CHEMISTRY LETTERS, pp. 789-792, 1994.

Combined Use of Diphenyltin Sulfide or Lawesson's Reagent and Silver Perchlorate as Effective Catalyst Systems in Aldol Reaction

Teruaki MUKAIYAMA, Katsuyuki SAITO, Hideo KITAGAWA, and Naoyuki SHIMOMURA
Department of Applied Chemistry, Faculty of Science,
Science University of Tokyo, Kagurazaka, Shinjuku-ku, Tokyo 162

Catalytic aldol reactions of several aldehydes with trimethylsilyl enol ethers are effectively performed by combined use of diphenyltin sulfide ($Ph_2Sn=S$) and silver perchlorate ($AgClO_4$) or Lawesson's reagent (2,4-bis(4-methoxyphenyl)-1,3-dithia-2,4-diphosphetane-2,4-disulfide) and silver perchlorate under mild conditions.

The reaction of carbonyl compounds activated by Lewis acids with carbon nucleophiles is one of the most efficient synthetic tools for carbon-carbon bond formation. Rather strong Lewis acids such as $TiCl_4$, $SnCl_4$, $BF_3{\cdot}Et_2O$, etc.[1) have frequently been used in many examples, especially in cross-aldol and related reactions. Therefore, exploration of new and mild catalysts still remains as one of the challenging topics in organic synthesis.

We have recently reported an efficient method for the synthesis of β-D-ribofuranosides from 2,3,5-tri-O-benzyl-1-O-iodoacetyl-D-ribofuranose or 2,3,5-tri-O-benzyl-D-ribofuranose and trimethylsilylated alcohols or alcohols by a combined catalyst system of [$Ph_2Sn=S$/silver salt] or [Lawesson's reagent/silver salt] under mild conditions.2) Now, in this communication, we would like to report catalytic aldol reactions of aldehydes with trimethylsilyl enol ethers which proceed under mild conditions by employing the above mentioned catalyst systems composed of neutral melocules and a very weak Lewis acid as $AgClO_4$.

In the first place, the reaction of benzaldehyde (**1**) with 1.1 equiv. of 1-phenyl-1-trimethylsiloxyethylene (**2**) was tried in dichloromethane at -78 °C by using a catalyst generated in situ from $Ph_2Sn=S$ (15 mol%) and $AgClO_4$ (5 mol%) at room temperature, and the corresponding aldol adduct was obtained in 85% yield. Next, the effect of concentration of **1** was examined in the above reaction, and the best result was given when the reaction was carried out in 0.16 M solution (Table 1, Entries 1, 2, and 4). Then, the effect of solvents (Table 1, Entries 2, 5, and 6) was examined under the conditions, and the best result was given in dichloromethane while the adduct was obtained in low yield along with the by-product (**4**, 4% yield) when toluene was used as a solvent. It is interesting to point out that even 1 mol% of the catalyst system gave good result (Table 1, Entry 3). Furthermore, the order of the addition of substrates **1** and **2** was studied. In the above experiments, a mixture of **1** and **2** was added to the catalyst system (method A). When **1** was added before **2** (method B) in the presence of 1 mol% of $AgClO_4$ and 3 mol% of $Ph_2Sn=S$, the corresponding adduct was obtained in 86% yield whereas the inversed addition (method C) gave the desired adduct in 93% yield. On the basis of these results, subsequent experiments were carried out according to the method C.

A similar result was obtained (89% yield) when the above reaction was carried out by using a catalyst generated in situ from $AgClO_4$ (1 mol%) and $Ph_2Sn=S$ (3 mol%) at -78 °C . Accordingly, the catalyst system, pre-treated at -78 °C, was employed in subsequent experiments. The yield was increased up to 95% when the amount of the catalyst system was decreased down to 0.25 mol% of $AgClO_4$ together with 0.75 mol% of $Ph_2Sn=S$. Then, the effect of the ratio of $Ph_2Sn=S$ to $AgClO_4$ was examined. When the reactions were tried by using catalyst systems, $Ph_2Sn=S/AgClO_4$ 1/1, 2/1, and 3/1, the adduct was obtained in almost the same yields (89-90%). On the basis of the above results concerning the ratio of $Ph_2Sn=S$ to $AgClO_4$ and the amount of catalyst system, the reaction was carried out by using 0.25 mol% of $AgClO_4$ and 0.25 mol% of $Ph_2Sn=S$, and the adduct was obtained in excellent yield (95%).

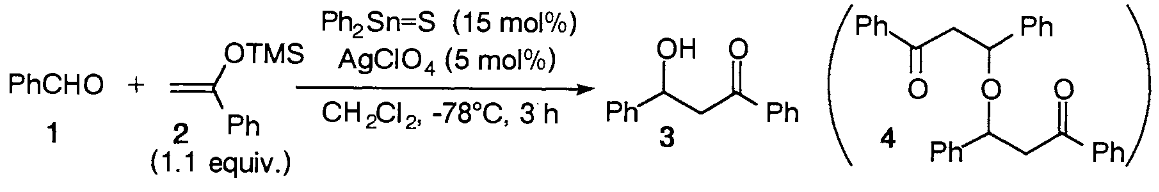


Table 1. Effect of Concentrations and Solvents

Entry	Solvent	Concentration of 1 / M	Yield / %[b)]
1	CH_2Cl_2	0.032	71
2	CH_2Cl_2	0.16	85
3[a)]	CH_2Cl_2	0.16	89
4	CH_2Cl_2	0.33	78
5	Toluene	0.16	40
6	EtCN	0.16	15

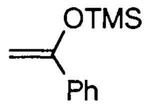
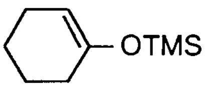
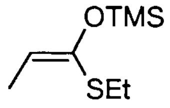
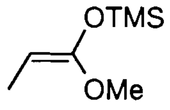
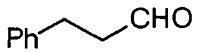
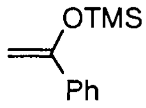
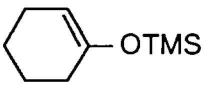
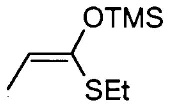
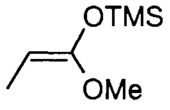
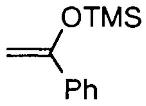
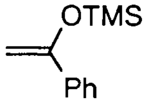
a) One mol% of $AgClO_4$ and 3 mol% of $Ph_2Sn=S$ was used. b) Isolated yield.

Next, Lawesson's reagent was used as a partner of $AgClO_4$. As Lawesson's reagent exists as a dimeric structure, a ratio of this reagent to $AgClO_4$ 1:2 was chosen. The reaction of **1** with **2** was carried out by using 0.25 mol% of $AgClO_4$ and 0.125 mol% of Lawesson's reagent and the corresponding aldol adduct was obtained in good yield (89%).

As demonstrated in Table 2, the corresponding aldol adducts were obtained from aldehydes and silyl enol ethers or silyl ketene acetals in good yields.

A typical experimental procedure for the reaction of **1** with **2** is as follows; to a stirred suspension of $AgClO_4$ (0.0077 mmol) in dichloromethane (1.6 ml) was added a solution of $Ph_2Sn=S$ (0.0077 mmol) in dichloromethane (1.1 ml) at -78 °C. After stirred for 5 min (15 min in the case of Lawesson's reagent), solutions of **2** (3.4 mmol) in dichloromethane (1.1 ml) and **1** (3.1 mmol) in dichloromethane (1.1 ml) were successively added. After stirred for 3 h, the reaction was quenched with phosphate buffer (pH 7). After extraction and

Table 2. Aldol Reaction Catalyzed by [$Ph_2Sn=S/AgClO_4$] and [Lawesson's Reagent/$AgClO_4$] Combined Systems

Entry	Aldehyde	Silyl enol ether	Catalyst / mol% a)	Time / h	Yield / % b)	Syn / Anti c)
1	PhCHO		A (0.25)	3	95	-
2			B (0.25)	3	89	-
3			A (0.25)	3	88	1 / 1.1
4			B (0.25)	3	88	1 / 1.6
5			A (5.0)	3	85	1 / 1.9 d)
6			B (20)	5	77	1 / 1.9 d)
7			A (10)	5	88	1 / 1.1 d)
8			B (0.25)	21	84	1 / 1
9			A (3.0)	3	81	-
10			B (0.25)	3	80	-
11			A (3.0)	3	82	1 / 1.2
12			B (0.25)	20	73	1 / 1
13			A (10)	21	72	1 / 1.2
14			B (20)	5	59	1 / 1.1
15			A (1.0)	3	83	1 / 1.1
16			B (5.0)	3	80	1 / 1.1
17	$C_5H_{11}CHO$		A (0.25)	3	95	-
18			B (1.0)	3	76	-
19	Cyclohexyl-CHO		A (0.25)	8	82	-
20			B (1.0)	3	78	-

a) Catalyst A: [$Ph_2Sn=S/AgClO_4(1/1)$], catalyst B: [Lawesson's reagent/$AgClO_4(1/2)$]. b) Isolated yield. c) Determined by ^1H-NMR analysis. d) Ratios were determined by isolated yields.

evaporation of the solvent, the residue was treated with THF/1N-HCl (20/1) at 0 °C. Usual work up and separation by TLC afforded the aldol adduct in 95% yield.

Thus, aldol reactions of aldehydes with trimethylsilyl enol ethers or silyl ketene acetals are smoothly carried out by using a catalytic amount of [$Ph_2Sn{=}S/AgClO_4$] or [Lawesson's reagent/$AgClO_4$] under mild conditions.

References

1) The aldol reaction catalyzed by Lewis acids was described in the following literatures; T. Mukaiyama, K. Narasaka, and K. Banno, *Chem. Lett.*, **1973**, 1011; T. Mukaiyama, K. Banno, and K. Narasaka, *J. Am. Chem. Soc.*, **96**, 7503 (1974); C. H. Heathcock, S. K. Davidsen, K. T. Hug, and L. A. Flippin, *J. Org. Chem.*, **51**, 3027 (1986); C. H. Heathcock, K. T. Hug, and L. A. Flippin, *Tetrahedron Lett.*, **25**, 5973 (1984); T. H. Chan, T. Aida, P. W. K. Lau, V. Gorys, and D. N, Harpp, *ibid.*, **1979**, 4029; M. Kawai, M. Onaka, and Y. Izumi, *Chem. Lett.*, **1986**, 1581; M. Onaka, R. Ohno, M. Kawai, and Y. Izumi, *Bull. Chem. Soc. Jpn.*, **60**, 2689 (1987); B. D. Gray and J. D. White, *J. Chem. Soc., Chem. Commun.*, **1985**, 20; R. D. Miller and G. N. Fickes, *J. Org. Chem.*, **50**, 2375 (1985); C. W. Jefford, D. Jaggi, and J. Boukouvalas, *Tetrahedron Lett.*, **28**, 4037 (1987); C. W. Jefford, D. Jaggi, G. Bernardinelli, and J. Boukouvalas, *ibid.*, **28**, 4041 (1987); Y. Naruse, Y. Ukai, N. Ikeda, and H. Yamamoto, *Chem. Lett.*, **1985**, 1451; C. Palazzi, L. Colombo, and C. Gennari, *Tetrahedron Lett.*, **27**, 1735 (1986); K. Banno and T. Mukaiyama, *Chem. Lett.*, **1976**, 279; C. Gennari, M. G. Beretta, A. Bernardi, G. Moro, C. Scolastico, and R. Todeschini, *Tetrahedron*, **42**, 893 (1986); C. Gennari, A. Bernardi, S. Cardani, and C. Scolastico, *Tetrahedron Lett.*, **26**, 797 (1985); C. Goasdoue, N. Goasdoue, and M. Gaudemar, *J. Organomet. Chem.*, **263**, 273 (1984); I. Matsuda and Y. Izumi, *Tetrahedron Lett.*, **22**, 1805 (1981); J. -E. Dubois, G. Axiotis, and E. Bertounesque, *ibid.*, **25**, 4655 (1984); K. Yamamoto, Y. Tomo, and S. Suzuki, *ibid.*, **21**, 2861 (1980); K. Yamamoto and Y. Tomo, *Chem. Lett.*, **1983**, 531; Y. Tomo and K. Yamamoto, *Tetrahedron Lett.*, **26**, 1061 (1985).

2) T. Mukaiyama and N. Shimomura, *Chem. Lett.*, **1993**, 781; N. Shimomura and T. Mukaiyama, *ibid.*, **1993**, 1941. [Diphenyltin sulfide/silver salt] combined catalyst system was also used for the synthesis of ribonucleosides in the following literature; T. Mukaiyama, T. Matsutani, and N. Shimomura, *Chem. Lett.*, **1993**, 1627.

(Received January 31, 1994)