The Stereochemistry of Sulfoxide in the Base-Catalyzed Hydrogen-Isotopic Exchange of Aryl-Methyl Sulfoxide[1]

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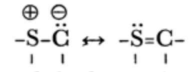
Because of the possible 3d orbital resonance of the following type:



$$\overset{\oplus}{\underset{|}{-S}}-\overset{\ominus}{\underset{|}{\ddot{C}}} \leftrightarrow -\underset{|}{\ddot{S}}=\underset{|}{C}-$$

the base-catalyzed hydrogen-isotopic exchange of the methyl or methylene group attached to a trivalent or tetravalent sulfur group has been known to take place very readily,[2] and the stereochemistry of both the sulfone and the sulfoxide stabilized carbanions have been pretty well worked out.[3,4]

When the incipient carbanion is presumed to be stabilized by a trivalent sulfur group, such as sulfinyl or sulfonio, an interesting problem is raised regarding the stereochemistry at the sulfur atom attached to the carbanion if one uses an optically-active sulfur group. A study of this kind would be quite significant, since it would answer the hitherto often-argued question of whether or not the π-bond between the sulfur atom and the carbon atom is of the 2p-3p overlapping type, with the promotion of the unshared outer valence electrons on the sulfur atom to a d-orbital, or if the π-bond is of the 2p-3d overlapping type.[5] That is, if the π-bond is of the 2p-3p overlapping type, the carbanion formation will result in the racemization of the trivalent sulfur group, while the retention of the configuration of the sulfur group will be observed if the carbanion is stabilized by a 2p-3d overlapping-type conjugation. Recently Cram et al. have observed a complete retention of the configuration of the sulfoxide group in the base-catalyzed racemization of optically-active 2-octyl phenyl sulfoxide, that has two asymmetric centers.[3c] We have chosen a simpler system, but with only one asymmetric center, namely, (+)-*p*-toly methyl sulfoxide, we have found that the base-catalyzed hydrogen isotopic exchange does not accompany the racemization of the sulfoxide group.

An optically-active *p*-tolyl methyl sulfoxide was prepared from the reaction of optically-active (−)-menthyl (−)-*p*-toluenesulfinate with methylmagnesium iodide[6] and was then subjected to base-catalyzed hydrogen isotopic exchange in various solvents in order to examine the possible racemization, along with the H–D exchange on the methyl group attached to the sulfoxide.

The solvents used were ethanol-d_1, *t*-butanol-d_1, and dimethyl sulfoxide. Ethanol-d_1 and *t*-butanol-d_1 were prepared from the reaction of deuterium oxide with sodium ethoxide and potassium *t*-butoxide respectively.[7]

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[1] Paper XII on Sulfoxides. XI; S. Oae, K. Kikukawa, N. Kunieda and W. Tagaki, This Bulletin, **39**, 614 (1966).

[2] a) J. Hochberg and K. F. Bonhoeffer, *Z. Physik. Chem.*, **184A**, 419 (1939); b) W. E. V. Doering and L. K. Levy, *J. Am. Chem. Soc.*, **77**, 509 (1955).

[3] a) D. J. Cram, W. D. Nielsen and B. Rickborn, ibid., **82**, 6415 (1960); b) D. J. Cram, D. A. Scott and W. D. Nielsen, ibid., **83**, 3696 (1961); c) D. J. Cram and A. S. Wingrone, ibid., **85**, 1096, 1101 (1963).

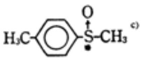
[4] a) S. Oae and C. C. Price, ibid., **80**, 3425, 4938 (1958); b) S. Oae, W. Tagaki and A. Ohno, ibid., **83**, 5036 (1961); c) S. Oae, "3d Orbital Resonance Involving the Sulfur Atom in Organic Sulfides," in "Org. Sulfur Compounds," Vol. IV, Ed. by N. Kharasch, Pergamon Press (in press).

[5] G. Suld and C. C. Price, *J. Am. Chem. Soc.*, **83**, 1770 (1961).

[6] K. Mislow, M. Green, P. Laur, J. T. Melillo, T. Simmons and A. L. Ternay, Jr., ibid., **87**, 1958 (1965).

[7] S. Oae, W. Tagaki and A. Ohno, *Tetrahedron*, **20**, 423 (1964).

TABLE I. THE BASE-CATALYZED HYDROGEN-DEUTERIUM EXCHANGE AND RACEMIZATION REACTION OF *p*-TOLYL METHYL SULFOXIDE

Sulfoxide	Solvent	Base	Molar ratio[a]	Temp. °C	Time hr.	H-D[b] Exchange %	$[\alpha]_D$
 [c]	C_2H_5OD[d]	C_2H_5ONa	(1 : 5 : 0.5)	30—35	15	60	+152°
	C_2H_5OD[d]	C_2H_5ONa	(1 : 10 : 0.5)	105—110	15	66	+148.7°
	$(CH_3)_3COD$[e]	$(CH_3)_3COK$	(1 : 10 : 0.5)	105—110	15	20	+149°
	$(CH_3)_2SO$	$(CH_3)_3COK$	(1 : 15 : 2)	105—110	15	—	+148.2°
	$(CH_3)_2SO$	$(CH_3)_3COK$	(1 : 20 : 5)	130—135	20	not recovered[f]	

a) The molar ratio is starting sulfoxide : solvent : base.

b) The deuterium contents were analyzed by means of infrared and nuclear magnetic resonance spectroscopy.

c) $[\alpha]_D^{25}+152.3°$ (*c* 2.68, ethanol).

d) Deuterium content: 70%.

e) Deuterium content: 60%.

f) The starting sulfoxide seems to be decomposed.

The sulfoxide was recovered quantitatively, and from its melting point, ultraviolet absorption, infrared and nuclear magnetic resonance spectroscopic analyses it was found to be identical with the starting sulfoxide, except that the sulfoxide recovered was found to have incorporated a considerable amount of deuterium at the methyl group. However, the sulfoxide was found to have retained its configuration completely. The experimental conditions and the results are shown in Table I.

Although a substantial hydrogen isotopic exchange was observed to occur at the *p*-methyl group at a high temperature and with a prolonged heating, only a very small amount of hydrogen isotopic exchange at the para methyl group was observed when the reaction was performed under the relatively mild conditions in which a substantial amount of hydrogen isotopic exchange was found to take place at the other methyl group.

Moreover, the configuration around the sulfur atom of the trivalent sulfur group is retained regardless of any change in the solvent used.

These observations appear to suggest strongly that the carbanion attached to a trivalent sulfur group such as sulfoxide is stabilized by the resonance involving the 2p-orbital of carbon and the 3d-orbital of sulfur.

Experimental

(−)-Menthyl (−)-*p*-Toluenesulfinate.—The sulfinate was prepared, according to the method reported by Mislow et al.,⁶⁾ from 18.8 g. of (−)-menthol and 21 g. of *p*-toluenesulfinyl chloride⁸⁾ to give 8 g. of (−)-menthyl (−)-*p*-toluenesulfinate. (60%) M. p. 105—106°C; $[\alpha]_D^{20}$ −201° (*c* 2.0, acetone).

(+)-*p*-Tolyl Methyl Sulfoxide.⁶⁾—To a solution of (−)-menthyl (−)-*p*-toluenesulfinate (6.2 g.) in anhydrous ether (50 ml.), an ether solution of methyl magnesium iodide (prepared from 5.36 g. of methyl iodide and 1.02 g. of magnesium was added drop by drop at room temp. After it had been stirred for an hour, the reaction mixture was quenched with aqueous ammonium chloride. The ether layer was separated, washed with water, and then dried over mangesium sulfate. After the ether had been removed, the residue was cooled in an ice bath, then the precipitate was filtered to give crude (+)-*p*-tolyl methyl sulfoxide, which was recrystallized from *n*-hexane. (3.0 g., 92%) M. p. 75—76°C; $[\alpha]_D^{25}$ +152.3° (*c* 2.0, ethanol). Lit.⁶⁾ m. p. 73—74°C; $[\alpha]_D^{25}$+145.5° (*c* 2.0, acetone).

The Base-catalyzed Hydrogen-deuterium Exchange and Racemization Reaction of (+)-*p*-Tolyl Methyl Sulfoxide.—The H–D exchange and racemization reaction of the sulfoxide was performed using both C_2H_5OD and *t*-BuOD as solvents. The bases used were sodium ethoxide and potassium *t*-butoxide. Ethanol-*O-d* and *t*-butanol-*O-d* were prepared from the corresponding alkoxides with deuterium oxide.⁷⁾ The deuterium contents were determined by means of infrared and NMR studies. The D content was about 70%. A typical run was as follows: optically active (+)-*p*-tolyl methyl sulfoxide (0.3 g.) and sodium ethoxide (0.052 g.) were dissolved in ethanol-*O-d* (0.46 g.) and sealed in a glass ampoule. The ampoule was then heated in an oil bath at 105—110°C. After it had been heated for 15 hr., the reaction mixture was evaporated and the sulfoxide was recovered by extracting it with ether. (0.2 g., m. p. 75—76°C from *n*-hexane.) The optical activity of the recovered sulfoxide was checked by using a polarimeter and found to be $[\alpha]_D^{25}$ +148.7° (*c* 2.68, ethanol). The deuterium content of the methyl group attached to the sulfoxide was determined by NMR spectra.

Found: 60—66% (τ=7.27 singlet.).

When DMSO was used as a solvent, the racemization reaction of the sulfoxide was carried out with only one base, namely, potassium-*t*-butoxide.

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8) "Organic Syntheses," Coll. Vol. 4, 937 (1963).