

Heteropoly acid as a novel nitrene transfer agent: a facile and practical aziridination of olefins with Chloramine-T†

G. D. Kishore Kumar and Sundarababu Baskaran*

Department of Chemistry, Indian Institute of Technology Madras, Chennai 600 036, India.

E-mail: sbhaskar@iitm.ac.in; Fax: 0091-44-22570545; Tel: 0091-44-22578260

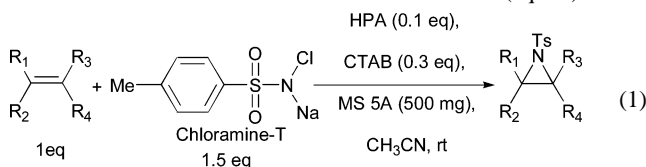
Received (in Cambridge, UK) 17th February 2004, Accepted 4th March 2004

First published as an Advance Article on the web 23rd March 2004

Environmentally benign HPA is found to be an efficient catalyst for aziridination of olefins in the presence of inexpensive Chloramine-T as a nitrogen source: instantaneous at room temperature, requires only stoichiometric amount of olefin and no allyl amine side product.

Heteropoly acids (HPAs) are promising solid acids, redox and bifunctional catalysts in homogeneous as well as heterogeneous conditions.¹ They exhibit high activities and selectivities and allow for cleaner processing compared to conventional catalysts and hence they are regarded as green catalysts.² As a consequence, a variety of synthetically useful transformations have been developed using HPAs as catalysts which are being commercialized.³ Recently, HPAs catalysed Fries rearrangement of phenyl acetate,⁴ and Friedel–Crafts acylation of phenol⁵ and oxidation of alcohols⁶ have been reported. HPAs are well known oxygen transfer agents to olefins forming epoxides,⁷ however, to the best of our knowledge, their synthetic potential as nitrogen transfer agents to olefins is yet to be explored.

Aziridine, an important three-membered heterocyclic ring system, is a useful precursor for the synthesis of several biologically important compounds such as amino acids, amino sugars and alkaloids.⁸ Many of the natural products possessing an aziridine ring exhibit potent biological activity.⁹ The transition-metal-catalysed reaction of olefin with nitrene, generated *in situ*, is an attractive approach for the direct synthesis of aziridines which has received much attention in recent years. PhI=NTs,¹⁰ Chloramine-T^{11,12} and Bromamine-T¹³ have been used as a source of nitrogen in the various transition-metal-catalysed aziridinations of olefins. Many of these procedures suffer from one or more drawbacks, which include, use of hazardous or expensive reagent, longer reaction time, low yield and perhaps least attractive is that in nearly all the cases excess of olefin must be used. These limitations prompted us to investigate a new and environmentally benign transition-metal-catalyst, which will be able to bring about aziridination of olefins in a facile and practical manner. As a prelude to this objective, we first sought a suitable polyoxometalate that could effect the desired aziridination of styrene in the presence of Chloramine-T (CT) as a nitrogen source. The results are summarized in Table 1. Upon screening, it was found that the use of an HPA is crucial to the success of the reaction (eqn. 1).



Among the HPAs tested, 12-phosphomolybdic acid (PMA) is found to be the most efficient catalyst compared to PMA/SiO₂, Cs_{2.2}H_{0.8}PMo₁₂O₄₀ and 12-phosphotungstic acid (PWA). MoO₃ and (NH₄)₆Mo₇O₂₇ are also found to be considerably less effective when compared to HPAs. The effects of various additives to the reaction were surveyed. We found cetyltrimethylammonium

† Electronic supplementary information (ESI) available: plot of % of yield vs. mol% PMA, experimental procedure and spectral data for all compounds. See <http://www.rsc.org/suppdata/cc/b4/b402371d/>

bromide (CTAB)‡ and powdered molecular sieves (MS 5Å)§ expedite the reaction and in general lead to better chemical yields.

Among the various solvents examined, acetonitrile was found to give better results in terms of chemical yields. In general, the aziridination is instantaneous even at room temperature and ideally requires only 10 mol% of PMA catalyst.¶ In addition, it was found that increasing the amount of PMA gave lower yields of aziridinated product.|| The nitrene transfer ability of PMA is found to be very versatile and gave consistent results even in large scale reactions.

To investigate the scope of the PMA catalysed aziridination reaction, several substituted olefins were examined and the results are summarized in Table 2. Both aliphatic and conjugated aromatic olefins reacted readily to give the corresponding aziridine in good yields.** In contrast to the reported procedures, no allyl amination product was observed under our reaction conditions. Styrene and α -methylstyrene were successfully converted to the corresponding aziridines without polymerisation (entries 1 & 2). Under the reaction conditions, *trans*-stilbene gave the corresponding aziridine in good yield (entry 3) as a mixture of *cis*- and *trans*-isomers (1 : 1.4). The non-stereoselective nature of the product indicates that the reaction takes place *via* a stepwise rather than a concerted pathway.¹⁴ Interestingly, cyclohexene and 1-methylcyclohexene instantaneously gave the corresponding aziridines in good yields without any allyl amine side product (entries 4 & 5). Similarly, 1-hexene, cycloheptene and cyclooctene afforded the corresponding aziridines in good yields (entries 6, 7 & 8). The azide functional group was found to be compatible with the reaction conditions (entry 9). However, electron deficient olefins such as methyl cinnamate failed to give the aziridinated product under these conditions (entry 10).

Salient features of this aziridination reaction are: (a) instantaneous even at room temperature, (b) requires only stoichiometric amount of olefins, (c) uses inexpensive Chloramine-T as nitrogen source and (d) no allyl amine side product is observed.

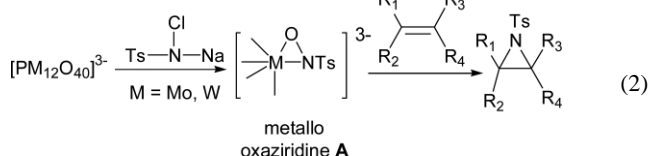
Although a detailed investigation of the mechanism of this novel transformation is yet to be carried out, a plausible mechanism is

Table 1 Heteropoly acids catalysed aziridination of styrene

Entry	Ph-CH=CH ₂ + catalyst		CH ₃ CN, rt		
	Catalyst (0.1 equiv.)	CTAB (equiv.)	MS 5Å (mg)	CT (equiv.)	Yield ^a (%)
1	no catalyst	0.3	500	1.5	0
2	PMA	0.3	500	0	0
3	PMA	0	0	1.5	9 (27)
4	PMA	0	500	1.5	11 (41)
5	PMA	0.3	0	1.5	38 (52)
6	PMA	0.3	500	1.5	56 (73)
7	PMA/SiO ₂	0.3	500	1.5	51 (60)
8	PWA	0.3	500	1.5	42 (68)
9	Cs _{2.2} H _{0.8} PMA	0.3	500	1.5	27 (60)
10	(NH ₄) ₆ Mo ₇ O ₂₇	0.3	500	1.5	17 (25)
11	MoO ₃	0.3	500	1.5	14 (36)

^a Isolated yield based on styrene. Yield based on styrene consumed are in parentheses.

given in eqn. 2. It is likely that PMA is only a precatalyst which may be undergoing rapid dissociation or decomposition to actual catalyst under the reaction conditions. In the presence of Chloramine-T, the catalyst can generate a highly reactive three membered metallo-oxaziridine intermediate **A**,^{15,16} which in turn can transfer nitrene to olefin, leading to product.



In summary, we report for the first time, environmentally friendly PMA as a novel and efficient catalyst for the rapid aziridination of olefins in which inexpensive Chloramine-T is used as a practical nitrogen source.

We thank DST & CSIR, New Delhi for providing financial support. GDKK (SRF) thanks CSIR, New Delhi for a research

fellowship. We thank RSIC, IIT Madras for providing spectroscopic data.

Notes and references

‡ Since these reactions are heterogeneous, phase transfer catalyst CTAB is believed to facilitate the reaction.

§ Use of molecular sieves improves the yield significantly by removing moisture from the reaction medium (see Table 1, entries 5 & 6).

¶ At the end of the reaction, the PMA is neither intact nor recyclable.

|| It was found that increasing the amount of PMA from 10 mol% to 30 mol% decreases the yield of aziridine (please see ESI†). Controlled experiments showed that the gradual hydrolysis of Chloramine-T to N-tosylsulfonamide increases with increasing amount of PMA catalyst.

** PMA is dried at 200 °C/1 mm Hg for 5 h and Chloramine-T trihydrate is dried under vacuum at 90 °C prior to use.

General experimental procedure for aziridination of olefin: A mixture of anhydrous PMA (0.1 equiv.), CTAB (0.3 equiv.), anhydrous Chloramine-T (1.5 equiv.), powdered MS 5Å (500 mg per mmol) in dry CH₃CN (5 ml) is treated with olefin (1 equiv.) at room temperature under N₂ atmosphere. The reaction mixture is filtered and washed with CH₃CN. The combined filtrate is concentrated under reduced pressure and purified by column chromatography over silica gel to give pure product.

Table 2 12-Phosphomolybdate catalysed aziridination of olefins ^a

Entry	Substrate	Product	% Yield ^b
1			56 (73)
2			70 ^c (69)
3			55 ^d (68)
4			77 ^e
5			79 ^e
6			53 (70)
7			51 (69)
8			73 ^e
9			30 (44)
10		no reaction	0

^a Reaction conditions: olefin : PMA : CTAB : Chloramine-T = 1 : 0.1 : 0.3 : 1.5 (molar ratio), MS 5Å (500 mg per mmol), rt, CH₃CN. ^b Isolated yield based on olefins. Yields based on the olefin consumed are in parentheses.

^c Trace amount of rearranged product was observed. ^d Yield refers to a mixture of isomers (1 : 1.4). ^e Isolated yield based on Chloramine-T (5 equiv. of olefin and 1 equiv. of Chloramine-T are used).

- I. V. Kozhevnikov, *Chem. Rev.*, 1998, **98**, 171.
- M. Misono, I. Ono, G. Koyano and A. Aoshima, *Pure Appl. Chem.*, 2000, **72**, 1305.
- Y. Izumi, K. Urabe and M. Onaka, *Zeolite, Clay and Heteropoly Acid in Organic Reactions*, Kodansha/VCH, Tokyo, 1992.
- E. F. Kozhevnikova, E. G. Derouane and I. V. Kozhevnikov, *Chem. Commun.*, 2002, 1178.
- J. Kaur, K. Griffin, B. Harrison and I. V. Kozhevnikov, *J. Catal.*, 2002, **208**, 448.
- H. Firouzabadi, N. Iranpoor and K. Amani, *Synthesis*, 2003, 408.
- Y. Ishii, K. Yamawaki, T. Ura, H. Yamada, T. Yoshida and M. Ogawa, *J. Org. Chem.*, 1988, **53**, 3587.
- D. Tanner, *Angew. Chem., Int. Ed.*, 1994, **33**, 599.
- H. M. I. Osborn and J. Sweeney, *Tetrahedron: Asymmetry*, 1997, **8**, 1693.
- In most of the reported procedures, the highly reactive PhI=NTs has been used as nitrene source with limited success mainly due to the expense and inconvenience of PhI=NTs as a reagent. D. A. Evans, M. M. Faul and M. T. Bilodeau, *J. Am. Chem. Soc.*, 1994, **116**, 2742.
- Use of Chloramine-T is especially attractive because it is inexpensive and easy to handle. M. M. Campbell and G. Johnson, *Chem. Rev.*, 1978, **78**, 65; T. Ando, S. Minakata, I. Ryu and M. Komatsu, *Tetrahedron Lett.*, 1998, **39**, 309; D. P. Albone, P. S. Aujla and P. C. Taylor, *J. Org. Chem.*, 1998, **63**, 9569; P. Brandt, M. J. Sodergren, P. G. Andersson and P.-O. Norrby, *J. Am. Chem. Soc.*, 2000, **122**, 8013; S. Minakata, D. Kano, Y. Oderaotoshi and M. Komatsu, *Angew. Chem., Int. Ed.*, 2004, **43**, 79.
- For non-metal catalysed aziridination, please see: J. U. Jeong, B. Tao, I. Sagasser, H. Henniges and K. B. Sharpless, *J. Am. Chem. Soc.*, 1998, **120**, 6844; S. I. Ali, M. D. Nikalje and A. Sudalai, *Org. Lett.*, 1999, **1**, 705; D. Kano, S. Minakata and M. Komatsu, *J. Chem. Soc., Perkin Trans. 1*, 2001, 3186.
- B. M. Chanda, R. Vyas and A. V. Bedekar, *J. Org. Chem.*, 2001, **66**, 30.
- J.-P. Mahy, G. Bedi, P. Battioni and D. Mansuy, *J. Chem. Soc., Perkin Trans. 2*, 1988, 1517.
- H.-J. Jeon and S. T. Nguyen, *Chem. Commun.*, 2001, 235.
- For molybdoxaziridine please see: S. K. Dutta, D. B. McConville, W. J. Youngs and M. Chaudhury, *Inorg. Chem.*, 1997, **36**, 2517.