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AN INTRIGUING COPPER SALT EFFECT UPON THE PHOTOCHEMISTRY OF PYRIDINE-N-OXIDES. SPECIFIC PHOTOINDUCED SYNTHESES OF 3-SUBSTITUTED 2-FORMYLPYRROLES[1]

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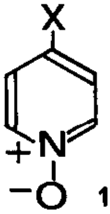
Ultraviolet irradiation of pyridine-N-oxides in water leads to the isomeric 2-formylpyrroles. Copper salts, and especially copper sulfate and copper perchlorate, dramatically increase the yields of the corresponding pyrrole aldehydes.

The photochemistry of heteroaromatic N-oxides has been studied extensively[2]. For example pyridine-N-oxides 1 undergo photoinduced rearrangement to the isomeric 2-formylpyrroles 2, albeit in low yield[3], the main photoproduct being an insoluble material which has not been analysed[4]. Simultaneously photoinduced oxygen abstraction takes place and leads to the parent pyridines[5]. Since the photolytic reaction is enhanced by triplet sensitisers[5], it was thought that the use of triplet quenchers would orient the photoreaction preferentially toward the ring contraction pathway.

Piperylene proved to be inefficient. Therefore we turned our attention to transition metal salt complexes in which the metal is known to act as a triplet quencher[6]. UV irradiation was performed in water solution with a few pyridine-N-oxide complexes[7]. As can be seen from Table 1 the copper nitrate complex leads to a dramatic increase in 2-formylpyrrole formation[8] whereas the paramagnetic cobalt and nickel complexes, as well as the diamagnetic zinc complex[7], do not seem to have any influence upon the photochemistry of the *N*-oxide ligand.

Table 1 Yield of 2-formylpyrrole obtained from the UV irradiation of various pyridine-N-oxide metal complexes in water solution.

pyridine-N-oxide transition metal complexes	yield of 2-formylpyrrole
C_5H_5NO uncomplexed	2%
$Co(C_5H_5NO)_6\ (ClO_4)_2$	2%
$Ni(C_5H_5NO)_6\ (ClO_4)_2$	2%
$Zn(C_5H_5NO)_2\ Cl_2$	2%
$Cu(C_5H_5NO)_2\ (NO_3)_2$	26%



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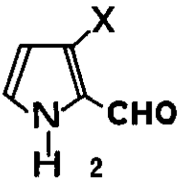

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a) X = H
b) X = CH_3
c) X = OCH_3
d) X = $OCH_2C_6H_5$
e) X = C_6H_5
f) X = Cl
g) X = CN

Furthermore it was found that UV irradiation of a copper salt water solution of pyridine-N-oxide leads to the same type of results; optimized experimental conditions require a copper/

ligand ratio of about 10, instead of only 0.5 for the copper nitrate complex. The copper salt anions also have some influence upon the yield of 2-formylpyrrole formation, the best results being obtained with copper sulfate (42%) and copper perchlorate (40%); copper acetate and copper nitrate give somewhat lower yields (30% and 29% respectively) whereas copper chloride leads only to 20% yield of 2-formylpyrrole. In order to simpflify matters, only 4-substituted pyridine-N-oxides are described in this communication (Table 2). 2- and 3-Substituted pyridine-N-oxides lead to more complex results[9].

Table 2 Yields of 2-formylpyrroles 2 obtained by UV irradiation of the corresponding pyridine-N-oxides 1 in the presence and in the absence of copper sulfate in water solution.

	2a	2b	2c	2d	2e	2f	2g
without $CuSO_4$	2.0%	1.5%	12%	4.5%	6.0%	1.6%	4.0%
with $CuSO_4$	42%	32%	40%	32%	33%	35%	40%

In a typical experiment a solution of 4-methoxypyridine-N-oxide 1c (5.0g; 0,04 mole/l) and copper^{II} sulfate (64g; 0.4 mole/l) in 2 l. distilled water[10] is irradiated at room temperature through quartz glass in a classical immersion well photoreactor by means of two 125W mercury high pressure lamps. After disappearance of the starting material, as monitored by UV spectroscopy and by thin layer chromatography, the water solution is saturated with sodium chloride and extracted several times with chloroform. The organic solutions are dried over sodium sulfate and evaporated to dryness in vacuo. The remaihing solid material is sublimed and yields 2.0 g of 2-formyl-3-methoxypyrrole 2c; m.p. 135-136° [UV (H_2O) λ_{max}294 nm (ϵ: 19,900); IR ($CHCl_3$) ν (N-H) 3470 and 3250 cm^{-1}, ν (C-H aldehyde) 2840 cm^{-1}, ν (C=O) 1640 cm^{-1}; NMR $^1H(CDCl_3)$ δ ppm 10.6-12 (1H; large band which disappears in the presence of D_2O), 5.80 (1H; H-4; triplet which becomes a doublet in the presence of D_2O; J=2.7 Hz), 6.85 (H-5; quartet after treatment with D_2O, J_1= 2,6;J_2=2,6), 3.75 (CH_3, singlet) and 9.40 (1H; CHO; doublet; J=1.0 Hz); ^{13}C NMR ($CDCl_3$): δ ppm: 118.95 (C-2), 159.14 (C-3), 95.40 (C-4), 127.23 (C-5), 175.41 (CHO) and 57.97 (CH_3)[11]. If the reaction mixture, instead of being sublimed, is chromatographed over silica gel, one isolates in addition to pyrrole 2c, 4-methoxypyridine in 4% yield; in the absence of copper salt this compound is isolated in 2% and the pyrrole 2c in 12% yield only. The difference is even more pronounced with the unsubstituted pyridine-N-oxide 1a since pyridine is obtained in 11% yield in the presence, versus only 2% in the absence of copper salt.

The results obtained with various copper salt anions seem to parallel those which have been found by Kochi during the photoinduced oxidative cleavage of biacetyl leading to acetic acid[12]: copper sulfate and copper perchlorate proved to be twice as effective oxidizing agents when compared to copper chloride. Since there is no change in the oxidation level during the photoinduced rearrangement of pyridine-N-oxides toward the corresponding 2-formylpyrroles, one would assume a reversible electron transfer to occur from and to some unknown intermediates[13]. As to the initial hypothesis of a triplet quenching mechanism, it has to be ruled out, oxygen abstraction having been increased in the presence of a copper salt instead of being reduced or suppressed.

The copper salt effect, which we have observed during the photochemistry of pyridine-N-oxides, is of interest in preparative organic chemistry since new and specifically substituted 2-formylpyrroles are easily obtained. These pyrroles can be used as synthons, for example in the syntheses of peculiar porphyrin molecules.

REFERENCES

1. Photochemistry of Heteroaromatic-N-Oxides, paper X. Preceding publication: F.Bellamy, P.Martz and J.Streith, Tetrahedron Letters, 1974, 3189
2. G.C.Spence, E.C.Taylor and O.Buchardt, Chem.Rev., 1970, 70, 231
3. J.Streith and C.Sigwalt, Tetrahedron Letters, 1966, 1347; Bull.Soc.chim.France, 1970, 1157
4. The I.R.spectrum of this solid material, measured with a KBr disc, shows an absorption band at 2200 cm^{-1} (polyacrylonitrile?)
5. J.Streith, B.Danner and C.Sigwalt, Chem.Comm., 1967, 979
6. R.S.Becker and M.Kasha, J.Amer.Chem.Soc., 1955, 77, 3669; L.Pekkarinen and H.Linschitz, ibid., 1960, 82, 2407; R.Livingston and E.Enzimori, ibid., 1958, 80, 5610
7. R.G.Garvey, J.H.Nelson and R.O.Ragsdale, Coordin.Chem.Rev., 1968, 3, 375

8. F.Bellamy, L.G.Ruiz-Barragan and J.Streith, Chem.Comm., 1971, 465

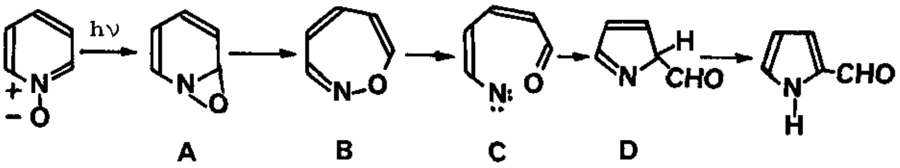
9. F.Bellamy, DSc.thesis, Université Louis Pasteur, Strasbourg, and Centre Universitaire du Haut-Rhin, Mulhouse,1974

10. These are optimal conditions as found experimentally.

11. All analytic data (elementary microanalyses; UV, IR, ^{1}H and ^{13}C NMR and mass spectra) fit with the proposed structures for the newly described pyrroles.

12. H.E. De la Mare, J.K.Kochi and F.F.Rust, J.Amer.Chem.Soc., 1963, 85, 1437

13. Merely as a hypothesis we propose the following mechanism for the rearrangement of pyridine-N-oxide toward 2-formyl pyrrole.



The intermediate nitrene C could either isomerize to the corresponding acrylonitrile or ring close to the pyrrolenine D. In our opinion the copper salt interacts with the nitrene C by virtue of a reversible electron transfer.

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