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THE REACTION OF DIARYL DISULFIDES WITH PYRIDINE N-OXIDES[1)]

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Pyridine and substituted pyridine N-oxides are known to be reduced by treatment with electrophilic sulfur compounds, such as p-nitrobenzenesulfenyl[3), 4)] and sulfinyl chloride[4), 5)]. Heteroaromatic amine oxides are also known to be deoxygenated by heating with sulfur[6)]. This reaction could be interpreted as another example of the nucleophilic attack on sulfur molecule by heteroaromatic amine oxides, since these amine oxides are weakly basic[7)].

We have found that the reaction of diaryl disulfides with pyridine N-oxide also leads to the deoxygenation of the N-oxide with the formation of diaryl disulfide and arylsulfonic acid, in nearly quantitative yields (in the ratio of 3/4 : 1/4 from 1 part of disulfide). This reaction is quite interesting because of the following reasons.
1) If the initial reaction would be the nucleophilic attack of pyridine N-oxide on the sulfur atom of diaryl disulfides, a kinetic study on unsymmetrical diaryl disulfides would reveal whether or not the transition state of the reaction involves the participation of the 3d orbitals of the central sulfur atom forming a sdp^3 configuration, since the electronic requirements of the reactive site in a typical SN_2 process, another alternative route, are considered to be different. Namely, a SN_2 path will be facilitated much less by the substitution of electron-withdrawing group than the other path involving the 3d orbitals of the sulfur atom[8)].
2) The same kinetic investigation on unsymmetrical disulfides bearing common aryl group will clarify the possibility of another possible mechanistic route, the oxidation of the disulfide by pyridine N-oxide. 3) Analyses of products of the reactions of unsymmetrical disulfides will also disclose which sulfur atom of the disulfide linkage is preferrably attacked.
Thus the reactions have been carried out with one symmetrical and three unsymmetrical diaryl disulfides. The reaction conditions, products isolated are tabulated in Table I together with

TABLE I.

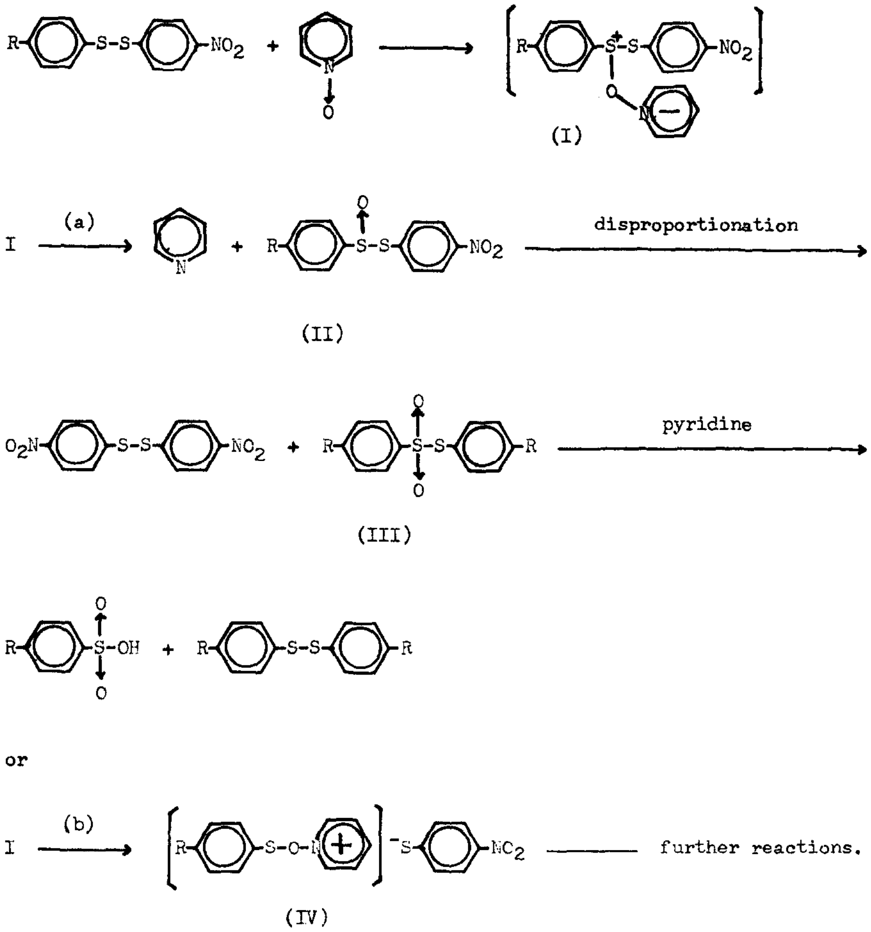
Reaction Condition, Products (other than Pyridine) and Kinetic Data of the Reaction of Various Diaryl Disulfides with Pyridine N-oxide

Disulfide	(m.p.)	Temp. (hrs)	Products (other than Pyridine)	Second-order Rate const. in Bromobenzene k_2(l/mole. sec)
⌬-S-S-⌬-NO_2	93-94°	150-160° (7 hrs)	(O_2N-⌬-S)$_2$, (PhS)$_2$, ⌬-SO_3H	6.27×10^{-2}
O_2N-⌬-S-S-⌬-NO_2	178-179°	180° (4 hrs)	(C_2N-⌬-S)$_2$, O_2N-⌬-SO_3H	3.75×10^{-2}
CH_3O-⌬-S-S-⌬-NO_2	67-68°	160° (3 hrs)	(O_2N-⌬-S)$_2$, (CH_3O-⌬-S)$_2$, CH_3O-⌬-SO_3H	3.10×10^{-1}
Cl-⌬-S-S-⌬-NO_2	52-53°	160° (3 hrs)	(O_2N-⌬-S)$_2$, (Cl-⌬-S)$_2$, Cl-⌬-SO_3H	1.18×10^{-1}

the kinetic data. With symmetrical di(p-nitrophenyl) disulfides, pyridine, di(p-nitrophenyl) disulfides, and p-nitrobenzene sulfonic acids are the products. Whereas with all the unsymmetrical aryl p-nitrophenyl disulfides, pyridine, diaryl and di(p-nitrophenyl) disulfides and arylsulfonic acids, and in no case p-nitrobenzenesulfonic acid was obtained suggesting that the attack of the N-oxide takes place on the sulfur atom attached to the less electron-withdrawing aryl groups.

The kinetic experiments were performed in bromobenzene by determining the amount of unreacted pyridine N-oxide through U.V. spectrophotometry and the rate was found to be of 2nd order with respect to both disulfide and the amine oxide.

The logarithm of the rate constants are nicely correlated with σ^+ values with the value of $\rho = -0.7$, but not with normal Hammett σ values. These observations reveal that pyridine N-oxide acts as an electrophile in this reaction and the transition state of the reaction is somewhat electron-demanding like the oxidation of olefin[9)] or disilanes with peracid.[10)] Therefore the reaction is not initiated by the nucleophilic attack of pyridine N-oxide, but is an oxidation of the disulfide by the amine oxide. In keeping with these observations, more basic 4-methoxypyridine N-oxide (pKa = 2.05 cf. pKa for pyridine N-oxide = 0.79) was found not react at all with di-(p-nitrophenyl) disulfide under the same condition for pyridine N-oxide. Thus the reaction may be formulated as shown below.



Once passing through a complex I, the reaction could proceed through either the path (a) involving the formation of II or the route (b) that involves IV which undergoes further reactions reported earlier$^{4)}$. To make a choice between these two possibilities we need further work which is now in progress.

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