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Pyridinium Hydrobromide Perbromide: A Versatile Catalyst for Aziridination of Olefins Using Chloramine-T

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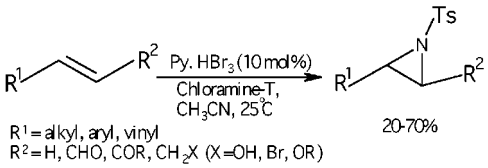
ABSTRACT



Pyridinium hydrobromide perbromide ($Py{\cdot}HBr_3$) catalyzes effectively the aziridination of electron-deficient as well as electron-rich olefins using Chloramine-T (*N*-chloro-*N*-sodio-*p*-toluenesulfonamide) as a nitrogen source to afford the corresponding aziridines in moderate to good yields.

The aziridine ring is a versatile building block for organic synthesis, not only because the ring opening of aziridines provides a convenient entry to the stereoselective preparation of functionalized amino compounds but also because the exocyclic N-substituent modulates the properties and reactivity of the three-membered ring.[1] Many biologically active compounds such as amino acids, β-lactam antibiotics, and alkaloids have been derived from aziridines.[2] The preparation of aziridines is generally achieved by several noncatalytic methods.[3] On the other hand, there exists two pathways for the catalytic preparation of aziridines: (i) transfer of a nitrene onto olefins catalyzed mostly by Cu,[4a] Mn,[4b,c] and Rh salts;[4] (ii) transfer of a carbenoid species onto imines by Rh,[5a] Re,[5b] Fe complexes,[5c] BF_3OEt_2,[5d] etc. Although the formation of aziridines from the addition of thermally or photochemicaly generated nitrenes to olefins is a well-known method, its utility is limited by (i) the formation of low yields due to competing C−H abstraction and insertion processes and (ii) the expense and inconvenience of PhI═NTs as a nitrene source.

Chloramine-T trihydrate[6] ($TsNClNa{\cdot}3H_2O$), a commercially available oxidant, finds wide synthetic applications in aminochalcogenation[7] and aminohydroxylation[8] of alkenes

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Table 1. Py·HBr_3-Catalyzed Aziridination of a Variety of Olefins Using Anhydrous Chloramine-T[a]

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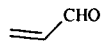
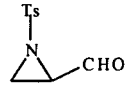
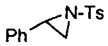
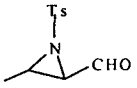
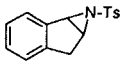
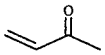
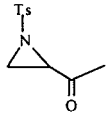
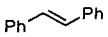
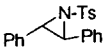
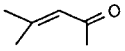
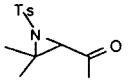
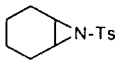
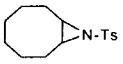
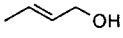
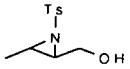
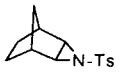
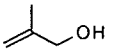
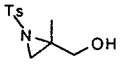
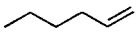
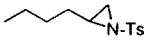
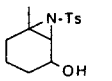
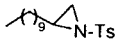
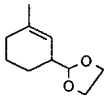
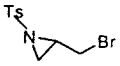
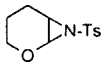
1		12		20	11		4		60
2		12		65	12		10		50
3		12		60	13		8		40[c]
4		14		60	14		12		70
5		8		40	15		6		65
6		8		30	16		16		50
7		14		55	17		12		40
8		12		40	18		12		42
9		12		50	19		12		65
10		5		65	20		10		40

a : Olefin (5 mmol), anhydrous chloramine-T (1.1 equiv.), Py.HBr_3 (10 mole%), CH_3CN, (25 ml), 25 °C. b : Isolated yields after column chromatographic purification. c: cis/trans isomers obtained in the ratio 2:3

and allylic amination via a selenium diimide intermediate.[9] It has recently been shown to aziridinate alkenes with Cu(I) triflate,[10] phenyltri methylammonium tribromide,[11] or iodine[12] as catalyst. However, these procedures have drawbacks such as (i) significant amounts of allylic amination products are often observed for activated substrates such as cyclohexene, (ii) electron-deficient olefins such as α,β-unsaturated ketones, aldehydes, esters, etc. have failed to undergo aziridination, and (iii) sometimes a large excess of olefin is required to obtain reasonable yields of aziridines. In this paper, we report the aziridination of a variety of alkenes utilizing anhydrous Chloramine-T as nitrogen source and pyridinium hydrobromide perbromide (Py·HBr_3) as a new catalyst (Scheme 1).

Scheme 1[a]

[a](i) Pyridinium hydrobromide perbromide (Py·HBr_3) (10 mol %), anhydrous Chloramine-T (1.1 equiv), dry MeCN, 25 °C, 12 h.

Under standard conditions (1 equiv of olefin, 1.1 equiv of anhydrous Chloramine-T, 10 mol % of Py·HBr_3, MeCN, 25 °C, 12 h), the catalyzed aziridination proceeds in good yields with both electron-deficient and electron-rich olefins.

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The influence of the amount of Py·HBr_3[13] as catalyst was evaluated using styrene as a representative case. It is observed that no aziridinated product was formed when 1 mol % of Py·HBr_3 was employed. Increasing the catalyst to either 5 or 10 mol % has resulted in the formation of aziridines in 65 and 70% yields, respectively. However, further increase of catalyst (50 mol % to stoichiometric amount) had a deleterious effect on improving the yield of aziridine. Also, when PPh_3Br_2 was employed as catalyst, aziridination of styrene still proceeded although in lowered yield (30%).

To gauge the scope and the generality of the reaction, various olefins were subjected to Py·HBr_3-catalyzed aziridination using anhydrous Chloramine-T as the nitrogen source at 25 °C (Table 1, ref 15). For instance, when styrene, cyclohexene, and cyclooctene were employed, the corresponding aziridines were obtained in good yields whereas terminal aliphatic olefins such as 1-hexene, 1-dodecene, and a variety of allylic alcohols gave only a moderate yield of aziridinated products. Substrates such as allyl bromide and dihydropyran also underwent reaction, affording good yields of aziridines, and no allylic amination was found in any of the cases studied. It is remarkable that when a conjugated diene such as 1,3-butadiene is subjected to aziridination, one of the double bonds is selectively aziridinated in high yields. Further, sensitive functional groups such as acetals and enol ethers are not affected during aziridination. A novel feature of the Py·HBr_3-catalytic system is the unexpected reactivity shown by a variety of electron-deficient olefins affording good yields of the aziridinated products. This reactivity pattern could be explained on the basis of the fact that Py·HBr_3, being more electrophilic in nature than $PhNMe_3$·Br_3, dissociates in the presence of olefins to give Py·Br_2 which in turn reacts with olefins to form bromonium ion as the key intermediate. This bromonium ion undergoes nucleophilic opening with Chloroamine-T followed by its cyclization to give the aziridine.[11] We have also prepared two new chiral perbromides from (−)-hydroquinidine-4-chlorobenzoate (DHQD-CLB) and (−)-sparteine by following a procedure similar to that employed for the preparation of Py·HBr_3.[13] When styrene was subjected to aziridination in the presence of these chiral perbromides, a low optical induction was realized in the aziridinated products (2% ee in each case).[14,15]

In conclusion, Py·HBr_3 is a versatile catalyst in aziridinating a variety of olefins; in particular, it is quite active in catalyzing the aziridination of electron-deficient olefins which is complementary to the existing methods.[11]

Acknowledgment. M.D.N. thanks CSIR, New Delhi, for SRF, and S.I.A. thanks the Director, NCL, for allowing the experiments to be carried out.

Supporting Information Available: Text and figures giving spectral data for the compounds described in this paper. This material is available free of charge via the Internet at http://pubs.acs.org.

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(15) **Typical Experimental Procedure for Aziridination**. To a mixture of mesityl oxide (0.490 g, 5 mmol) and anyhydrous Chloramine-T (1.248 g, 5.5 mmol) in dry MeCN (25 mL) was added pyridinium hydrobromide perbromide (0.160 g, 0.5 mmol) at 25 °C. The pale yellow colored solution was stirred vigorously at 25 °C. The progress of the reaction was monitored by TLC. After completion of the reaction, the reaction mixture was concentrated under reduced pressure to give the crude product which was purified by column chromatography (silica gel, 20% EtOAc−petroleum ether as eluant). *N*-(*p*-Toluenesulfonyl)-2-acetyl-3,3′- dimethylaziridine: yield, 0.801 g; viscous liquid; IR ($CHCl_3$, cm^{-1}) 3398, 3139, 3023, 2964, 2927, 1717, 1699, 1451, 1401, 1325, 1217, 1157, 1091, 1048; ^1H NMR (200 MHz, $CDCl_3$) δ 7.85 (2H, d, J = 8.2 Hz), 7.35 (2H, d, J = 8.2 Hz), 3.50 (1H, s), 2.45 (3H, s), 1.95 (3H, s), 1.80 (3H, s), 1.30 (3H, s); ^{13}C NMR (200 MHz, $CDCl_3$) δ 20.85, 21.37, 21.71, 28.39, 53.08, 55.03, 127.23, 129.49, 137.33, 144.13, 201.63; MS *m*/*z* (% rel intensity) 267 (M^+, 2), 224 (6), 155 (14), 139 (6), 113 (15), 112 (100), 91 (73), 84 (21), 71 (32), 70 (87), 65 (47), 55 (9). Anal. Calcd for $C_{13}H_{17}NSO_3$: C, 58.40; H, 6.40; N, 5.23; S, 11.99. Found: C, 58.41; H, 6.42; N, 5.25; S, 11.99.