Lewis Base-catalyzed [2,3]-Wittig Rearrangement of Silyl Enolates Generated from α-Allyloxy Ketones

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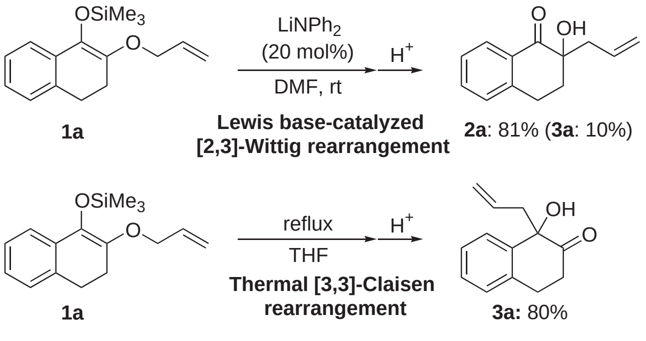
Silyl enolates generated from α-allyloxy ketones afforded the [2,3]-Wittig rearrangement products in good to high yields in the presence of a catalytic amount of Lewis base such as lithium 2-pyrrolidone, lithium acetamide, or lithium hexamethyldisilazide in DMF at room temperature.

The sigmatropic rearrangement of enolates generated from α-allyloxy carbonyl compounds is an important tool for the formation of new carbon–carbon bond. These enolates undergo two competitive thermal sigmatropic shifts, i.e. [3,3]-Claisen and [2,3]-Wittig rearrangement and the possibilities of these two types of rearrangements are dependent on the nature of the enolates:[1] i.e. metal enolates generated from esters or amides generally afford the rearranged products via [2,3]-Wittig rearrangement[2,3] while the enolates generated from ketones undergo both the above two types of sigmatropic rearrangements,[4,5] and silyl enolates generated from esters or ketones afford the rearranged products via [3,3]-Claisen rearrangement.[3,5,6] On the other hand, [2,3]-Wittig rearrangement of trimethylsilyl (TMS) enolates generated from esters takes place in the presence of a catalytic amount of silyl triflate.[7]

It was shown from our laboratory that TMS enolates were successfully activated with a Lewis base catalyst such as the nitrogen or oxygen containing-anions generated from amides, imides, or carboxylic acids, which promoted aldol,[8] Michael,[9] and Mannich-type reactions.[10] Then, in order to further extend the synthetic utility of these catalysts, Lewis base-catalyzed intramolecular rearrangement of silyl enolates was considered. In this communication, we would like to report on a Lewis base-catalyzed [2,3]-Wittig rearrangement of silyl enolates generated from α-allyloxy tetralones and α-allyloxy-4-chromanone.

In the first place, Lewis base-catalyzed [2,3]-Wittig rearrangement was tried by using TMS enolate generated from α-allyloxy tetralone **1a** as a model (Scheme 1). Expectedly, the reaction proceeded smoothly to afford the [2,3]-Wittig rearrangement product **2a** in 81% yield, however, [3,3]-Claisen rearrangement product **3a** was obtained in 10% yield when **1a** was treated with a catalytic amount of lithium diphenylamide in DMF at room temperature. While, the thermolysis in THF afforded the [3,3]-Claisen rearrangement product **3a**. These results indicate that the possibility of the above two rearrangements is controlled by either methods of Lewis base-activation or thermolysis of silyl enolate.

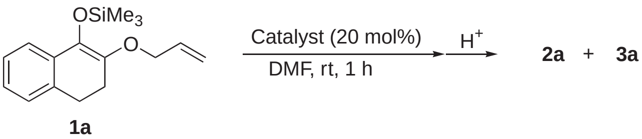


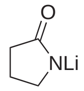
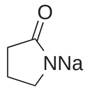
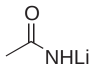
Scheme 1.

Then, Lewis base catalysts were screened in order to increase the amount of **2a** (Table 1). It was then found that lithium 2-pyrrolidone, lithium acetamide, and lithium hexamethyldisilazide (LHMDS) were effective Lewis base catalysts and thereaction proceeded smoothly at room temperature in DMF to fford the corresponding [2,3]-Wittig rearrangement product **2a** selectively.[11,12]

Next, Lewis base-catalyzed [2,3]-Wittig rearrangement was studied by using silyl enolates prepared from 6-substituted α-allyloxy tetralones (**1b**, **1c**) and α-allyloxy-4-chromanone (**1d**) in the presence of 20 mol % of lithium 2-pyrrolidone in DMF at room temperature (Table 2). Trimethylsilyl enolates generated from α-allyloxytetralones having an electron-donating or -withdrawing substituent afforded the [2,3]-Wittig rearrangement products along with a small amount of [3,3]-Claisen rearrangement products. Next, Lewis base-catalyzed [2,3]-Wittig rearrangement of TMS enolate generated from α-allyloxy-4-chro-

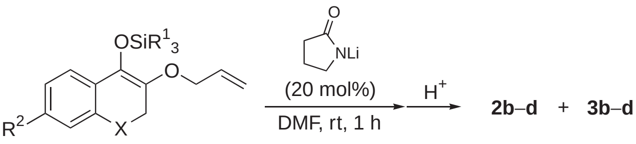
Table 1. Screening of Lewis base catalysts



Entry	Catalyst	Yield[a] /% 2a	Yield[a] /% 3a
1[b]	none	n.d.	80
2	$LiNPh_2$	81	10
3	$LiN(SiMe_3)_2$	83	n.d.
4		93	n.d.
5		10	n.d.
6		91	n.d.
7	Phthalimide Li[c]	32	23

[a]Isolated yield. [b]Reaction was carried out in THF at 50 °C for 6.5 h and farther 2 h under reflux conditions. [c]Lithium salt of phthalimide.

Table 2. Lithium 2-pyrrolidone-catalyzed [2,3]-Wittig rearrangement of silyl enolates



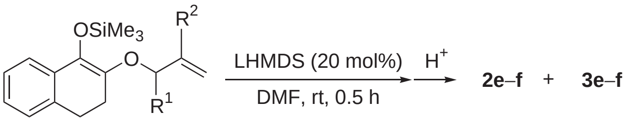
1b–d

	Substrate			Yield^a /%	
	SiR$^1_3$	R^2	X	2b–d	3b–d
1b	SiMe$_3$	OMe	CH$_2$	71	12
1c	SiMe$_3$	CN	CH$_2$	64	16
1d	SiEt$_3$	H	O	70	n.d.

^{a}Isolated yield.

manone was attempted, however, the enolate was not isolated because the [3,3]-Claisen rearrangement took place spontaneously at room temperature. In order to prevent this thermal rearrangement, triethylsilyl (TES) enolate **1d** was prepared and it was found that it is stable enough to isolate by column chromatography at room temperature. Then, Lewis base-catalyzed [2,3]-Wittig rearrangement of TES enolate **1d** was tried and the corresponding [2,3]-Wittig rearrangement product **2d** was obtained in a good yield without accompanying [3,3]-Claisen rearrangement product **3d**.

Further, effect of an allyloxy part of the TMS enolate on the rearrangement was examined by using **1e** and **1f** (Scheme 2). When reactions were carried out in the presence of lithium 2-pyrrolidone, yields of **2e**[13] and **2f** were 76 and 50%, respectively. Lewis base catalysts were further examined in order to improve the yields and it was found that LHMDS was an appropriate catalyst for these enolates and the corresponding [2,3]-Wittig rearrangement products were afforded in better yields than those when lithium 2-pyrrolidone was used.



1e: R^1 = CH$_3$, R^2 = H **2e**: 85% **3e**: n.d.
1f: R^1 = H, R^2 = CH$_3$ **2f**: 84% **3f**: trace

Scheme 2.

It is noted that Lewis base-catalyzed reactions of silyl enolates generated from α-allyloxy ketones afforded the [2,3]-Wittig rearrangement products. Further development of this reaction is now in progress.

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11 Silyl enolates were synthesized from the corresponding α-allyloxyketones with lithium diisopropylamide or lithium hexamethyldisilazide followed by treatment with chlorotrimethylsilane in THF at $-78\,^{\circ}$C. After evaporation of the solvent they were purified by column chromatography on silica gel (elution with ethyl acetate in hexane with 1% triethylamine). α-Allyloxyketones were prepared from a solution of the corresponding α-diazoketones[11a] in allylalcohol by using a catalytic amount of boron trifluoride etherate:[11b] a) M. Rosenberger and P. Yates, *Tetrahedron Lett.*, **5**, 2285 (1964). b) M. S. Newman and P. F. Beal, III, *J. Am. Chem. Soc.*, **72**, 5161 (1950).

12 Typical experimental procedure of [2,3]-Wittig rearrangement is as follows (Table 1, Entry 4): a) Preparation of catalyst; To a solution of 2-pyrrolidone (46.8 mg, 0.55 mmol) in THF (4.5 mL) was added methyllithium in Et$_2$O (0.98 M, 0.51 mL, 0.5 mmol) and the mixture was stirred for 30 min. b) The experimental procedure of lithium 2-pyrrolidone-catalyzed [2,3]-Wittig rearrangement; A solution of lithium 2-pyrrolidone (0.36 mL, 0.036 mmol) was concentrated under reduced pressure and the residue was dissolved in DMF (0.5 mL). Then, the solution of silyl enolate **1a** (50.6 mg, 0.18 mmol) in DMF (1.5 mL) was added at room temperature under argon atmosphere. The mixture was stirred for an hour at the same temperature, and aqueous HCl (1.0 M) was added. After stirring for 30 min, the mixture was extracted with Et$_2$O. Organic layer was washed with water and brine, and dried over anhydrous Na$_2$SO$_4$. After filtration and evaporation of the solvent, the crude product was purified by preparative TLC to afford **2a** (34.5 mg, 93%).

13 The [2,3]-Wittig rearrangement product **2e** was obtained as *E*-isomer. Stereochemistry of **2e** was determined by the comparison with reported ^{1}H and ^{13}C NMR data: J. L. Wood, G. A. Moniz, D. A. Pflum, B. M. Stoltz, A. Holubec, and H.-J. Dietrich, *J. Am. Chem. Soc.*, **121**, 1748 (1999).

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