J. Org. Chem. **1997,** 62, 8612−8613

Generation of Nonstabilized Carbonyl Ylides with a Manganese−Lead Reducing System and Their [3 + 2] Cycloaddition Reactions

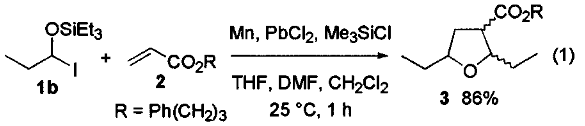
Kazuhiko Takai,* Hiroya Kaihara,
Ken-ichi Higashiura, and Norihiko Ikeda

Department of Applied Chemistry, Faculty of Engineering, Okayama University, Tsushima, Okayama 700, Japan

Received August 1, 1997

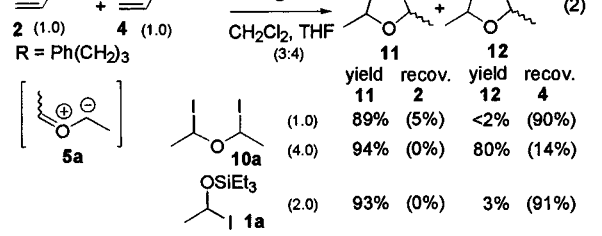
Cycloaddition reactions with carbonyl ylides are one of the most valuable methods to construct highly substituted oxygen heterocycles.[1] Stabilized carbonyl ylides have been developed by Padwa et al.,[1b−d] and more recently, Hosomi et al. generated nonstabilized ylides by treatment of 1-iodoalkyl triethylsilyl ethers with SmI_2.[2] Unfortunately, SmI_2 is a rather strong reductant, which sometimes causes undesirable side reactions.[2a,3] Herein, we report the generation of nonstabilized carbonyl ylides using a manganese−$PbCl_2$−Me_3SiCl system.[4] Several novel features of the [3 + 2] cycloaddition reactions due to the mild conditions are also discussed.[5]

A solution of 1-iodopropyl triethylsilyl ether[6] (**1b**), derived from propanal and Et_3SiI[7] in dichloromethane at 25 °C, was added to a mixture of manganese and a catalytic amount of $PbCl_2$ and Me_3SiCl in THF and DMF. This afforded a diastereomeric mixture of substituted tetrahydrofurans **3** in 86% combined yields, although a 1,4-addition product of the α-triethylsiloxy radical to **2** was not obtained.[8] The mechanism can be explained by [3 + 2] cycloaddition of the nonstabilized carbonyl ylide **5b** with the acrylate **2** (eq 1).



In contrast to previous methods for manganese activation,[4] addition of a catalytic amount of Me_3SiCl was not necessary for the reaction, probably due to the effect of Et_3SiI used in the formation of **1**. Mild reductants such as zinc and chromium(II) gave unsatisfactory results.[9]

The [3 + 2] cycloaddition with the manganese system showed a number of interesting features. (1) In contrast to SmI_2,[3] the manganese system does not reduce an α,*β*-unsaturated carbonyl compound or promote pinacol coupling of an aldehyde; therefore, [3 + 2] cycloaddition with an α,*β*-unsaturated ketone or ester proceeded without the formation of undesirable byproducts (Table 1, runs 1−6 and 10), and the reaction with an aldehyde leading to a dioxolane took place without the coupling (run 11).[2a] (2) The bis(1-iodoalkyl) ether **10**[10] could be used instead of the 1-iodoalkyl triethylsilyl ether **1**,[2a] with almost the same yield and selectivity (runs 4 and 5). (3) When acrylates were employed, the [3 + 2] cycloaddition proceeded without the addition of $PbCl_2$, and the diastereomeric ratios of products between acrylates and the nonstabilized carbonyl ylide **5a** depended on the presence of $PbCl_2$. For example, tetrahydrofuran derivatives **6** having the *trans*-configuration between the 2- and 5-positions were produced mainly by the addition of $PbCl_2$ (runs 1, 2, and 4). On the contrary, 2,5-*cis*-tetrahydrofurans **7** were obtained in a 4:1 ratio without addition of $PbCl_2$ (runs 3 and 5).[11] (4) Chemoselectivity in the [3 + 2] cycloaddition between an α,*β*-unsaturated ester and a simple olefin was observed (eq 2). When 4 equiv of **5a** was generated from the bis(1-iodoethyl) ether (**10a**) and manganese, in the presence of the acrylate **2** and 1-dodecene (**4**), the [3 + 2] cycloaddition products **11** and **12** of both olefins were obtained in 94% and 80% yields, respectively. Meanwhile, the cycloaddition product **11** was produced with **2** in 89% yield, and **4** was recovered in 90% yield when 1 equiv of **5a** was generated.



---

[1] For some reviews, see: (a) Carruthers, W. *Cycloaddition Reactions in Organic Synthesis*; Pergamon Press, Oxford, 1990. (b) Padwa, A.; Schoffstall, A. M. In *Advances in Cycloaddition*; Curran, D. P., Ed.; JAI Press: Greenwich, 1990; Vol. 2, p 1. (c) Padwa, A.; Weingarten, M. D. *Chem. Rev. (Washington, D.C.)* **1996**, *96*, 223. (d) Padwa, A. *Acc. Chem. Res.* **1991**, *24*, 22.

[2] (a) Hojo, M.; Aihara, H.; Hosomi, A. *J. Am. Chem. Soc.* **1996**, *118*, 3533. (b) Hojo, M.; Aihara, H.; Ito, H.; Hosomi, A. *Tetrahedron Lett.* **1996**, *37*, 9241.

[3] Namy, J. L.; Souppe, J.; Kagan, H. B. *Tetrahedron Lett.* **1983**, *24*, 765. Souppe, J.; Danon, L.; Namy, J. L.; Kagan, H. B. *J. Organomet. Chem.* **1983**, *250*, 227.

[4] (a) Takai, K.; Ueda, T.; Hayashi, T.; Moriwake, T. *Tetrahedron Lett.* **1996**, *37*, 7094. (b) Takai, K.; Ueda, T.; Ikeda, N.; Moriwake, T. *J. Org. Chem.* **1996**, *61*, 7990.

[5] Prof. Akira Hosomi kindly informed us that they also found the formation of nonstabilized carbonyl ylides with the manganese system independently. We thank Prof. Hosomi for exchanging valuable information prior to publication: Hojo, M.; Aihara, H.; Suginohara, Y.; Sakata, K.; Nakamura, S.; Murakami, C.; Hosomi, A. *J. Org. Chem.* **1997**, *62*, 8610.

[6] Jung, M. E.; Mossman, A. B.; Lyster, M. A. *J. Org. Chem.* **1978**, *43*, 3698.

[7] Kunai, A.; Sakurai, T.; Toyoda, E.; Ishikawa, M.; Yamamoto, Y. *Organometallics* **1994**, *13*, 3233.

[8] Treatment of iodoalkanes with the manganese reductant generates alkyl radicals in high yields.[4b] Similarly, the reduction of chloromethyl methyl ether with the manganese system in the presence of LiI produced a methoxymethyl radical, and 1,4-addition to the acrylate **2** occurred to give an adduct in 37% yield.

[9] Zinc-mediated [3 + 2] cycloaddition proceeded in THF; however, the yield of **3** was only 29%. A similar reaction with $CrCl_2$ in DMF did not afford **3**.

[10] Voronkov, M. G.; Komarov, V. G.; Albanov, A. I.; Korotaeva, I. M.; Dubinskaya, E. I. *Izv. Akad. Nauk. SSSR., Ser. Khim.* **1981**, 1391.

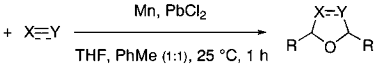
[11] A tetrahydrofuran derivative having the *all-cis* configuration of **7a** was prepared by the following method. Hosokawa, T.; Nakajima, F.; Iwasa, S.; Murahashi, S.-I. *Chem. Lett.* **1990**, 1387. A 2,5-*cis* 2,3-*trans* isomer of **7b** was prepared by isomerization of the *all-cis* compound **7a** with sodium methoxide in methanol and dichloromethane. The diastereomeric ratios (2,5-*trans* isomers **6**/2,5-*cis* isomers **7**) were determined by NMR.

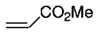
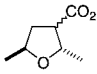
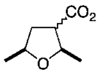
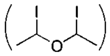
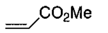
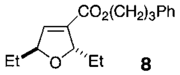
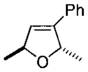
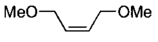
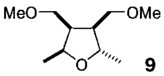
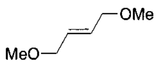
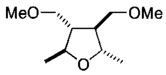
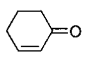
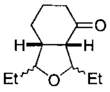
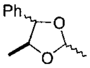
[12] **General Procedure**: Iodotriethylsilane (8.0 mmol)[7] was added to a solution of an aldehyde (8.0 mmol) in toluene (6 mL) at −40 °C over a period of 5 min. The resulting mixture was stirred at 25 °C for 3 h and used without further purification. A solution of an olefin (2.0 mmol) in THF (2 mL) was added at 25 °C to a stirring mixture of manganese powder (0.66 g, 12 mmol) and $PbCl_2$ (34 mg, 0.12 mmol) in THF (4 mL), followed by slow addition of the solution of 1-iodoalkyl triethylsilyl ether in toluene at 25 °C over a period of 10 min. An exothermic reaction (ca. 40 °C) was observed. After being stirred at 25 °C for 1 h, the reaction was quenched by addition of a few drops of water. The resulting mixture was filtered with Celite using ether (50 mL) as an eluent. Organic extracts were washed with water, dried over $MgSO_4$, and concentrated. Purification of the crude product by column chromatography on silica gel gave the desired coupling product.

[13] Although a lot of byproducts were obtained without addition of a catalytic amount of $PbCl_2$, the yield of **8** increased to 15% when 4 equiv of Me_3SiCl was added to the reaction mixture.

S0022-3263(97)01421-7 CCC: $14.00

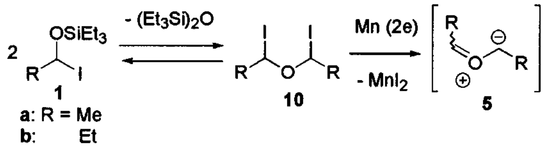
Table 1. [3 + 2] Cycloaddition Reactions of Nonstabilized Carbonyl Ylides Generated with Manganese[a]



run	R	X=Y	$PbCl_2$ (equiv)	product (major isomer(s))	yield[b] (%)	diastereomeric ratio[c] (2,5-*trans* / 2,5-*cis*)
1	Me		0.06	 **6**	85[d]	83 / 17[e]
2			1.0	**6**	91[d]	88 / 12[e]
3			0	 **7**	78[d]	23 / 77[e]
4			0.06	**6**	82[f]	77 / 23
5			0	**7**	58[f]	23 / 77
6	Et	≡–$CO_2(CH_2)_3Ph$	0.06	 **8**	93[d,g,h]	>97 / <3
7	Me	≡–Ph	0.06		75	>97 / <3
8	Me		0.06	 **9**	81[h]	86 / 14[i]
9	Me		0.06		59	*j*
10	Et		0.06		88	*k*
11	Me	PhCHO	0.06		80	*l*

[a] Reactions were conducted on a 2.0 mmol scale.[12] 1-Iodoalkyl triethylsilyl ether (4.0 mol) and Mn (6.0 mol) were used per mol of an olefin (or an acetylene). A mixture of toluene and THF (1:1) was used as a solvent unless otherwise noted. [b] Isolated yields. [c] Diastereomer ratios were determined by isolation or NMR. [d] A mixture of dichloromethane and THF (3:4) was used as a solvent. [e] Relative stereochemistries between the 2- and 3-positions of *trans-* and *cis*-diastereomers were almost a 1:1 ratio. [f] Me_3SiCl (0.10 mmol) was added. [g] A one-to-two adduct of propiolate and the carbonyl ylide **5a**, having a 3,7-dioxabicyclo[3.3.0]octane structure was obtained in 19% yield along with the normal [3 + 2] adduct in 74% yield when 1-iodoethyl triethylsilyl ether was employed. [h] Without addition of $PbCl_2$, a lot of unidentified products were formed, and the desired [3 + 2] cycloadduct (**8** or **9**) was produced in less than 3% yield.[13] [i] 3,4-*trans*-Isomers were not obtained. [j] 3,4-*cis*-Isomers were not obtained. Two diastereomers were obtained in a ratio of 81 / 19. The configuration of the minor isomer (2,3-*cis*-3,4-*trans*-4,5-*trans* or 2,3-*cis*-3,4-*trans*-4,5-*cis*) was not determined. [k] A mixture of diastereomers of undetermined structures. [l] A mixture of four diastereomers. 4,5-Stereochemistry of diastereomers was *trans* / *cis* = 53 / 47 ratio.

Because of the similar reactivity of carbonyl ylides from the bis(1-iodoalkyl) ether **10** and 1-iodoalkyl triethylsilyl ether **1**, we are tempted to assume that the nonstabilized carbonyl ylide **5** is generated by manganese reduction of **10** that is in equilibrium with the 1-iodoalkyl triethylsilyl ether **1** (eq 3).[6]



1

a: R = Me
b: Et

10

5

(3)

Acknowledgment. We are grateful to Professors Takahiro Hosokawa of Kochi University of Technology and Shun-Ichi Murahashi of Osaka University for providing NMR spectra of a 2,3,5-*all-cis* isomer of tetrahydrofuran **7a**. Financial support from the Ministry of Education, Science, Sports and Culture of Japan is also gratefully acknowledged.

Supporting Information Available: Spectroscopic and analytical data of compounds in Table 1 (6 pages).

JO971421A