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A general method for the deoxygenation of aromatic *N*-oxides using $RuCl_3 \cdot xH_2O$

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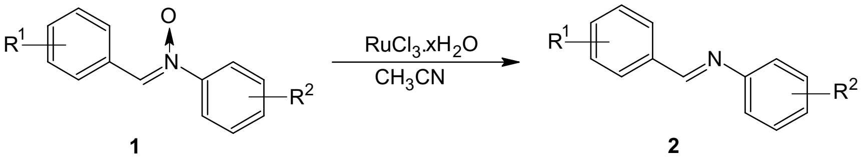
Abstract—An efficient, simple and selective method for the deoxygenation of aromatic *N*-oxides, such as *N*-arylnitrones, azoxybenzenes, *N*-heteroarene *N*-oxides using ruthenium(III) chloride to afford deoxygenated products in excellent yields, is described.

Currently, there is interest in developing novel methodologies utilizing ruthenium salts and complexes in organic synthesis. Ruthenium(III) chloride is reported to cleave epoxides to yield *trans*-diols,[1] to catalyse Prins reactions[2] and to catalyse the well-known Biginelli reaction.[3] Its utility has been further extended to coupling of furans,[4] reduction of azides[5] and aldol condensation.[6] When employed with oxidants like H_2O_2, $NaIO_4$ or even aerial oxygen, an array of oxidative transformations have been reported,[7] notably *N*-alkyl pyrrolidines to pyrrolidin-2-ones,[7b] Hantzsch 1,4-dihydropyridines to pyridines,[7c] double bond cleavage,[7d,e] conversion of alcohols to aldehydes[7f] and ethers to lactones.[7g] Several reagents have been used for the deoxygenation of various nitrones,[8] azoxybenzenes[9] and *N*-heteroarenes[10] such as sodium hydrogen telluride,[8] phosphorus,[9a] aluminium/nickel alloy,[9b] titanium reagents,[10c,d] silanes,[11] metal hydrides,[12] organotin derivatives,[13] indium halides[14] and for heterocyclic *N*-oxides triphenylphosphine-dichlorodioxomolybdenum.[15] All these methods suffer from one or other disadvantage like formation of side products,[16] a hazardous procedure,[17] or require strict controls over temperature and are not of general applicability.[11a,13,18]

Since ruthenium trichloride has a good affinity for oxygen, we envisioned its use for deoxygenation of organic *N*-oxides and indeed it worked well, deoxygenated products being obtained in excellent yields (Scheme 1). To the best of our knowledge, this is the first report employing ruthenium(III) chloride for deoxygenation.

In a typical example, to a stirred solution of benzaldehyde *N*-phenylnitrone **1a** in acetonitrile (15 mL) was added $RuCl_3 \cdot xH_2O$ (1 equiv) and the mixture stirred at 80 °C for 25 min. After completion of the reaction (monitored by TLC), the solvent was removed under reduced pressure and the residue treated with water (50 mL). The resultant mixture was extracted with dichloromethane, the organic layer dried (Na_2SO_4) and the solvent distilled off to give the crude product, which was purified by column (silica) chromatography



Scheme 1.

Keywords: Deoxygenation; Ruthenium(III) chloride; Nitrones; Azoxybenzenes; *N*-Heteroarene *N*-oxides.

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Table 1. RuCl$_3$·xH$_2$O-mediated deoxygenation of aromatic *N*-oxides

Product[a]	R^1/X	R^2	Time (min)	Yield[b] (%)
2a	H	H	25	94
2b	H	4-Cl	25	97
2c	4-Cl	H	20	91
2d	4-Cl	4-Cl	20	88
2e	4-CH$_3$	H	30	89
2f	4-CH$_3$	4-Cl	30	87
4a	H	H	40	82
4b	4-Cl	4-Cl	35	80
4c	4-CH$_3$	4-CH$_3$	40	78
4d	3-Cl	3-Cl	40	80
6a	H	—	45	76
6b	Cl	—	50	72
6c	OCH$_2$CH=CH$_2$	—	55	70
8a	H	—	50	68
8b	Cl	—	55	70

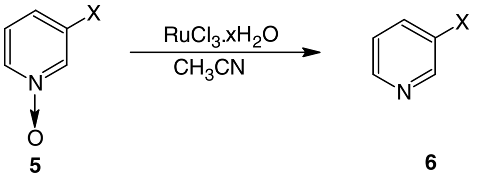
[a] Melting points, IR, ^{1}H NMR were in accordance with those of authentic samples.

[b] Isolated yields.

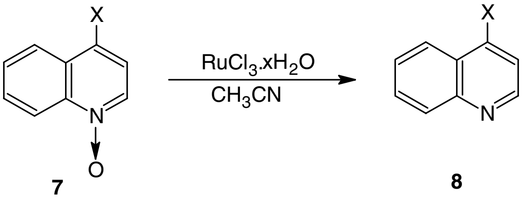
(hexane/ethyl acetate) to afford benzylidine aniline **2a** in 94% yield,[19] mp 52 °C. Similarly, other nitrones gave the corresponding imines (**2b**–**f**) in excellent yields (Table 1), without the formation of any side products. Encouraged by these results, we extended this to azoxybenzenes **3** and *N*-heteroarene *N*-oxides **5** and **7**. Azoxybenzenes gave the corresponding azobenzenes **4** (Scheme 2, Table 1) and *N*-heteroarene *N*-oxides, that is, pyridine *N*-oxides **5** and quinoline *N*-oxides **7** afforded the deoxygenated products **6** and **8** (Schemes 3 and 4), respectively, in quantitative yields (Table 1).

The selectivity of the present method was illustrated by several functionalities, such as cyano, halogen, ethers and esters, which were unaffected. Ethers and esters are prone to cleavage when strong Lewis acids like aluminium halides are used for deoxygenation.[20] There was no evidence for the formation of any undesirable rearranged or other side products from aldonitrones.[21] Attempts to perform the deoxygenation with less reagent afforded low yields but still with high selectivity. Furthermore, no halogenation of heteroarene nucleus was observed, a serious drawback of chlorine-containing reagents like PCl$_5$, POCl$_3$, SO$_2$Cl$_2$, etc.[22] Finally, the present method is a one-pot procedure and does not involve any prior preparation of the reagent system.[20]

In conclusion, the present protocol is mild, efficient and of fairly wide scope for the deoxygenation of *N*-oxides. Excellent yields, short reaction periods, the survival of ether and halogen substituents, avoidance of harsh reagents and mild reaction conditions are the main advantages of this method.



Scheme 3.



Scheme 4.

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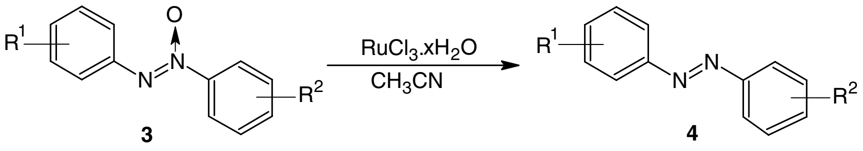

Scheme 2.

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