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Reduction of monothioacetals with SmI₂: application to [2,3]-Wittig rearrangement

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Abstract—Simple reduction of O,S-acetals with SmI₂ yielding ethers with selective liberation of the sulfenyl group can be accomplished using benzene–HMPA with *t*-BuOH. When O,S-acetals possess an O-allyl group, the [2,3]-Wittig rearrangement yielding homoallyl alcohols follows the elimination of a sulfenyl group. For chemoselective elimination of an alkoxy group to give sulfides, MeOTf serves as a moderately effective additive. © 2001 Elsevier Science Ltd. All rights reserved.

The [2,3]-Wittig rearrangement is a useful tool for preparing homoallyl alcohols.¹ We have already demonstrated that samarium diiodide (SmI₂) can effect the [2,3]-sigmatropic rearrangements. Addition of samarium carbenoids to allylic sulfides produces allylic sulfonium ylides, which undergo [2,3]-rearrangement.² α -Allyloxy carbanions that undergo the [2,3]-Wittig rearrangement can be generated by an intramolecular 1,5-hydrogen atom transfer of either a vinyl or aryl radical, followed by a single electron transfer from

 SmI_2 .³ All the methods provide a regioselective and nonbasic approach for generating an α -allyoxy carbanion species undergoing the rearrangement.

Reductive removal of an α -substituent of allyl ethers with SmI₂ provides a more direct route for the regioselective generation of α -allyloxy carbanions. We were able to generate the carbanions by reduction of diallyl acetals with SmI₂ in acetonitrile.⁴ This is not only a new method for effecting the [2,3]-Wittig rearrangement but

Table 1. Preliminary studies on the reduction of an O,S-acetal with SmI₂

			ml₂ dditive ► F				
		Phi OBu rt 1		2	3		
Run	Additive (equiv.)	SmI_2	Solvent	Time	2 (%) ^a	3 (%) ^a	1 (%) ^a (recovery)
1	t-BuOH (2)	5 equiv.	PhH–HMPA	24 h	80	0	1
2	t-BuOH (1)	4 equiv.	PhH–HMPA	15 h	71	0	13
3	_	3 equiv.	PhH-HMPA	18 h	22	0	16
4	MeOH (2)	5 equiv.	PhH–HMPA	7.5 h	54	0	27
5	EtOH (2)	5 equiv.	PhH-HMPA	7 h	54	0	31
6	<i>i</i> -PrOH (2)	5 equiv.	PhH–HMPA	7 h	39	0	40
7	AcOH (2)	5 equiv.	PhH–HMPA	12 h	31	0	56
8	$TsOH \cdot H_2O(2)$	5 equiv.	PhH–HMPA	5 min	4	0	74
9 ^ь	_	2.5 equiv.	CH ₃ CN	2 h	20	0	56
10	$AlCl_3(1)$	2.5 equiv.	CH ₃ CN	2 min	0	0	89

^a Determined by GC. No sulfide was detected.

^b Conducted at reflux temperature.

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also indicates that reduction of acetals can be achieved by SmI_2 without any additives.⁵ In a related reaction, we have also demonstrated that partial reduction of dithioacetals to sulfide could be achieved by using a SmI_2 -benzene-HMPA-*t*-BuOH system.⁶ Based on these findings, we expected that reduction of monothioacetals (*O*,*S*-acetals) could be effected by using SmI_2 .⁷ In this letter, we report a partial reduction of *O*,*S*-acetals to ethers by chemoselective reductive elimination of a sulfenyl group using SmI_2 , and its applicability to effecting the Wittig rearrangement.⁸ Chemoselective removal of an alkoxy group to give sulfides is also described.

Reduction of O,S-acetals **1** as a test substrate with SmI₂ was attempted under several conditions, as summarized in Table 1.^{9,10} Using the conditions (SmI₂-benzene-HMPA system in the presence of 2 equiv. of *t*-BuOH) that had been successfully employed for reduction of dithioacetals,⁶ gave benzyl butyl ether **2** in a good yield (80%).^{11,12} The yield of **2** decreased slightly when *t*-BuOH was decreased to 1 equiv., and dropped to 22% in the absence of the alcohol. When *t*-BuOH was replaced by other alcohols, such as MeOH, EtOH, and *i*-PrOH, the product **2** was formed in moderate yields. Acetic acid and *p*-toluenesulfonic acid gave low

yields of **2** with the recovery of **1**. Benzyl phenyl sulfide **3**, arising from reductive elimination of the alkoxy group, was not observed under any of the conditions employed, even under reflux in CH₃CN (run 9), which was employed for reductive removal of an alkoxy group from acetals.⁴ However, it should be noted that treatment of **1** with methyl trifluoromethanesulfonate (MeOTf) prior to the addition of SmI₂ gave **3** selectively, albeit in moderate yield (Eq. (1)).¹³

When the reaction was conducted using *t*-BuOD and subsequently quenched with D_2O or H_2O , deuterium was found at the benzylic position of **2** in 69% D and 67% D, respectively (Eq. (2)). We conclude from this that the α -alkoxy carbanion is involved as an intermediate, and that *t*-BuOH acts as a principal proton source. Because of the instability of alkylsamariums,¹⁴ the intermediate is likely to decompose when proton sources are absent. The lower yields observed with MeOH, EtOH, and *i*-PrOH compared to that observed with *t*-BuOH may be attributed to the consumption of SmI₂ by direct reaction of the alcohols with SmI₂.



Table 2. [2,3]-Wittig rearrangement of O,S-acetals mediated by SmI₂

SP R ¹	h 3Sml ₂ solvent HMPA rt	$ \begin{array}{c} $	[2,3]- rearranger	ment R ¹	OH
run	O,S-acetals	products	time	solvent	yield
1 ^{a)}	SPh	ŎН	24 h	PhH	48%
2	Ph 0	Ph	22 h	PhH	65%
3	4a	5a	43 h	THF	53%
4	SPh Ph O Me 4b (91% <i>E</i>)	Ph Me 5b (erythro : threo	36 h = 65 : 35)	PhH	62%
5	SPh	ŎН	40 h	THF	80%
6 /		\sim	18 h	PhH	71%
	4c ັ	5 c			
7 ^{b)}	SPh	OH 	15 h	PhH	6% ^{c)}
8 ^{b)}	C ₉ H ₉ O	C ₉ H ₉	12 h	THF	12% ^{d)}
	4d	5d			

^{a)} Performed in the presence of *t*-BuOH (2eq). ^{b)} Performed at reflux temperature.

^{c)} Recovery of 4c (84%). ^{d)} Recovery of 4d (39%).

Based on these findings, we examined the possibility of effecting the [2,3]-Wittig rearrangement using O-allyl-S-phenylacetals 4.¹⁵ When the reaction of 4a was performed by the SmI₂-benzene-HMPA system in the presence of t-BuOH, homoallyl alcohol 5a was obtained in 48% yield (Table 2, run 1). In contrast to simple reduction, the α -allyloxy carbanion intermediate 6 is capable of undergoing the [2,3]-rearrangement (to give more stable alkoxides) before its decomposition. In this case, t-BuOH as a proton source would not be required, and, indeed, may somewhat prevent the rearrangement. In fact, the yield of 5 increased to 65% in the absence of *t*-BuOH.¹⁶ A reaction system using THF instead of benzene was also found to be useful. The reactions of aromatic or vinylic *O*-allyl-*S*-phenylacetals (4a-c) allow rearrangement at rt whereas an aliphatic reactant (4d) gave 5d in very low yield, even under reflux. The base-induced [2,3]-Wittig rearrangements are generally conducted at a low temperature to avoid the competition of [1,2]-rearrangements.¹⁷ However, there was no evidence for the formation of the [1,2]-rearranged product in the reaction of 4b conducted at rt. The observed low *erythro*/*threo* stereoselectivity (65:35) of **5b** obtained from **4b** with *E*-geometry agreed with those (61:39, 62:38) reported previously in the other SmI₂-induced Wittig rearrangements.^{3a,4,18} On the bases of the regioselection rule regarding lithiation on unsymmetrical diallyl ethers established by Nakai et al.,¹⁹ the formation of 5c is expected to be very difficult using conventional deprotonation methods. Thus, it is noteworthy that 5c was regioselectively formed from 4c in a good yield. In comparison with the Wittig rearrangement involving reductive desulfenylation of O,S-acetals with lithium naphthalenide,8 the present reaction proceeds under nonbasic conditions.

In summary, for reduction of O,S-acetals with SmI₂: 1) benzene–HMPA with *t*-BuOH is an effective system for giving ethers with liberation of the sulfenyl group, 2) benzene–HMPA or THF–HMPA without alcohols resulted in the [2,3]-Wittig rearrangement when O,S-acetals possess an O-allyl group, 3) MeOTf enables chemoselective elimination of an alkoxy group to give sulfides in a moderate yield.

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- 13. For general procedure for the reductive removal of the alkoxy group: MeOTf (0.11 mmol) was added to a solution of 1 (0.11 mmol) in 2 ml Et₂O at rt under nitrogen. After stirring for 14 h, SmI₂ (111 mM, 4.0 ml, 0.44 mmol) in THF containing 10% HMPA was added at rt. The reaction mixture was stirred for 4 h and quenched with aq. NaHCO₃. The crude mixture was subject to GC analysis.
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- 16. For general procedure for the Wittig rearrangement: a solution of 4a (0.12 mmol) in 0.5 ml benzene was added to SmI₂ (67 mM, 5.2 ml, 0.35 mmol) in benzene containing 10% HMPA at rt under nitrogen. After stirring for 22 h, the mixture was quenched and extracted. The crude mixture was purified on preparative TLC to give 5a.
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