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A Convenient Method for the Preparation of Secondary Propargylic Ethers. The Reaction of Acetals with 1-Trimethylsilylalkynes Promoted by the Combined Use of Catalytic Amounts of Tin(IV) Chloride and Zinc Chloride

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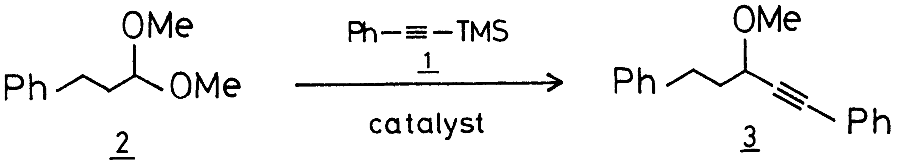
In the coexistence of catalytic amounts of $SnCl_4$ and $ZnCl_2$, acetals undergo a coupling with 1-trimethylsilylalkynes in good yields to give secondary propargylic ethers, which are also directly produced from aldehydes by the reaction with alkoxytrimethylsilanes and 1-trimethylsilylalkynes under the same conditions.

Recently, trityl cation promoted carbon-carbon bond forming reactions[1] have been developed in our laboratory, and it becomes apparent that a stoichiometric amount of Lewis acid, such as $TiCl_4$,[2] is not necessarily required in these acid promoted reactions of carbonyl compounds with various silyl nucleophiles. During our continuing work on the development of efficient promotors, a useful carbon-carbon bond forming reaction was studied by the combined use of catalytic amounts of various Lewis acids.[3]

The reaction of 1-trimethylsilylalkynes with acetals generally requires an equimolar amount or a large excess of Lewis acids, such as $TiCl_4$,[4] and it was also shown that the above mentioned reaction was hardly promoted by a catalytic amount of the activators. In this communication, we wish to describe that the reaction of 1-trimethylsilylalkynes with acetals takes place smoothly in the coexistence of catalytic amounts of $SnCl_4$ and $ZnCl_2$ to give secondary propargylic ethers. The ethers can be also obtained directly from aldehydes, alkoxytrimethylsilanes and 1-trimethylsilylalkynes under the same conditions.

In the first place, cinnamaldehyde dimethyl acetal was treated with 1-trimethylsilylethynylbenzene(1) in the presence of 10 mol% of $TrClO_4$[5] to afford the corresponding propargylic ether in 23% yield. But most of other acetals, such as 3-phenylpropanal dimethyl acetal (2), did not react with 1, or only a trace of the desired products were obtained. So, we tried the reaction of 2 with 1 in the coexistence of 10 mol% each of $TiCl_4$ and $SnCl_2$, and it was found that the reaction took place smoothly in CH_2Cl_2 at 0 °C to give the product 3 in 47% yield.



Scheme 1.

Table 1. Examination of catalysts and reaction conditions[a)]

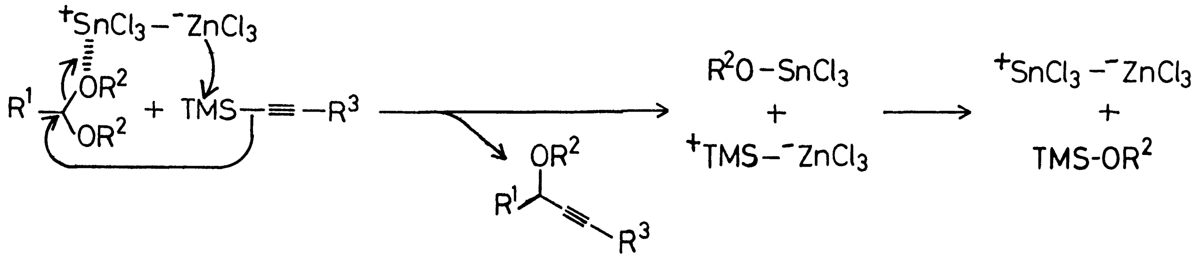
Entry	Catalyst[b)]	Temp /°C	Time/h	Yield of 3/%
1	$TiCl_4$-SnF_2	0	24	6
2	$TiCl_4$-$SnCl_2$	0	24	47
3	$TiCl_4$-$SnBr_2$	0	24	33
4	$TiCl_4$-$ZnCl_2$	0	3.5	49
5	$TiCl_4$-$ZnBr_2$	0	24	38
6	$SnCl_4$-$SnCl_2$	0	3.5	39
7	$SnCl_4$-$ZnCl_2$	0	3.5	68[c)]
8[d)]	$SnCl_4$-$ZnCl_2$	-20	7	74
9[d)]	$SnCl_4$-$ZnCl_2$	20	3.5	85
10	$SnCl_4$-$ZnBr_2$	0	3.5	53

a) Reactions were carried out in CH_2Cl_2 with 1.0 equivalent of 1 except for entries 8 and 9.
b) In all experiments, 10 mol% catalysts were used.
c) Ref. 6.
d) Molar ratio of 1:2=1.5:1.

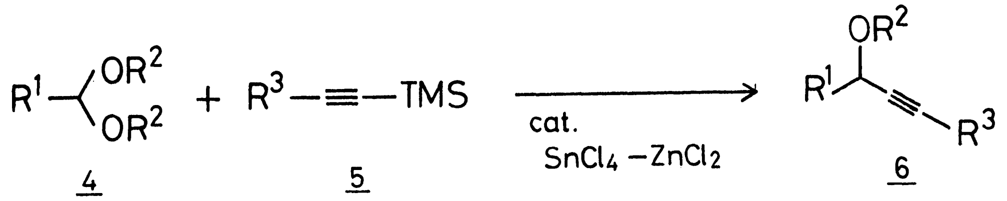
After screening various combinations of metal salts by taking the reaction of 2 with 1 as a probe, it was found that the reaction proceeded smoothly in CH_2Cl_2 at the room temperature by the combined use of $SnCl_4$ and $ZnCl_2$ as the catalyst to afford the desired product (3) in an excellent yield (85%) (Table 1).

Next, according to this method, the reaction of various acetals (4) with 1-trimethylsilylalkynes (5) was tried (see Table 2), and the corresponding secondary propargylic ethers (6) were obtained in good yields.

It is assumed that $^{+}SnCl_3$-$^{-}ZnCl_3$ species is initially generated from $SnCl_4$ and $ZnCl_2$, and while $^{+}SnCl_3$ activates acetals, $^{-}ZnCl_3$ attacks silicon atom of 1-trimethylsilylalkynes to form TMS-Cl-$ZnCl_2$ like species which is in turn transformed into TMS-OR^2 and the original catalytic species as sketched below.



Typical procedure is described for the synthesis of 1,5-diphenyl-3-methoxypent-1-yne (Table 2, entry 1): Under an argon atmosphere, a CH_2Cl_2 (4 ml)



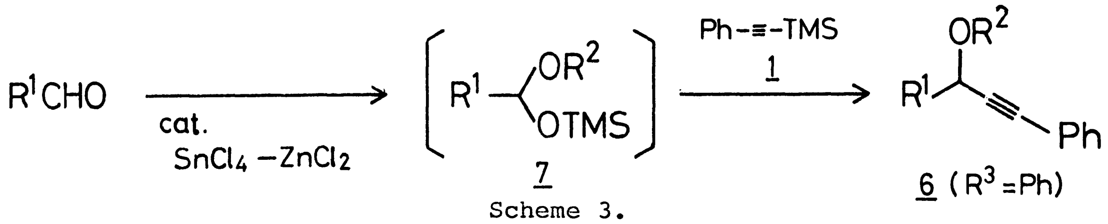
Scheme 2.

Table 2. Synthesis of secondary propargylic ethers from acetals[a)]

Entry	4 (or 2)		5 (or 1)	Time/h	Yield of 6/%[b)]
	R^1	R^2	R^3		
1	$Ph(CH_2)_2$	CH_3	Ph	3.5	85
2[c)]	$Ph(CH_2)_2$	CH_3	CH_3	3.5	82
3	$Ph(CH_2)_2$	CH_3	$CH_3(CH_2)_4$	3.5	78
4	$Ph(CH_2)_2$	CH_2Ph	Ph	3.5	44
5	$CH_3(CH_2)_7$	CH_3	Ph	3.5	79
6	$CH_3(CH_2)_7$	CH_3	CH_3	3.5	74
7	$CH_3(CH_2)_7$	CH_3	$CH_3(CH_2)_4$	48	71

a) Reaction was carried out in CH_2Cl_2 at room temperature in the coexistence of 10 mol% each of $SnCl_4$ and $ZnCl_2$. Molar ratio of 4:5=1.5:1.
b) Isolated yield. All samples gave satisfactory ^{1}H-NMR and IR spectra.
c) Molar ratio of 4:5=2:1. Catalyst 20 mol% was used.

suspension of $SnCl_4$ (0.11 mmol) and $ZnCl_2$ (0.11 mmol) was stirred for 30 min at room temperature, to which were added successively 1 (1.0 mmol) in CH_2Cl_2(2 ml) and 2 (1.5 mmol) in CH_2Cl_2 (3 ml). The reaction mixture was stirred for 3.5 h at the same temperature, then quenched with aqueous solution of sodium bicarbonate. The organic materials were extracted with CH_2Cl_2, and the combined



Scheme 3.

Table 3. Synthesis of secondary propargylic ethers from aldehydes[a)]

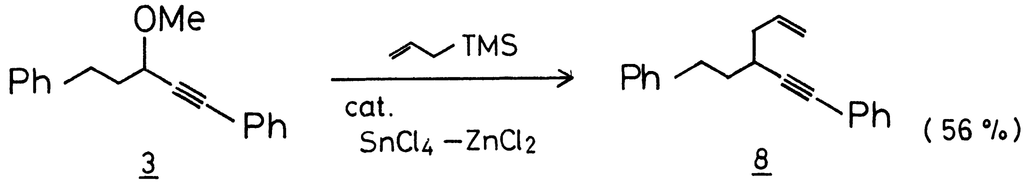
Entry	R^1	R^2	Yield of 6/%[b)]
1	$Ph(CH_2)_2$	CH_2Ph	67
2	$Ph(CH_2)_2$	CH_3	78
3	$Ph(CH_2)_2$	CH_3CH_2	77
4	$CH_3(CH_2)_5$	CH_3	73

a) Reaction was carried out in CH_2Cl_2 at 0 °C for 6 h in the coexistence of 20 mol% each of $SnCl_4$ and $ZnCl_2$. Molar ratio of R^1CHO:TMS-OR^2:1=1:1.2:1.5.
b) Isolated yield. All samples gave satisfactory ^{1}H-NMR and IR spectra.

extracts were dried over $MgSO_4$. After evaporation of the solvent, the residue was purified by preparative TLC (silica gel) to afford 1,5-diphenyl-3-methoxypent-1-yne (0.85 mmol, 85%).

From the synthetic point of view, it is more desirable to prepare secondary propargylic ethers directly from aldehydes instead of acetals in the above reaction. Based on this consideration, the reaction of the hemiacetal-type compounds 7 with 1 was tried. As shown in Table 3, it was found that in the coexistence of 20 mol% of $SnCl_4$ and $ZnCl_2$, adducts 7 were initially formed from alkoxytrimethylsilanes and aldehydes, and 7 reacted in turn with 1 to form the desired secondary propargylic ethers (6).

It was reported from our laboratory that allyl ethers reacted with an allylsilane to afford 1,5-diene derivatives by the use of a catalytic amount of $TrClO_4$.7) This result suggests us to develop a convenient method of the two carbon-carbon bonds formation. Secondary propargylic ethers thus obtained have a potentiality of coupling with other nucleophile such as an allylsilane. The desired 1,5-ene-yne derivative (8) was obtained in good yield when 3 was treated with allyltrimethylsilane in the coexistence of 20 mol% each of $SnCl_4$ and $ZnCl_2$.8)



Scheme 4.

It is noted that the combined use of $SnCl_4$ and $ZnCl_2$ effectively promotes the reaction of 1-trimethylsilylalkynes with an acetal, and also secondary propargylic ethers thus obtained are converted into 1,5-ene-yne derivatives by the reaction with allyltrimethylsilane in the presence of the same catalyst. Further studies directed to useful carbon-carbon bond forming reactions utilizing the above mentioned promoter are currently in progress.

References

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3) N. Iwasawa and T. Mukaiyama, Chem. Lett., 1987, 463. T.Mukaiyama, S. Kobayashi, M. Tamura, and Y. Sagawa, *ibid.*, 1987, 491.
4) W. S. Johnson, R. Elliott, and J. D. Elliott, J. Am. Chem. Soc., 105, 2904 (1983).
5) $TrClO_4$ promoted the reaction of allylsilanes with acetals. T. Mukaiyama, H. Nagaoka, M. Murakami, and M. Ohshima, Chem. Lett., 1985, 977.
6) When the reaction was carried out in CH_3CN at the same condition, the yield of 3 was 9%.
7) M. Murakami, T. Kato, and T. Mukaiyama, Chem. Lett., 1987, 1167.
8) Trityl perchlorate did not promote this reaction. The desired product (8) was obtained in 60% yield based on 3-phenylpropanal by one-pot procedure.

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