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# Can Chloramine-T be a Nitrene Transfer Agent?

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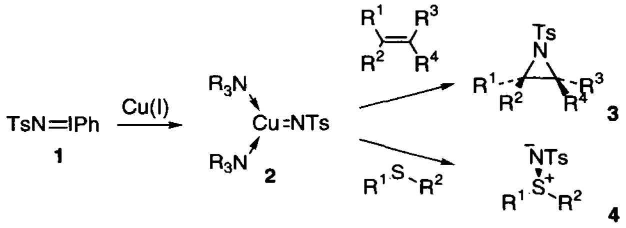
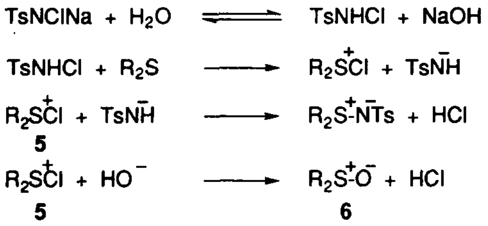
***Abstract:*** Reaction of chloramine-T and methyl *p*-tolyl sulfide to give the corresponding sulfimide appears to proceed *via* a nitrene transfer mechanism in the presence of a copper(I) catalyst and a second nitrogen ligand. © 1997 Elsevier Science Ltd.

In 1993 the groups of Evans and of Jacobsen simultaneously reported an asymmetric aziridination procedure;[1] reaction of the nitrene (or imido) tranfer agent TsN=IPh **1** with alkenes in the presence of a copper (I) or copper (II) catalyst and a chiral diimine ligand was shown to yield *N*-tosyl aziridines **3** with very high *ee*s (Scheme 1). More recently, a closely related asymmetric sulfimidation procedure was discovered by the group of Uemura and by ourselves;[2] in this case the sulfide substrate led to sulfimides **4** with up to *ca* 70% *ee* (Scheme 1). A significant drawback of these two procedures, apart from the lower *ee*s in the sulfimidation, is that the nitrene transfer agent, TsN=IPh, requires a troublesome two-step synthesis.[3] However, none of the other possible tosyl nitrene transfer agents, of which tosyl azide is the most-used, gave satisfactory results.[4]



**Scheme 1**

Racemic sulfimides have been prepared routinely by the reaction of sulfides with the very cheap, commercial reagent chloramine-T ($TsNClNa.xH_2O$);[5] the reaction is widely believed to proceed *via* an ionic mechanism. A feature of this mechanism is that, unless the water of crystallisation is removed from the chloramine-T, the sulfonium intermediate **5** is intercepted by water to produce a sulfoxide **6** (Scheme 2). Perhaps due to the prominence of these ionic reactions, chloramine-T has never been considered as a nitrene transfer agent.[6] Nevertheless, when we used chloramine-T in place of TsN=IPh in the asymmetric sulfimidation reaction, very similar results were obtained; the sole difference being a disappointing reduction in *ee*, which we were able to show was due to interference from the sodium chloride by-product.



$$\begin{array}{lcl} \mathrm{TsNClNa} + \mathrm{H_2O} & \rightleftharpoons & \mathrm{TsNHCl} + \mathrm{NaOH} \\ \mathrm{TsNHCl} + \mathrm{R_2S} & \longrightarrow & \mathrm{R_2\overset{+}{S}Cl} + \mathrm{Ts\overset{-}{N}H} \\ \underset{\mathbf{5}}{\mathrm{R_2\overset{+}{S}Cl}} + \mathrm{Ts\overset{-}{N}H} & \longrightarrow & \mathrm{R_2\overset{+}{S}\text{-}\overset{-}{N}Ts} + \mathrm{HCl} \\ \underset{\mathbf{5}}{\mathrm{R_2\overset{+}{S}Cl}} + \mathrm{HO^-} & \longrightarrow & \underset{\mathbf{6}}{\mathrm{R_2\overset{+}{S}\text{-}\overset{-}{O}}} + \mathrm{HCl} \end{array}$$

**Scheme 2**

In this study, we aimed to establish under what conditions the reactions of chloramine-T might switch from an ionic to a nitrene transfer mechanism. In particular, we noted that the sulfoxide by-product, which is inevitable in ionic reactions unless water is excluded, can not arise from a nitrene transfer mechanism. Formation of sulfoxide in the presence of water is thus indicative of an ionic mechanism.

Comparison of entries 2 and 3 in Table 1 shows that copper (I) does catalyse the reaction of chloramine-T and methyl tolyl sulfide in dichloromethane, but the presence of sulfoxide in 3 indicates an ionic mechanism. However, when nitrogen donor ligands are added in sufficient amounts (entries 5-9), the product is entirely free of sulfoxide. Furthermore, when the solvent is acetonitrile (entry 10), which is also a good ligand, no sulfoxide is observed.

The following explanation is consistent with these data. The conventional reaction of chloramine-T and sulfide in dichloromethane is very slow at 0°C. Addition of copper (I) triflate catalyses the reaction, but the mechanism is still ionic, hence the sulfoxide by-product. We speculate that the copper is simply acting as a Lewis acid in this case. In the presence of a second ligand, the copper (III) nitrenoid intermediate **2** proposed by Jacobsen[7] can be formed and the nitrene transfer mechanism takes over.

**Table 1: Products of reactions of chloramine-T and methyl tolyl sulfide [a]**

| entry | solvent | T / °C | mol% CuOTf | ligand | mol% ligand | sulf-imide [b] | sulf-oxide [b] |
|---|---|---|---|---|---|---|---|
| 1 | $CH_2Cl_2$ | 20 | 0 | none | | ✓ | ✓ |
| 2 | $CH_2Cl_2$ | 0 | 0 | none | | ✗ | ✗ |
| 3 | $CH_2Cl_2$ | 0 | 5 | none | | ✓ | ✓ |
| 4 | $CH_2Cl_2$ | 20 | 5 | $Et_3N$ | 25 | ✓ | ✓ |
| 5 | $CH_2Cl_2$ | 20 | 5 | $Et_3N$ | 100 | ✓ | ✗ |
| 6 | $CH_2Cl_2$ | 20 | 5 | py | 25 | ✓ | ✗ |
| 7 | $CH_2Cl_2$ | 20 | 5 | py | 100 | ✓ | ✗ |
| 8 | $CH_2Cl_2$ | 20 | 5 | bipy | 12 | ✓ | ✗ |
| 9 | $CH_2Cl_2$ | 20 | 5 | bipy | 100 | ✓ | ✗ |
| 10 | $CH_3CN$ | 20 | 5 | none | | ✓ | ✗ |

[a] To a solution of $(CuOTf)_2.C_6H_6$ was added ligand, methyl *p*-tolyl sulfide (100mol%) and chloramine-T hydrate (110mol%). Reactions were monitored by tlc. Yields of sulfimide, when the sole product, were between 70 and 85%.

[b] Sulfimide:sulfoxide ratios were determined by $^1H$ nmr. The maximum observed proportion of sulfoxide was 50%. Ratios were found to be very dependent on the precise amount of water present and are thus not given as proportions. The presence of >2% sulfimide or sulfoxide in the product mixture is indicated by ✓ and their absence is indicated by ✗.

The need for a second donor ligand also provides an explanation for literature observations on the nitrene transfer reactions of TsN=IPh. Both Evans (aziridination[4]) and Uemura (sulfimidation[2a]) have found that for the racemic reactions, acetonitrile is the solvent of choice, in terms of rate and yield. In the asymmetric reactions, when chiral diimine ligands are added, *ee*s in acetonitrile are very poor, a non-coordinating solvent such as toluene being needed for high *ee*s. We propose that TsN=IPh always reacts *via* a nitrene transfer mechanism and that the rate of nitrene transfer decreases markedly in the absence of donor ligands, hence acetonitrile is the solvent of choice.[8] In the asymmetric version, exclusive coordination from the chiral ligand is required and competition from a coordinating solvent such as acetonitrile is detrimental.

In summary, we believe that, in the presence of appropriate ligands and metal catalysts, chloramine-T can act as a nitrene transfer agent. It is a cheap (£25/kg), crystalline solid which produces only salt as a by-product and is thus an attractive alternative to TsN=IPh. Further applications will be reported in due course.

## ACKNOWLEDGEMENTS

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## REFERENCES AND NOTES.

1. (a) Evans, D.A., Faul, M.M., Bilodeau, M.T., Anderson, B.A., Barnes, D.M. *J. Am. Chem. Soc.*, **1993**, *115*, 5328; (b) Li, Z., Conser, K.R., Jacobsen, E.N. *J. Am. Chem. Soc.*, **1993**, *115*, 5326.
2. (a) Takada, H., Nishibayashi, Y., Ohe, K., Uemura, S. *Chem. Commun.* **1996**, 931; (b) Takada, H., Nishibayashi, Y., Ohe, K., Uemura, S., Baird, C.P., Sparey, T.J., Taylor, P.C. *J. Org. Chem.*, in the press.
3. (a) Yamada, Y.; Yamamoto, T.; Okawara, M. *Chem. Lett.*, **1975**, 361; (b) Besenyei, G., Nemeth, S. and Simandi, L.I. *Tetrahedron Lett.*, **1993**, *34*, 6105.
4. Evans, D.A., Faul, M.M., Bilodeau, M.T. *J. Am. Chem. Soc.*, **1994**, *116*, 2742.
5. (a) Gilchrist, T. L.; Moody, C. J. *Chem. Rev.*, **1977**, *77*, 409; (b) Johnson, C. R. In *Comprehensive Organic Chemistry*, Barton, D. H. R.; Ollis, W. D. Pergamon., Eds.; 1979, vol. 3, section 11.10; (c) Koval, I. V. *Russ. Chem. Rev.*, **1990**, *59*, 819.
6. Harlan, E.W., Holm, R.H. *J. Am. Chem. Soc.*, **1990**, *112*, 186.
7. Li, Z., Quan, R.W., Jacobsen, E.N. *J. Am. Chem. Soc.*, **1995**, *117*, 5889.
8. Anhydrous acetonitrile was also found to be the solvent of choice for uncatalysed imidation of sulfimides to form sulfodiimides free from sulfoximides (Furukawa, N., Akutagawa, K., Yoshimura, T., Akasaka, T., Oae, S. *Synthesis*, **1979**, 289). The role of the acetonitrile in this reaction, which we assume has an ionic mechanism, is presumably simply as a dipolar aprotic solvent.

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