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THE MECHANISM OF THE REACTION OF PHENYL METHYL SULFOXIDE WITH ACETIC ANHYDRIDE (1)

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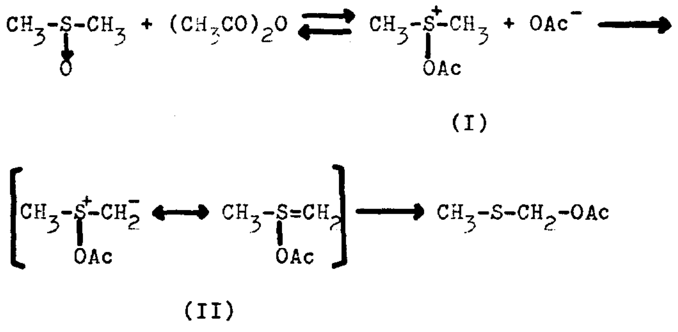
Earlier, we have suggested (2) on the basis of ^{18}O tracer experiments with ^{18}O-labelled acetic anhydride that the Pummerer reaction of dimethyl sulfoxide with acetic anhydride proceeds through an intermolecular nucleophilic attack of acetoxy group on the methylen carbon of the ylide-ylene intermediate II. However, relatively facile acetoxy interchange with the salt II casts doubt on the significance of our previous ^{18}O tracer experiments (3).



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

$$\left[CH_3-\underset{OAc}{\overset{+}{S}}-CH_2^- \longleftrightarrow CH_3-\underset{OAc}{S}=CH_2\right] \longrightarrow CH_3-S-CH_2-OAc$$

Meanwhile in order to fully understand the over-all feature of the reaction, the kinetic investigation of the reaction has been desired.

We now have made sufficient observations on the over-all rates of the Pummerer reaction of a few p-substituted phenyl methyl sulfoxides and also that of the concurrent oxygen exchange. The rate of the Pummerer reaction can be readily followed spectrophotometrically, taking an advantage of the difference of UV spectra of the starting and the final compounds.

When the reaction was carried out in dioxane, the rate was found to be carelated by the second order equation, i.e, $v = k_2 [PhSOCH_3] [Ac_2O]$ The over-all rates of a few p-substituted phenyl methyl sulfoxides were determined and the results are listed together with those of trideuterated compounds in Table I. The rates are nicely correlated with the Hammett equation and a negative ρ value, -1.60, was obtained.

TABLE I

Kinetic Data on Pummerer Reaction in Acetic Anhydride

R_1 R_2 in R_1--SO-R_2 [a]		k_H (sec^{-1})	k_D (sec^{-1})	k_H/k_D
R_1	R_2			
CH_3	CH_3	2.07×10^{-4} (0.10)		
H	CH_3	1.09×10^{-4} (0.22)		2.9
H	CD_3		3.67×10^{-5} (0.42)	
Cl	CH_3	4.00×10^{-5} (0.08)		
NO_2	CH_3	6.12×10^{-6} (0.24)		2.8
NO_2	CD_3		2.15×10^{-6} (0.11)	

a) Sulfoxide, $0.4 \sim 0.6 \times 10^{-4}$ mole l^{-1}, was reacted with acetic anhydride and no solvent was used. Each kinetic run was carried out at 120°C.

When one looks at only the rate variation of p-substituted phenyl methyl sulfoxides, it appears as if the 1 st. step of the reaction, i.e, the acetylation is the rate-determining step of the reaction. However, the kinetic isotope affect,

k_H/k_D = 2.85 indicates that the rate-determining step is the succeeding step of the reaction, namely the proton removal by acetate ion. The relatively small value of the kinetic isotope effect, is due mainly to the fact that the 1 st. step of the reaction requires also a substantial energy of activation, like in the reaction between quinaldine N-oxide and acetic anhydride (4).
Here too, the addition of sodium perchlorate and acetic acid was found to accelerate the over-all rate by 3 fold and 4 fold, respectively. Apparently the addition of perchlorate tends to shift the equilibrium to the right hand side, to increase the concentration of the acetoxy sulfonium salts, thus increasing the rate of the Pummerer reaction. Meanwhile, the addition of both sodium perchlorate and acetic acid was found to increase the rate of the reaction of the acyloxy exchange markedly. The energy and the entropy of an activation for Pummerer reaction were found to be 21.8 Kcal/mole and -20.7 e.u., respectively. The over-all picture of the reaction can be depicted shown below.*
We have measured the rate of racemization of an optically active tolyl methyl sulfoxide in acetic anhydride, in order to estimate the rate of concurrent oxygen exchange during the reaction. The results are listed together with the rates of Pummerer reaction in Table II.

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* A similar mechanism was recently suggested by Professor C. R. Johnson (Private Communication).

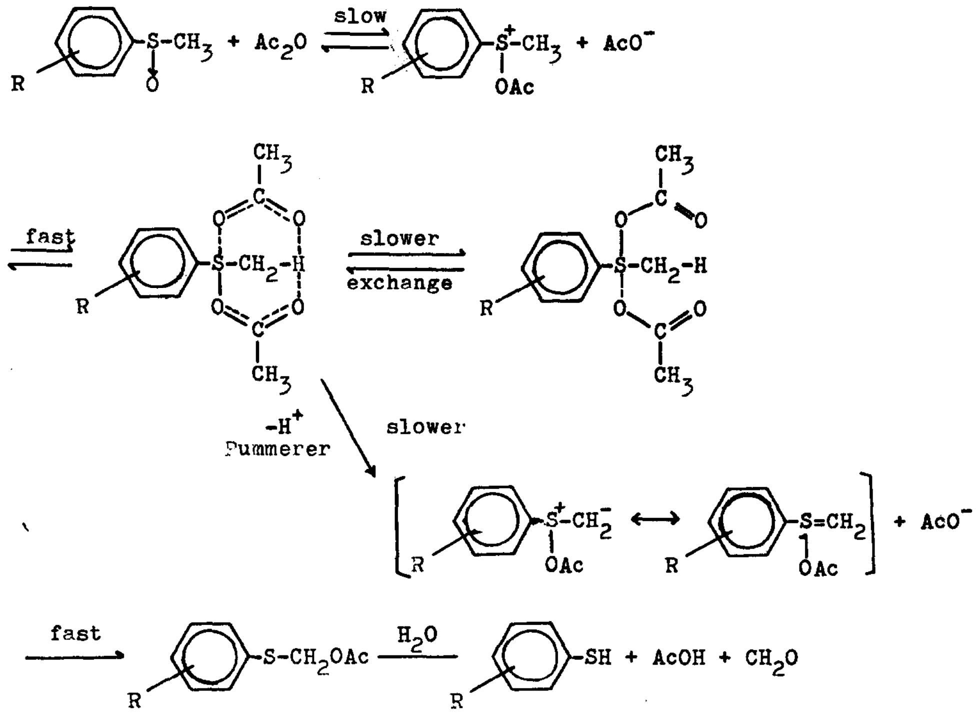

TABLE II.

Kinetic Data on Pummerer and Racemization Reaction in Acetic Anhydride[a)]

kobs. / Temp. (°C)	x 10^4 k racemization[b)] (sec^{-1})	x 10^4 k pummerer (sec^{-1})	x 10^4 2 k exchange (sec^{-1})	kpummerer / kexchange
100	0.720 (0.04)			
110	1.25 (0.19)	0.853 (0.037)	0.397	4.3
120	2.35 (0.06)	1.77 (0.12)	0.610	5.8
130	4.48 (0.09)	3.53 (0.05)	0.950	7.4

a) Sulfoxide. 0.4~0.6 x 10^{-4} mole. l^{-1} was reacted with acetic anhydride and no solvent was used. This reaction was carried out at 120°C in sealed tube.

b) k racemization = k pummerer + 2 k exchange is assumed.

Apparently, the rate of Pummerer reaction takes place much faster than the possible oxygen exchange reaction, suggesting that our earlier ^{18}O experiment may be still significant in the interpretation of the mechanism, though both the S-O bond cleavage and the succeeding formation of the ester are considered to be so fast that these steps can not be important in the energy profile of the over-all reaction.

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b) S. Oae and M. Kise, Tetrahedron Letter, 1409 (1967)

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