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OXYGEN EXCHANGE AND RACEMIZATION REACTIONS OF SULFOXIDES IN ACETIC ANHYDRIDE (1)

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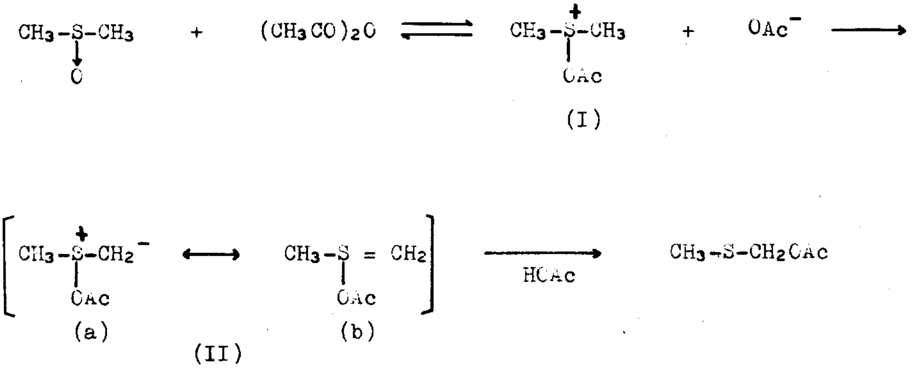
In the previous paper (2), we have shown that sulfoxides undergo concurrent oxygen exchange and racemization reactions through an acid catalyzed SN_1 type process in weak carboxylic acids. In this communication, we would like to report another oxygen exchange reaction of aromatic sulfoxides in acetic anhydride, which appears to proceed through an SN_2 type route.

Earlier, we have suggested (3) on the basis of ^{18}O tracer experiments with ^{18}O-labeled acetic anhydride that the Pummerer reaction of dimethyl sulfoxide with acetic anhydride proceeds through an intermolecular nucleophilic attack of acetoxy group on the methylene carbon of the ylide-ylene intermediate II.



$$CH_3-\underset{\substack{\downarrow\\ O}}{S}-CH_3 + (CH_3CO)_2O \rightleftharpoons CH_3-\overset{+}{\underset{\substack{|\\ OAc}}{S}}-CH_3 + OAc^- \longrightarrow$$

(I)

$$\left[CH_3-\overset{+}{\underset{\substack{|\\ OAc}}{S}}-CH_2^- \longleftrightarrow CH_3-\underset{\substack{|\\ OAc}}{S}=CH_2\right] \xrightarrow[HOAc]{} CH_3-S-CH_2OAc$$

(a) (II) (b)

However, the rather fast interchange of alkoxy group in the following reactions found recently by Johnson and Phillips (4) casts doubt on the significance of

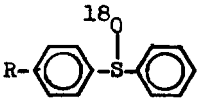
our ^{18}O tracer experiments, since a facile acetoxy interchange could also take place within the salt I. In fact, the acetoxy interchange appears to be quite facile in this case and a thorough kinetic investigation of the rearrangement is now underway in these laboratories.

Meanwhile, we have investigated the oxygen exchange and racemization reactions of a few unsymmetrical diaryl sulfoxides in acetic anhydride in order to focus our attention only on the acetoxy interchange. The reactions were carried out by heating both optically active and ^{18}O-labeled sulfoxides in a large excess of acetic anhydride while the sulfoxides employed in this study were p-toryl phenyl, p-chlorophenyl phenyl and diphenyl sulfoxides. The rates of ^{18}O exchange and racemization together with the other pertinent data are shown in Table I.

Several significant informations can be deduced from the kinetic data. The fact that the rate of racemization, k(rac), of p-toryl phenyl sulfoxide was twice of that of the oxygen exchange, k(exch), suggests the reaction to involve S_N2 type inversion at the rate determining stage. The energy and the entropy of an activation for this reaction were found to be 19.2 kcal/mole and -28.6 e.u., respectively. The small value of the entropy of activation also accords well with the suggested mechanism. Incidentally in the ^{18}O exchange reactions which is presumed to proceed through a S_N1 type path in both nitrogen tetraoxide and sulfuric acid, k(exch)/k(rac) is unity, and the entropies of activation of both reactions are substantially large and positive (5).

TABLE I

Kinetic Data on Oxygen-Exchange and Racemization Reaction in Acetic Anhydride[a)]

R in 	Added Salt	k(rac) x 10^5 (sec^{-1})	k(exch) x 10^5 (sec^{-1})
CH_3 [b)]		9.97 ± 0.35	5.00 ± 0.20
"	CH_3COONa [c)]	2.35 ± 0.10	
"	$NaClO_4$ [d)]	497. ± 22.	275. ± 45.
Cl [e)]			3.97 ± 0.55
H [f)]			4.68 ± 0.42

a) Sulfoxide, 0.005 mole was reacted with 0.5 mole of acetic anhydride, namely, the mole ratio was kept at 1 : 100. Each kinetic run was carried out at 120° (± 0.03°C), while the sulfoxide, recovered quantitatively after the treatment by quenching the solution, and was subjected to both the usual ^{18}O analysis and the measurement of the optical rotation.

b) Optical rotation, $[\alpha]_D^{20} = + 26.90°$; ^{18}O content = 1.06 atom%.

c) NaOAc, 0.001 mole in 0.5 mole Ac_2O.

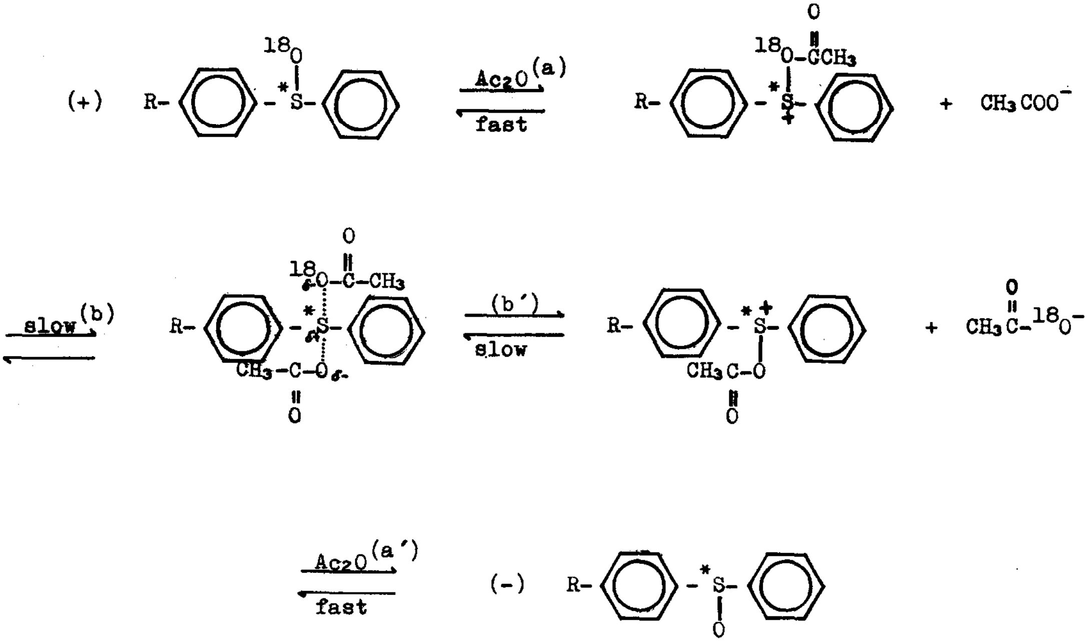
d) $NaClO_4$, 0.001 mole in 0.5 mole Ac_2O.

e) ^{18}O content = 1.05 atom%.

f) ^{18}O content = 0.89 atom%.

The remarkably small effects of the substituents also support the S_N2 type mechanism, since the reaction is expected to pass through an ideal transition state in which both the entering and the leaving groups are identical and the polar effect of substituent is considered to be cancelled and therefore diminished in such a case (6). Thus, the over-all process of the reaction can be illustrated in Fig. I.

Fig. I.



It is known that the acetate ion once formed undergoes a rapid interconversion with acetic anhydride as represented by equation 1. (7).

$$CH_3\overset{O}{\overset{\|}{C}}-{}^{18}O^- + CH_3-\overset{O}{\overset{\|}{C}}-O-\overset{O}{\overset{\|}{C}}-CH_3 \rightleftharpoons CH_3-\overset{O}{\overset{\|}{C}}-{}^{18}O-\overset{O}{\overset{\|}{C}}-CH_3 + CH_3-\overset{O}{\overset{\|}{C}}-O^- \qquad (1)$$

Therefore ${}^{18}O$-incoporated acetate ion once cleaved will be quickly diluted away by the rapid interchange with a bulk of acetic anhydride.

The marked retardation of the rate of racemization by the addition of common salt is obviously due to the shift of the equilibrium (a) to the left hand side. A similar, though small, negative common salt effect was known in a few rearrangement reactions of heteroaromatic N-oxides and acetic anhydrides (8). Meanwhile the remarkable large acceleration of the rate of racemization by the addition of sodium perchlorate is also presumed to be caused by the shift of the equilibrium (a) to the right hand side because of the increase of the ionic strength of the medium.

A Similar magnitude of rate acceleration by the addition of perchlorate ion was also observed in the reaction of quinaldine N-oxide and acetic anhydride (9).

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