# Structural Differentiation of Isomeric N-Oxides

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The recently reported photochemical isomerization of 1-(2-pyridyl)benzotriazole 3-oxide to the 2-oxide created a need for a method of distinguishing between the structural isomers. Nmr experiments using Eu(fod)3 established the position of the oxygen atoms and also yielded convincing evidence regarding attachment of the lanthanide shift reagent to these multi-functional compounds. Double irradiation experiments were used to resolve the structural problem while shift gradient considerations led to probable sites of coordination.

Hubert and Anthoine (1) recently reported the photo-chemical isomerization of 1-(2-pyridyl)benzotriazole 3-oxide (3) to the 2-oxide (2).
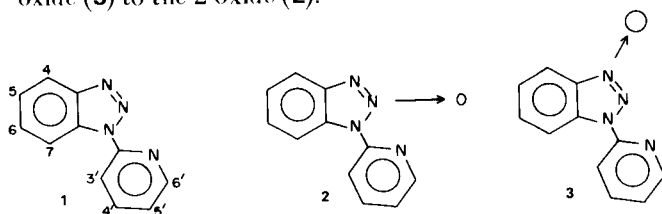
The characterization of these compounds with respect to the position of oxygen was based on tenuous, indirect evidence. Until now, apart from X-ray crystallography, there was no chemical or physical approach to a positive assignment of the two isomers. Since **2** is the only reported example of a benzotriazole 2-oxide, it is especially important to establish these structures unambiguously. We are currently interested in the chemistry of benzo-triazole oxides, and we have found it necessary to remove any uncertainty concerning the positional assignment of the oxygen.

Based on our recent success in using Eu(fod)3 (2) to spectrally separate and identify isomeric azoxybenzenes, (3) it seemed that a similar approach was in order for these compounds. However, in the azoxybenzene work, as well as in the majority of the applications of lanthanide shift reagents (LSR) reported to date, monofunctional compounds were used and the resulting spectra contained easily monitored and readily assignable resonances. In the case of the benzotriazole derivatives, however, none of the compounds contains a single strong isolable reso-nance. In fact, all three spectra consist of two overlapping complex ABCD spin systems with eight non-equivalent hydrogens theoretically capable of generating 112 tran-

sitions. An additional complication is the fact that each compound contains three potential donor sites for coordin-ation with the shift reagent.

Despite these drawbacks, the potential of Eu(fod)3 for spectral clarification is illustrated for the parent benzo-triazole in Figure 1. Comparison of the top spectrum with the bottom, untreated spectrum shows that sufficient paramagnetic shifting occurs to invite spin decoupling experiments. Also, the fact that significant shifts occurred for all resonances suggests that complexation occurs at the triazole nitrogens as well as at the pyridyl nitrogen. Finally, the broad downfield doublet which is eventually segregated in the two top spectra can be attributed to the proton adjacent to the nitrogen in the pyridine ring (4). Thus, the stepwise application of Eu(fod)3 to the parent compound revealed several useful spectral subtleties which can be used in the analysis of the two oxides.

Treatment of **2** with the LSR (5) resulted in the series of spectra shown in Figure 2. The information gained from the systematic addition of Eu(fod)3 as well as from double resonance experiments on the top spectrum of Figure 2 led to the gradual separation and eventual assignment of all eight protons. The shift gradients are those of the pyridyl ring hydrogens. Lack of significant shifts of the benzenoid ring protons indicates that little or no complexation occurs at the unsubstituted triazole nitrogen. The predominant site of complexation is there-fore either at the formally charged oxygen, at the π-deficient pyridyl nitrogen, or both.

Exclusive attachment at the N → O site to form a co-linear O ..... Eu linkage of approximately 2.3Å (6) creates a O-Eu-H5 angle, ϕ, of 64°, (7). Because of the $3 \cos^2 \phi - 1$ term in the expression for pseudocontact interactions (8) a reversed, upfield shift is predicted for this proton. Since all observed shifts were downfield,
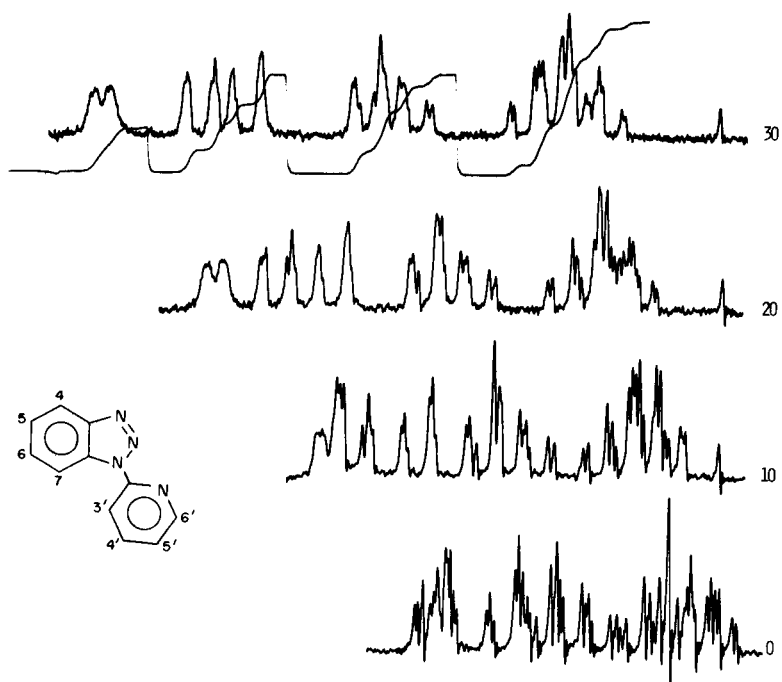
Figure 1. Spectra (60 MHz) of 1-(2-pyridyl)benzotriazole (20 mg., 1.0×10^{-4} mole) in 0.5 ml. carbon tetrachloride containing 0-30 mg. (3.0×10^{-5} mole) of Eu(fod)$_3$. TMS used as internal reference.
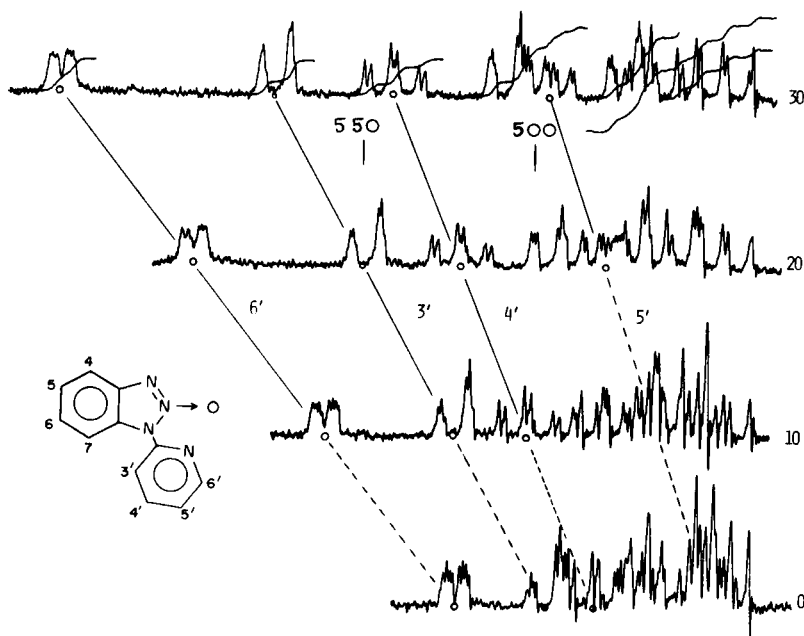

Figure 2. Spectra (60 MHz) of 1-(2-pyridyl)benzotriazole 2-oxide (21 mg., 1×10^{-4} mole) in 0.5 ml. carbon tetrachloride containing 0-30 mg. (3.0×10^{-5} mole) of Eu(fod)$_3$.
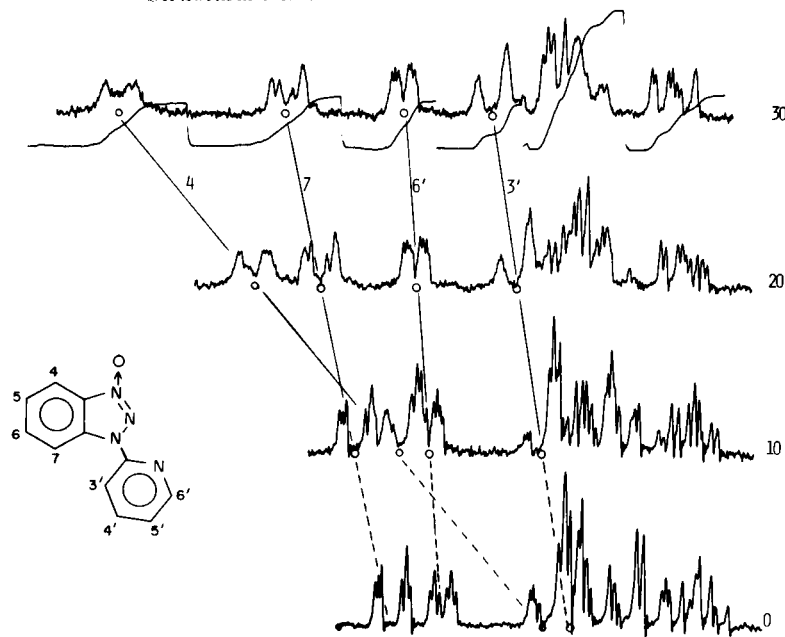
Figure 3. Spectra (60 MHz) of 1-(2-pyridyl)benzotriazole 3-oxide (21 mg., 1 x 10^{-4} mole) in 0.5 ml. carbon tetrachloride containing 0-30 mg. (3.0 x 10^{-5} mole) of $Eu(fod)_3$.

co-linear attachment at the oxygen can be ruled out. Also, the approach of the bulky tris-chelate for exclusive complexation at the pyridyl nitrogen lone pair would appear to be somewhat sterically hindered by the nearby oxygen atom. On the other hand, scale drawings reveal the potential for bidendate chelation involving both donor atoms. Recent X-ray studies of $Pr(fod)_3$ report that the "bite" (9) of the fod ligand is 2.775Å (10). The optimum "bite" presented by the pyridyl nitrogen and oxygen atom of the 2-oxide was measured to be 2.8Å. Coordination involving both the N and O atoms creates a sterically favored 6-membered ring and eliminates the possibility of upfield shifts by reducing all O-Eu-H angles to $< 55°$.

Figure 3 demonstrates the advisability of treating the organic substrate in a systematic way. For example, the doublet farthest downfield in the untreated spectrum was originally attributed to the proton peri to the oxygen atom, H_4. This tentative assignment was based on a recent report of a 0.65 ppm deshielding effect on the peri hydrogen of quinoline N-oxide as compared to the parent quinoline (11). However, the methodical addition of shift reagent clearly refuted the initial assignment by yielding a conspicuously shallow gradient whose broadened components strongly suggest a relatively short distance between that proton and the site of complexation. Also, the insignificant shifts experienced by the 6' proton supports the conclusion that coordination is almost exclusively at the oxygen atom. Double irradiation experiments with the top spectrum of Figure 3 confirm

the assignments and unambiguously identify the compound as the 3-oxide.

REFERENCES

(1) A. J. Hubert and G. Anthoine, Bull. Soc. Chim. Belges, 78, 553 (1969).

(2) fod stands for the anion of 1,1,1,2,2,3,3-heptafluoro-7,7-dimethyl-4,6-haptanedione. The tris chelate was prepared according to C. S. Springer, D. W. Meek and R. E. Sievers, Inorg. Chem., 6, 1105 (1967).

(3) R. E. Rondeau, M. A. Berwick, R. N. Steppel and M. P. Serve, J. Am. Chem. Soc., 94, 1096 (1972).

(4) The small ortho coupling (ca. 5 Hz) and the broadening from the ^{14}N nucleus are characteristic of alpha hydrogens in 2-substituted pyridines (S. Castellano, C. Sun and R. Kostelnik, J. Chem. Phys., 46, 327 (1967)) and serve to identify this particular proton.

(5) Adding the LSR in equal increments and spacing the spectra baselines accordingly provide a convenient means (i) for observing the progress of the experiment, (ii) for "tracking" shifted resonances, (iii) for selecting the optimum shifted spectrum for double irradiation experiments, (iv) for obtaining superimposed plots of induced shift as a function of added LSR, and (v) for obtaining the chemical shift of the diamagnetic substrate by extrapolation to the untreated spectrum.

(6) W. DeW. Horrocks, et al., J. Am. Chem. Soc., 93, 5258 (1971).

(7) Obtained from scale models.

(8) H. M. McConnell and R. E. Robertson, J. Chem. Phys., 29, 1361 (1958).

(9) The "bite" is the distance between the two carbonyl oxygens of the β-diketone in the chelate.

(10) J. P. R. DeVilliers and J. C. A. Boeyens, Acta Cryst., B27, 692 (1971).

(11) P. Hamm and W. Philipsborn, Helv. Chim. Acta, 54, 2363 (1971).