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

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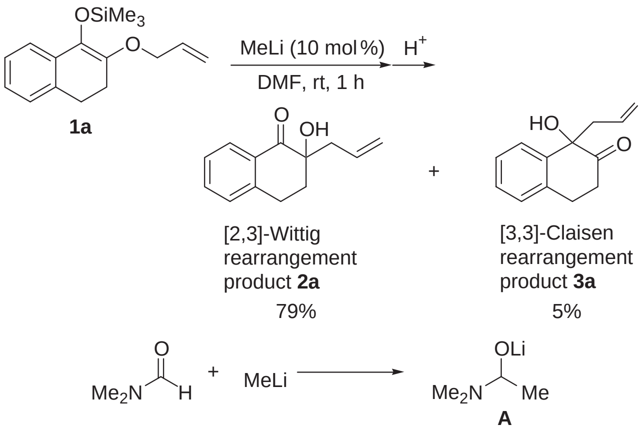
The [2,3]-Wittig rearrangement of silyl enolates generated from α-allyloxy ketones proceeded smoothly in DMF by the promotion of a catalytic amount of metal alkoxides such as sodium benzylate to afford the corresponding rearrangement product in good yields at room temperature, which indicated that the oxygen anion initially formed in the above product effectively catalyzed the [2,3]-Wittig rearrangement as a Lewis base.

Product-catalyzed reactions attract much attention in organic chemistry.[1] In the course of our investigations on Lewis base-catalyzed reactions using trimethylsilyl (TMS) enolates, therefore, the product-catalyzed aldol, Michael, and Mannich-type reactions initiated by metal alkoxides were studied with much interest.[2]

It was shown recently that the nitrogen anions generated from lithium 2-pyrrolidone or lithium hexamethyldisilazide effectively promoted the catalytic [2,3]-Wittig rearrangement of silyl enolates derived from α-allyloxy ketones,[3] and that they proceeded via a pathway different from that of conventional thermal [3,3]-Claisen rearrangement of silyl enolates.[4] Now, in order to show further synthetic utilities of this reaction, new Lewis base catalyzed [2,3]-Wittig rearrangement was studied. In this communication, we would like to report on the product-catalyzed [2,3]-Wittig rearrangement of silyl enolates generated from α-allyloxy ketones.

During our investigation on a new Lewis base catalyst of the [2,3]-Wittig rearrangement, it was found that the rearrangement of **1a** proceeded smoothly in the presence of a catalytic amount of MeLi in DMF to afford the [2,3]-Wittig rearrangement product **2a** in 79% yield together with 5% of [3,3]-Claisen rearrangement product **3a** (Scheme 1). It was considered then that the alkoxide **A**, which was generated by the reaction of MeLi with DMF, effectively activated the enolate to promote the rearrangement.



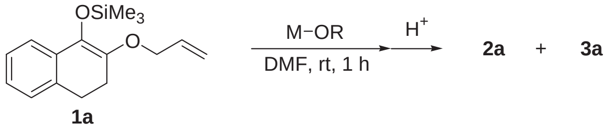
Scheme 1.

In previous papers, no regeneration processes of a catalyst were shown to take place in aldol, Michael, and Mannich-type reactions when alkoxide anions were used, and the successive alkoxide-initiated and product-catalyzed processes were then suggested accordingly.[2] Upon considering the above, the alkoxide-initiated and product-catalyzed [2,3]-Wittig rearrangement was examined.

In the first place, the [2,3]-Wittig rearrangement of TMS enolate **1a** was tried by using 20 mol % of LiOBn. The reaction then proceeded smoothly at room temperature to afford desired product **2a** in good yield together with a small amount of [3,3]-Claisen rearrangement product **3a** (Table 1, Entry 1). In order to increase the efficiency of this [2,3]-Wittig rearrangement, the effect of initiators, the metal alkoxides, was studied. Both yield and selectivity depended on the nature of a counter cation and the sodium cation was the most effective.

Next, the above alkoxide-initiated [2,3]-Wittig rearrangement was tried by using silyl enolates **1b**, **1c**, and **1d** in the presence of 10 mol % lithium or sodium benzylate (Table 2). Then, the reaction proceeded smoothly to afford the corresponding [2,3]-Wittig rearrangement product **2** selectively in a good to high yield when sodium was used as a counter cation of the

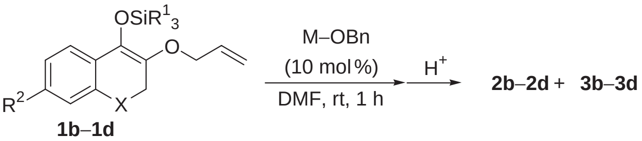
Table 1. [2,3]-Wittig rearrangement of TMS enolate **1a** in the presence of a catalytic amount of alkoxide anion as an initiator



Entry	M–OR	/mol %	Yield[a]/%	
			2a	**3a**
1	LiOBn	20	87	12
2	NaOBn	20	94	n.d.[c]
3[b]	NaOBn	20	81	n.d.[c]
4	NaOBn	10	93	n.d.[c]
5	KOBn	20	84	n.d.[c]
6	Bu$_4$NOBn	20	88	n.d.[c]
7	LiO*t*-Bu	20	86	7
8	KO*t*-Bu	20	84	n.d.[c]
9	LiOEt	20	89	3
10	NaOEt	20	96	n.d.[c]
11	LiOMe	20	79	5
12	NaOMe	10	93	n.d.[c]

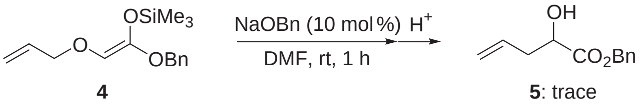
[a] Isolated as mixture of **2a** and **3a**. Yields of these compounds were determined by ^{1}H NMR analysis (400 MHz). [b] THF was used insted of DMF. [c] n.d.; not detected.

Table 2. Alkoxide anion-initiated [2,3]-Wittig rearrangement of silyl enolates



Entry		Substrate			M–OBn	Yield[a]/%	
		SiR^1_3	R^2	X		**2b–2d**	**3b–3d**
1	**1b**	$SiMe_3$	OMe	CH_2	LiOBn	88	8
2	**1b**	$SiMe_3$	OMe	CH_2	NaOBn	98	n.d.[c]
3	**1c**	$SiMe_3$	CN	CH_2	LiOBn	76	13
4	**1c**	$SiMe_3$	CN	CH_2	NaOBn	82	n.d.[c]
5	**1d**[b]	$SiEt_3$	H	O	LiOBn	79	n.d.[c]
6	**1d**[b]	$SiEt_3$	H	O	NaOBn	84	n.d.[c]

[a] Isolated as mixture of **2** and **3**. Yields of these compounds were determined by ^{1}H NMR analysis (400 MHz). [b] Triethylsilyl enolate was used insted of TMS enolate because the corresponding TMS enolate was unstable. [c] n.d.; not detected.



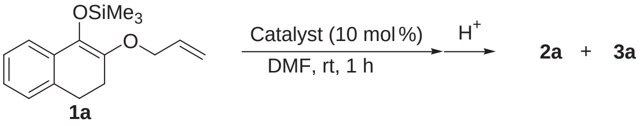
Scheme 2.

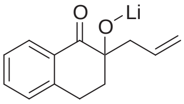
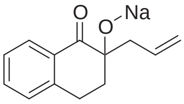
benzylate.

When the reaction was carried out by using ketene silyl acetal **4** in the presence of sodium benzylate as a catalyst, only a trace amount of rearrangement product **5** was obtained although ammonium carboxylates effectively promoted the reaction (Scheme 2).[5]

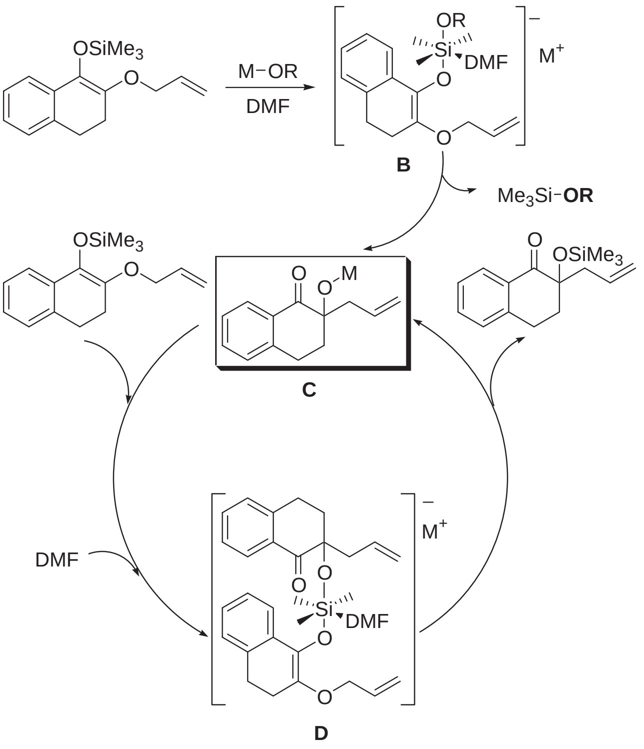
From the environmental point of view, the product-catalyzed reaction has a great advantage because neither disposal of the catalyst nor its separation from the reaction mixture is needed. Based on this consideration, the product-catalyzed [2,3]-Wittig rearrangement was tried next (Table 3) and the reaction proceeded smoothly to give the rearranged product in good yield when sodium ion was employed as a counter cation of the catalyst.

Table 3. Product-catalyzed [2,3]-Wittig rearrangement of TMS enolate



Entry	Catalyst[a]	Yield[b]/%	
		2a	**3a**
1		82	3
2		92	n.d.[c]

[a] Catalysts were prepared from **2a** and MeLi (Entry 1) or NaHMDS (Entry 2). [b] Isolated as mixture of **2a** and **3a**. Yields were determined by ^{1}H NMR analysis (400 MHz). [c] n.d.; not detected.



Scheme 3.

The proposed catalytic cycle of this reaction is illustrated in Scheme 3. At first, both the metal alkoxide (M–OR) and the Lewis basic solvent DMF coordinated to the silicon atom of TMS enolates to form hypervalent silicate **B**. The reactivity of thus formed enolate was sufficient enough to undergo the [2,3]-Wittig rearrangement to afford **C**. The enolate was activated by thus formed **C** and the product-catalyzed cycle was achieved.

Thus, this [2,3]-Wittig rearrangement of silyl enolates generated from α-allyloxy ketones proceeded smoothly in the presence of a catalytic amount of a metal alkoxide as an initiator. Further development of this reaction is now in progress.

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