# Aziridination of Alkenes using *N,N*-Dichloro-*p*-toluenesulfonamide as Nitrogen Source and Palladium Acetate as Catalyst

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## Abstract

Aziridines are a group of organic compounds sharing the aziridine functional group which is a three membered heterocycle with one amine group and two methylene groups. The parent compound of the aziridines is called aziridine with molecular formula $C_2H_5N$. Aziridine is less basic than acyclic aliphatic amines with a pKa of 7.9 for the conjugate acid due to increased s character of the nitrogen free electron pair. As aziridines can be prepared in organic synthesis in several ways, *N,N*-Dichloro-*p*-toluenesulfonamide ($TsNCl_2$) was found to be one of the most efficient nitrogen sources for the aziridination of unfunctionalized alkenes using palladium acetate as the catalyst. Alkenes were reacted at room temperature with $TsNCl_2$ to form the desired aziridines in moderate to good yields. This method can complement the previous protocol, which is limited to the use of electron-deficient α,β-unsaturated alkenes.

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## Introduction

The catalytic aziridination of olefins has attracted wide interest among the synthetic community since aziridines are synthetically and biologically important building blocks.[1] In particular, their highly regio- and stereoselective ring opening with a range of nucleophiles makes them very useful precursors for the synthesis of a variety of functionalized amines.[2] Many catalytic systems have been developed for aziridinations in the presence of halogen,[3] borate,[4] and transition metal compounds[5] as catalysts. Among them, the use of transition metal complexes as aziridination catalysts has received considerable attention in recent years. Although a number of transition metals have been studied and great progress has been made, there still have several drawbacks, such as tedious catalyst preparation,[5b-5d,6] high catalyst loadings,[7] an excessive amount of alkenes and low chemical yields. Searching for more simple and efficient metal catalysts and catalytic systems is still necessary.

The mechanism is shown in appendix 1. Palladium(0) is assumed to be the catalytic species produced by reduction of Pd(II) with olefin as proposed by Yamamoto and coworkers.[8] The first step of the catalytic cycle involves the formation of palladium-nitrogen intermediate (A). The intermediate then reacts with olefin to form intermediate B. Intermediate B then decomposes to give the aminochlorination product and to regenerate the Pd (0) species. Upon reaction with potassium carbonate, the aminochlorination product is cyclized to form the aziridine.

In the past several years, a variety of nitrogen sources have been developed for the aziridination of olefins, these nitrogen sources include PhI=NTs, TsNKI, chloramine-T, bromamine-T and azides.[1,5-9] Among them PhI=NTs has been very popular due to its convenience in handling. However, this reagent suffers from several shortcomings, such as high-cost, high molecular weight and commercial unavailability. Although *N*-halonium salts of sulfonamides have also been used as inexpensive and convenient nitrogen sources for aziridination, they often suffer from competing side reactions.

The use of $TsNCl_2$ as a nitrogen source for aminohalogenation has been well studied and the resulting vicinal chloroamines have been cyclized in an additional step to form aziridines.[9] This reagent is quite attractive since it can be readily prepared by the treatment of $TsNH_2$ with commercial bleach. The resulting product is easily isolated in pure form by simple filtration and additional purification is typically not required. However, the direct use of $TsNCl_2$ for aziridination reaction of normal alkenes has not been documented. Previously, $TsNCl_2$ was only utilized for the aminohalogenation of $\alpha,\beta$-unsaturated ketones and $\alpha,\beta$-unsaturated esters in the presence of various catalysts. It was also used for the aminohalogenation of alkynes in the presence of palladium acetate as the catalyst.[10-11] However, it has now been discovered that $TsNCl_2$ can be conveniently delivered onto unfunctionalized alkenes in the presence of palladium catalyst, which is indeed the first such catalysis for aziridination/aminohalogenation of normal alkene as appendix 2 displays.

## Procedure

*Preparation of* $TsNCl_2$

An oven-dried 250 mL RBF was charged with 5.15 g 2-5 nitrobenzenesulphonylamide and 120 mL bleach (6% NaOCl). The resulting mixture was stirred at room temperature for 24 hours. At 0 ºC, 9 mL $CH_3CO_2H$ was used to quench the reaction. The resulting mixture was filtered and washed by water. The filter cake was dissolved into the $CH_2Cl_2$ (dichloromethane), and then $CH_2Cl_2$ was removed by rotavapor, which yields a yellow solid as appendix 3 demonstrates.

*Aziridination using N,N-Dichloro-p-toluenesulfonamide as Nitrogen Source and Palladium Acetate as Catalyst*

All moisture-sensitive reactions were performed under nitrogen or argon atmosphere. Solvents and regents were dried and distilled prior to use. Melting points were uncorrected. IR spectra were collected on Bruker Vector 22 in KBr pellets. $^1H$ NMR, $^{13}C$ NMR (TMS used as internal standard) spectra were recorded on Bruker ARX-300 spectrometer and $CDCl_3$ was used as solvent. Elemental analyses were performed on a Perkin-Elmer 240 elemental analysis instrument.

Into a dry Schlenk tube was added styrene (312 mg, 3 mmol) and freshly distilled DMF (2 mL). The reaction vial was immersed in a room temperature bath with stirring under a nitrogen atmosphere. Then potassium carbonate (304 mg, 2.2 mmol) and palladium acetate (8.9 mg, 2 mol%) was added. After stirring for five minutes, solid $TsNCl_2$ was added into the mixture. The resulting mixture was stirred at room temperature for 24 h. After completion of the reaction, it was quenched by addition of $H_2O$ (15 mL). The aqueous solution was extracted with ethyl acetate (3 × 20 mL). The combined organic layers were washed with brine, dried over anhydrous sodium sulfate, and concentrated. It is then purified by column chromatography.
Aziridination of alkenes catalyzed by $Pd(OAc)_2{}^a$

## Results and Conclusions

Purification by column chromatography (EtOAc/ petroleum ether = 1:5) provided white solid N-(p-Tolyosulfonyl)-2-phenyl aziridine **(1)** (382 mg, 70% yield). $^1H$ NMR (300MHz, $CDCl_3$), 7.88 (d, 2H, $J = 8.3$ Hz), 7.22-7.36 (m, 7H), 3.80 (dd, 1H, $J = 7.1, 4.5$ Hz), 2.99 (d, 1H, $J = 7.2$ Hz), 2.45 (s, 3H), 2.41 (d, 1H, $J = 4.5$ Hz); $^{13}C$ NMR (300MHz, $CDCl_3$), 145.0, 135.4, 133.5, 130.2, 128.9, 128.7, 128.3, 126.9, 41.4, 36.3, 22.1. After purification, it is found that the experiment came to a 70% yield. In conclusion, the first direct, one-step aziridination using $TsNCl_2$ as the nitrogen source and palladium acetate as the catalyst can be accounted as successful; This catalytic system can be carried out under mild and convenient conditions with $TsNCl_2$ as the limiting regent in moderate to good yields. (see Appendix 4 for more on % yield).

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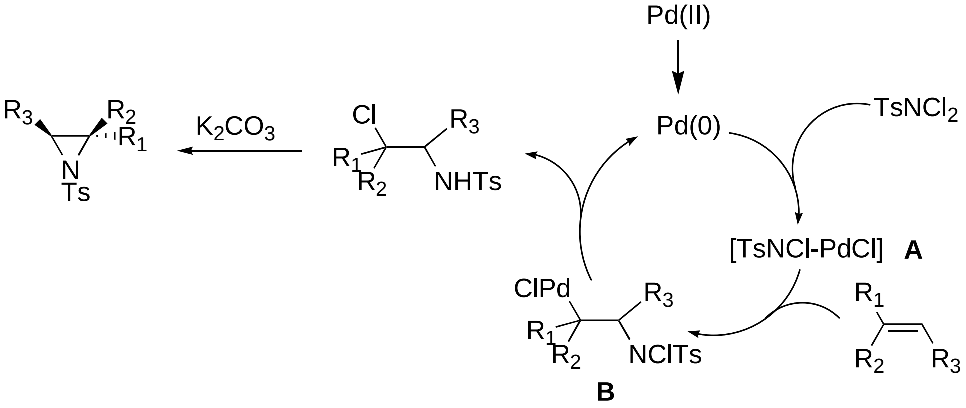
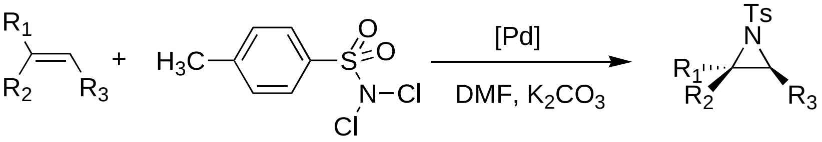
# Appendices

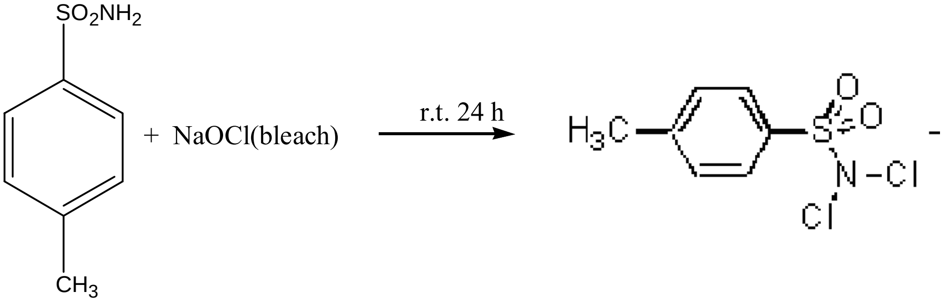
**Appendix 1.** Possible mechanism for aziridination of alkenes catalyzed by palladium.



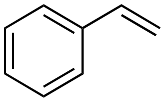
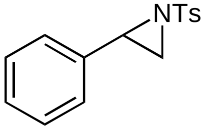
**Appendix 2.** Aziridination of alkenes catalyzed by palladium



**Appendix 3.**



## Appendix 4.

| Olefin | Aziridine | Yield (%)[b] |
|---|---|---|
|  |  | 70 |

[a] Reactions were operated at room temperature in DMF under Ar atmosphere in the presence of a slightly excess of potassium carbonate (1.1 equv) using 2 mol% $Pd(OAc)_2$ for 24h.

[b] Isolated yield with $TsNCl_2$ as limiting regents (styrene: $TsNCl_2$ = 1.5: 1).