

Efficient Catalytic Conversion of Pyridine *N*-Oxides to Pyridine with an Oxorhenium(V) Catalyst

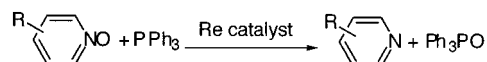
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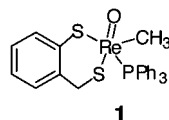
ABSTRACT



The compound $\text{CH}_3\text{Re}(\text{O})(\text{SR})_2\text{PPh}_3$, where $(\text{SR})_2$ represents the dianion of 2-(mercaptomethyl)thiophenol, catalyzes the rapid and efficient transfer of an oxygen atom from a wide range of ring-substituted pyridine *N*-oxides to triphenylphosphine, yielding the pyridines in high yield.

The selective deoxygenation of heteroaromatic *N*-oxides has received previous attention, being an important step in the synthesis of heterocycles in many procedures.^{1,2} Various methods have been developed,^{3–6} but many are limited by side reactions or reduction of the ring substituents and may require tedious procedures.^{3–5,7,8}

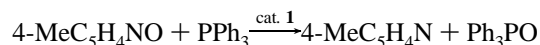
We have found that rhenium compound **1**⁹ catalyzes the transfer of oxygen from numerous pyridine *N*-oxides to triphenylphosphine. The synthesis of **1** has been reported



previously;^{10,11} only a small quantity is needed. One group of reactions was carried out in benzene-*d*₆, where the

reactions occur rapidly. Typical conditions are as follows: 14 mM 4-picoline *N*-oxide and 14 mM PPh₃, with 42 μM **1** (0.3% mol/mol) in 0.7 mL of C₆D₆ in air. The reaction reached completion (100% conversion) within 1 min. The other compounds in Table 1 also gave quantitative conversions with 0.1–5% **1**, within a few minutes (entries 1–6) or hours (entries 7–15), when studied on this scale. The system is tolerant of nitro and halide substituents, which can cause problems in earlier procedures.^{3,12–14} Even sterically hindered compounds such as 2-picoline *N*-oxide and 2,6-lutidine *N*-oxide gave 100% conversion, the latter more slowly; on a larger (1 g) scale, however, 2-picoline was formed in only 67% yield. Other amine oxides undergo this conversion: both 6-methoxyquinoline *N*-oxide and trimethylamine *N*-oxide also gave high yields of product.

As a control, the reagents were mixed without **1**; no reaction was found for >10 h. Molecular oxygen is not involved in the catalysis or stoichiometry, in that the same reaction performed under argon gave virtually the same result. The overall stoichiometry is simply



Benzene was usually used as solvent, and in limited tests toluene did as well. THF can be used, but it must be freshly

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Table 1. Oxygen Transfer from Pyridine *N*-Oxides to Triphenylphosphine, Catalyzed by **1**

entry	RC ₅ H ₄ NO, R =	scale ^a	solvent ^b	1	time/h	Py yield, ^c %
1	4-Me	1.0 g	AB	0.1%	0.7	100
2	4-Cl	1.0 g	B	0.1%	3	94
3	4-MeO	1.0 g	AB	0.5%	3	93
4	2-Me	1.0 g	AB	0.1%	0.3	67 ^d
5	4-Ph	1.0 g	B	0.1%	0.3	100
6	4-(CH ₂) ₃ Ph	1.0 g	B	0.1%	0.3	100
7	4-NO ₂	1.0 g	B	0.5%	6	100
8	4-CN	1.0 g	AB	0.5%	6	92
9	2,6-Me ₂	1.0 g	B	0.5%	7	100
10	2-Me, 4-NO ₂	1.0 g	B	0.5%	5	100
11	2-OH	1.0 g	AB	0.5%	3	50
12	3-CH ₂ OH	1.0 g	B	0.1%	1	90
13	3-OH	1.0 g	B	0.5%	7	99
14	3-C(O)NH ₂	0.5 g	THF	0.5%	2	51
15	3-COOH	0.5 g	THF	0.5%	3	57

^a With 1.0 equiv of PPh₃. ^b Solvents are 60 mL of benzene (B), 10% water with benzene containing 5% (*n*-Bu)₄NBr (AB), and tetrahydrofuran under argon (THF). ^c The solution was stirred throughout and monitored intermittently by TLC and ³¹P NMR. After the reaction had finished, the water layer was separated, the organic layer was dried over anhydrous magnesium sulfate and evaporated to dryness; the residue was then taken up in C₆D₆ for determination of the Py yield. ^d On a smaller scale, 100% conversion of 2-picoline *N*-oxide was obtained.

distilled and the reaction run under argon, as a trace of peroxide destroys the catalyst. Acetone gave adequate results, but the reactions proceeded more slowly and in reduced yield. In chloroform and acetonitrile, the reaction stopped at an early stage.

To show the generality of this catalytic system and extend its applicability to reactions carried out on a larger scale, many pyridine oxides were studied on a scale of 1.0 g of substrate and 1.0 equiv of phosphine in 60 mL of solvent. Since several of the pyridine *N*-oxides are nearly insoluble in benzene, in some cases 5 mL of water and 55 mL of benzene were used as a two-phase medium. In such cases 5% of (*n*-Bu)₄NBr was added as a phase-transfer catalyst. Table 1 presents 15 examples on this larger scale. Most of the reactions run in ambient-temperature benzene (or benzene—

water mixtures) proceeded nearly quantitatively with 0.1–0.5% **1**. At this scale, reaction times were 0.3–7 h, dividing into two groups as with smaller-scale reactions.

As it turns out, (*n*-Bu)₄NBr may be more than a phase-transfer catalyst. Both it and pyridine are pronounced accelerators (cocatalysts) as shown in Figure 1. Their role

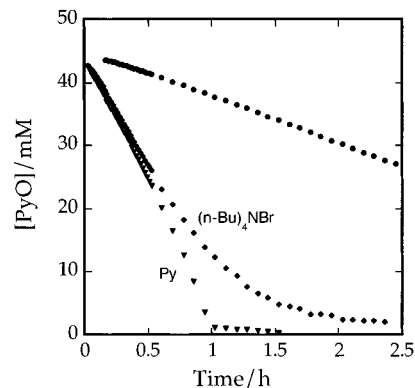


Figure 1. An experiment in benzene with 44.4 mM each of 2-methyl-4-nitropyridine *N*-oxide and Ph₃P containing 1.0 mM **1**, showing the decrease in the concentration of the pyridine oxide in the catalyzed reaction and the further rate acceleration brought about with 4.4 mM (*n*-Bu)₄NBr or 8.8 mM pyridine added.

is likely to be one of promoting ligand substitution reactions of **1**.^{15,16} The mechanism of this interesting transformation remains under investigation, but entry of PyO into the coordination sphere of rhenium will certainly play a role; release of pyridine *may* occur by a process we abbreviate as follows: L_{*n*}Re–OPy → L_{*n*}Re=O + Py.

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