in **5–7** reduces external as well as some internal association, compared to **10** and **11**.

The final compound of interest, **12**, clearly is similar to **4** in its properties. The hydroxyl resonance is observed to be a triplet (Figure 3) due to equivalent three- and four-bond coupling to hydroxyl[35,36] (J_{AD} = J_{BD} = 1.6 Hz). The hydrogen bond to the sulfinyl group holds the hydroxyl group in a conformation favorable for long-range coupling, namely, the W arrangement.[35,36] The long-range coupling, J_{AD} =



12

J_{AB} = *ca.* 2Hz
J_{AD} = 1.6
J_{BC} = 10.0
J_{BD} = 1.6

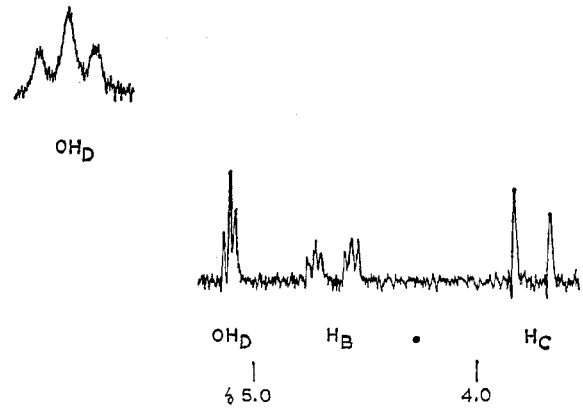


Figure 3.—Partial nmr spectrum of **12**, showing the hydroxyl triplet.

0.7 Hz, observed with **11**, is consistent with the W arrangement if a dimeric structure is postulated.

Experimental Section

The materials **2–9** were prepared and their configuration proven as will be reported in a later paper. The materials **10** and **11** were synthesized as follows.

To 31 g of styrene (0.298 mol) stirred in 150 ml of water plus 0.5 ml of concentrated H_2SO_4 was added 53 g of *N*-bromosuccinimide (0.241 mol) and the mixture allowed to stir overnight. The bromohydrin was taken up in 200 ml of ether, extracted several times with water, then extracted with dilute sodium bicarbonate solution, and dried ($MgSO_4$), and the solvent evaporated. The remaining oil showed the expected ABX pattern in the nmr spectrum. The oil was treated with 32.8 g of thiophenol (0.298 mol) and 16.6 g of potassium hydroxide and stirred in 150 ml of ethanol. The ethanol was evaporated by passing an air stream over the warmed solution in the hood. The remainder was taken up in ether and extracted with dilute hydrochloric acid and twice with an equal volume of water. The solution was dried ($MgSO_4$) and evaporated. Attempted vacuum distillation resulted in decomposition, and the product of another run (47 g, 0.101 mol) was oxidized directly with $NaIO_4$ (41 g, 0.191 mol). The sulfide was added to about 100 ml of methanol and the $NaIO_4$, dissolved in the minimum amount of water, was added in increments with stirring. Additional water or methanol was added from time to time to attempt to maintain a homogeneous solution. However, the precipitation of sodium iodate made this difficult. The final solution was stirred for 24 hr and filtered and extracted many times with chloroform. Each organic extract was monitored by nmr to see if additional sulfoxide was being removed from the aqueous layer. The combined chloroform layers were dried ($MgSO_4$) and evaporated, and crystallization

(35) J. C. Jochims, G. Taigel, A. Seeliger, P. Lutz, and H. Driesen, *Tetrahedron Lett.*, 4363 (1967), and later papers.

(36) C. Kingsbury, R. Egan, and T. Perun, *J. Org. Chem.* **35**, 2913 (1970).

was induced. The crude mixture of diastereomers was separated by the triangle scheme resulting in 10.4 g of **10** (mp 129.2–129.8°) and 8 g of **11** (mp 106.3–106.9°).

Anal. Calcd for $C_{14}H_{14}O_2S$: C, 68.27; H, 5.73. Found: C, 68.10; H, 5.55.

Anal. Calcd for $C_{14}H_{14}O_2S$: C, 68.27; H, 5.73. Found: C, 68.30; H, 5.72.

Compound **12** was prepared by generation of the lithium salt of phenyl benzyl sulfoxide and addition of this to isobutyraldehyde. Phenyllithium was prepared by adding 7.1 g of bromobenzene (0.046 mol) to 0.65 g of lithium stirred under nitrogen in 50 ml of ether. To this was added phenyl benzyl sulfoxide (9.0 g, 0.046 mol) dissolved in a minimum amount of tetrahydrofuran. To the resulting orange solution, isobutyraldehyde was added until the color was eliminated. The product was stirred 10 min and then added to NH_4Cl on ice. The product was taken up in warm chloroform (*ca.* 100 ml) and extracted twice with water and dried ($MgSO_4$). Separation by crystallization by the triangle scheme afforded some of two sulfoxides, mp 177–178° and 122–123°, and starting material, mp 125–126°. After a few cycles no more pure sulfoxides could be obtained. The remaining solutions were combined, concentrated, and chromatographed on a 2 × 26 cm column of Florisil.

The low-melting sulfoxide was eluted with 50% benzene in hexane yielding a total of 2.7 g from all sources. Then starting material was eluted (total of 0.9 g). Finally a mixture of sulfoxides and starting material was eluted with *ca.* 20% ether in benzene. From this more of the high-melting sulfoxide was obtained, mp 177–178° (2.2-g total). The remainder, 0.3 g, was a mixture of the high-melting sulfoxide and another sulfoxide which could not be further purified. Compound **12** melted at 122.5–123.5°.

Anal. Calcd for $C_{17}H_{20}O_2S$: C, 70.80; H, 6.94. Found: C, 70.38; H, 7.12.

The nmr spectra were determined on a Varian A-60D instrument. The coupling constants were determined from the average of several traces of expanded spectra. In order to observe hydroxyl splittings, the chloroform solvent had to be purified by distillation from barium oxide and used soon after distillation. It was belatedly found that Linde Molecular Seive 4A would keep the solvent free from hydrochloric acid. The ABX spectra of **10** and **11** were simulated using computer techniques until the calculated trace of the spectrum was superimposible on the original. The solvent DMSO was redistilled from molecular sieve. The ir spectra were determined on a Perkin-Elmer 237 instrument standardized *vs.* polystyrene. The absorptions quoted are considered reliable to ±5 cm^{-1}. The molecular weights were determined on a Hewlett-Packard osmometer standardized *vs.* benzil, using ethanol-free chloroform as solvent. The low concentration molecular weights were determined by Dornis and Kolbe, Mülheim, West Germany. Within the context of this work, a "free" hydroxyl infrared absorption is intended to signify a hydroxyl not bonded to sulfoxide. In the ir spectra, a weak absorption at 3700 cm^{-1} was noted which was considered spurious.

Registry No.—**2**, 28520-72-1; **2** OBz, 28520-73-2; **3**, 28455-72-3; **3** OBz, 28455-73-4; **4**, 28455-74-5; **5**, 28455-94-9; **6**, 28455-75-6; **6** OBz, 28455-76-7; **7a** OBz, 28455-76-7; **7b**, 28455-78-9; **8**, 28520-74-3; **8** OBz, 28455-79-0; **9**, 28520-75-4; **10**, 28455-80-3; **11**, 28520-76-5; **12**, 28455-81-4.

Reactions of Carbanions of Dimethyl Sulfoxide and Dimethyl Sulfone with Isocyanates, Isothiocyanates, and Other Electrophilic Reagents. Preparation of β-Amido and β-Thioamido Sulfoxides and Sulfones

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Reaction of the carbanions of dimethyl sulfoxide and dimethyl sulfone with isothiocyanates gave β-thioamido sulfoxides and β-thioamido sulfones, respectively (Table I, C and E). With isocyanates, the anion of dimethyl sulfone yields methylsulfonylmalonamides (D), whereas the anion of dimethyl sulfoxide gives a mixture of β-amido sulfoxides and methylsulfinylmalonamides (A and B).

Additions of the conjugate bases of dimethyl sulfoxide or dimethyl sulfone to esters,[1,2] Schiff bases,[1] aldehydes, and ketones[3] have led to the preparation of a variety of substituted sulfoxides and sulfones. In view of the proven usefulness of these compounds in organic synthesis,[4] and of our continuing interest in new carbon to carbon bond formations,[5] we have investigated the reaction of the carbanions of dimethyl sulfoxide and dimethyl sulfone with other electrophilic reagents, such as isocyanates, isothiocyanates, nitrile, isonitrile, and benzoxazinone.

Addition of phenyl isocyanate to a solution of sodium methylsulfinylmethide gave two readily separable compounds which were assigned structures **1** and **2** (Scheme I).

The structure assignment of compound **2** was based on elemental analysis and the following physical data: ν^{Nujol} 3280 (NH), 1680 (CO), 1040 cm^{-1} (SO); λ_{max}^{EtOH} 253 mμ (ε 25,400) (nearly twice as intense as the corresponding band of **1**); δ (DMSO) singlet at 4.91 (CH), two one-proton singlets in the $CONHC_6H_5$ region (confirmed by D_2O exchange) at 9.43 and 9.69 ppm. Compound **2** was readily cleaved to malonanilide in aqueous base. Compound **1** has been previously described;[6] spectral evidence supporting its structure is given in the Experimental Section.

Attempts at directing the synthesis toward exclusive formation of **2** by the use of a large excess of isocyanate resulted in lower yields of **2**. In line with this finding was the observation that the anion of **1** was converted to **2** very slowly, even in the presence of a large excess of isocyanate. This is perhaps surprising, since step **1** → **2** appears to be irreversible, as indicated by the failure to produce some **1** by treatment of **2** with sodium hydride.

(1) E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, **87**, 1345 (1965).

(2) (a) H. D. Becker and G. A. Russell, *J. Org. Chem.*, **28**, 1896 (1963); (b) H. O. House and J. K. Larson, *ibid.*, **33**, 61 (1968).

(3) (a) E. J. Corey and M. Chaykovsky, *J. Amer. Chem. Soc.*, **84**, 866 (1962); (b) G. A. Russell and H. D. Becker, *ibid.*, **85**, 3406 (1963).

(4) G. A. Russell and L. A. Ochrymowycz *J. Org. Chem.*, **34**, 3618 (1969).

(5) (a) M. von Strandtmann, M. P. Cohen, C. Puchalski, and J. Shavel, Jr., *ibid.*, **33**, 4306 (1968); (b) M. von Strandtmann, M. P. Cohen, and J. Shavel, Jr., *Tetrahedron Lett.*, **35**, 3103 (1965).

(6) N. Hellstrom and T. Lauritzson, *Ber.*, **69**, 1999 (1936).