A Convenient Method for the Synthesis of β,γ-Unsaturated Amines from Alkenes via α,β-Unsaturated Diphenylsulfonium Salts

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(Received April 15, 2003; CL-030324)

1,1-Disubstituted and trisubstituted alkenes were converted into the corresponding β,γ-unsaturated amines **4** via three steps: the initial formation of α,β-unsaturated diphenylsulfonium triflates **2** from alkenes and diphenyl(trifluoromethanesulfonyloxy)sulfonium trifluoromethanesulfonate (**1**), followed by double bond migration of **2** to β,γ-unsaturated sulfonium triflates **3** with primary or secondary amines, and successive nucleophilic substitution of **3** with these amines.

Allyl amines are valuable target products in medicinal chemistry[1] and are also used as versatile synthetic intermediates.[2] Although many methods are available for the preparation of allyl alcohols by allylic oxidation of alkenes,[3] only a few are known for the synthesis of allyl amines from alkenes, as reported in stoichiometric allylic aminations using S-[4] or Se-imido[5] derivatives, and catalytic aminations with hydroxylamines in the presence of the molybdenum[6] or iron[7] catalyst.

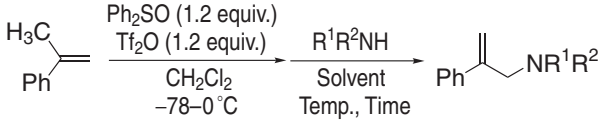
A convenient synthesis of 2-arylaziridines from alkenes and primary amines via 2-arylethenyl(diphenyl)sulfonium salts was recently reported from our laboratory.[8] In the attempted aziridination of α-methylstyrene with benzylamine according to our procedure, 3-benzylamino-2-phenyl-1-propene was obtained in 80% yield instead of expected 1-benzyl-2-methyl-2-phenylaziridine. This might be attributed to the steric hindrance at β-position of diphenyl(2-phenyl-1-propenyl)sulfonium triflate which apparently prevented the initial Michael type addition[8] of benzylamine at the β-position. The above reaction turned out to be useful for introducing amino functions into alkenes to form β,γ-unsaturated amines.

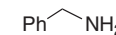
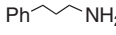
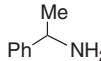
In this communication, we would like to describe a novel and convenient method for the preparation of β,γ-unsaturated amines by the reaction of α,β-unsaturated diphenylsulfonium triflates **2**, formed from alkenes and diphenyl(trifluoromethanesulfonyloxy)sulfonium trifluoromethanesulfonate (**1**),[9] with primary or secondary amines.

Results in Table 1 indicate that α-methylstyrene was converted into various α-(aminomethyl)styrenes on treating with **1** followed by various primary or secondary amines in good yields without accompanying the formation of aziridines. The reactions with monoalkylamines proceeded smoothly at room temperature (entries 1-4), while higher temperature was required in the case with aniline (entry 5). In a similar fashion, the reactions with secondary amines also provided the corresponding β,γ-unsaturated tertiary amines in good yields (entries 6 and 7).

Next, the amination of various alkenes with benzylamine was tried in order to study the scope and limitation of the present reaction (Table 2). 1,1-Disubstituted alkenes gave the β,γ-unsaturated amines in moderate to good yields (entries 1-8). 2-Phenyl-1-butene afforded a mixture of (*E*)- and (*Z*)-1-benzylamino-2-phenyl-2-butene (1:1) in 55% combined yield along with 1-benzyl-2-ethyl-2-phenylaziridine in 25% yield (entry 4). In the case of 2-phenyl-3-methyl-1-butene, consumption of the corresponding sulfonium salt **2** was incomplete even after prolonged reaction time or heating, presumably because the steric hindrance at γ-position of **2** inhibited its smooth double bond migration (entry 5). 2-Methyl-1-pentene afforded the expected two regioisomers with no significant regioselectivity (entry 7). Trisubstituted alkenes gave the desired amines as well although the yields were low (entries 9 and 10), which may be due to the steric repulsion between the intermediate **3** and the amine. In the cases of aliphatic monosubstituted and 1,2-disubstituted alkenes, the corresponding β,γ-unsaturated amines were not obtained. It seemed that the amount of the key intermediates, sulfonium salts **2**, was not sufficient since secondary carbocations generated from alkenes and **1** were not stable enough to form the adducts.

Table 1. β,γ-Unsaturated amines from α-methylstyrene and various primary or secondary amines via α,β-unsaturated diphenylsulfonium salts

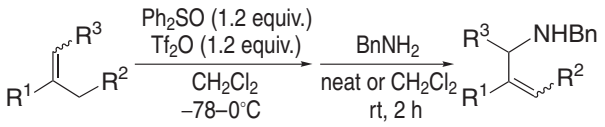


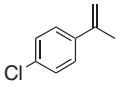
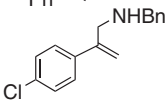
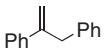
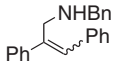
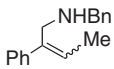
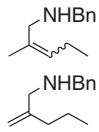
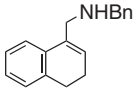
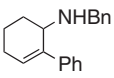
Entry	Amine / equiv.	Solvent	Temp., Time	Yield /%[a]
1	 / 5.0	CH_2Cl_2	rt, 2 h	80
2	 / 10	none	rt, 2 h	78
3	 / 5.0	CH_2Cl_2	rt, 24 h	84
4	*t*-$BuNH_2$ / 5.0	CH_2Cl_2	rt, 12 h	91
5	$PhNH_2$ / 10	DMF	100 °C, 5 h	82
6	*i*-Pr_2NH / 5.0	CH_2Cl_2	rt, 12 h	89
7	Bn_2NH / 5.0	DMF	100 °C, 2 h	81

[a]Isolated yield.

A proposed reaction mechanism is shown in Scheme 1: the initial formation of α,β-unsaturated diphenylsulfonium triflate **2** by the reaction of an alkene with **1** was supported by ^1H NMR analysis. Thus formed **2** reacted with a primary or second-

Table 2. β,γ-Unsaturated amines from various alkenes and benzylamine[a] via α,β-unsaturated diphenylsulfonium salts



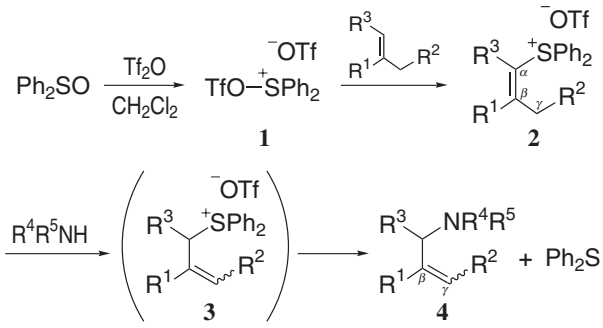
Entry	Alkene	Product	Yield /%[b]
1[c]			79
2[c]			82
3[d]			80[e]
4[d,f]			55[g]
5[d]			45
6[h,i]			79
7[h,i]			44[g] / 34
8[j]			50
9[i]			45
10[i]			47

[a]$BnNH_2$ (10 equiv.) was used without any solvent unless otherwise noted. [b]Isolated yield. [c]$BnNH_2$ (5 equiv.) was used without any solvent. [d]Reaction time of the second step was 45 h. [e]The ratio of *E*:*Z* was 4.4:1, determined by the NOE difference experiment. [f]1-Benzyl-2-ethyl-2-phenylaziridine was also obtained in 25% yield. [g]The ratio of *E*:*Z* was 1:1. [h]Ph_2SO (1.5 equiv.) and Tf_2O (1.5 equiv.) were used. [i]$BnNH_2$ was added to the solution of the sulfonium salt in CH_2Cl_2 at $-78\,^{\circ}C$, and then the mixture was warmed to rt and stirred at rt for 2 h. [j]The reaction of the second step was carried out at $100\,^{\circ}C$ for 6 h.

ary amine to give the corresponding β,γ-unsaturated amine **4** and diphenyl sulfide via double bond migration from **2** to **3** and subsequent nucleophilic substitution with the amine.

Thus, it was noted that a variety of β,γ-unsaturated amines were synthesized from alkenes and primary or secondary amines via the α,β-unsaturated diphenylsulfonium salts.

A typical experimental procedure for the synthesis of β,γ-unsaturated amines is as follows (Table 1, entry 4): to a solution of diphenyl sulfoxide (121 mg, 0.60 mmol) in dichloromethane (1 mL) was added triflic anhydride (0.098 mL, 0.60 mmol) un-



Scheme 1.

der an argon atmosphere at $-78\,^{\circ}C$, followed by dropwise addition of α-methylstyrene (59 mg, 0.50 mmol) in dichloromethane (1 mL) at the same temperature. After stirring for 10 min, the reaction mixture was warmed up to $0\,^{\circ}C$, and the solvent was removed under reduced pressure. A solution of *tert*-butylamine (183 mg, 2.50 mmol) in dichloromethane (1 mL) was added to the mixture and stirred at room temperature for 12 h. The reaction was quenched by adding 0.1 M (1 M = mol dm^{-3}) aqueous sodium hydroxide solution (20 mL), and the organic material was extracted with dichloromethane. The combined organic layers were dried over anhydrous sodium sulfate, filtrated, and concentrated in vacuo. The crude product was purified by preparative TLC to give 3-(*tert*-butylamino)-2-phenyl-1-propene (86 mg, 91%).

This study was supported in part by the Grant of the 21st Century COE Program from the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan.

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Published on the web (Advance View) June 24, 2003; DOI 10.1246/cl.2003.626