## **Reaction of Allylic-type Diindium Compounds with Electrophiles**

Tsunehisa Hirashita,\* Shun Arai, Kazuma Mitsui, Hajime Makino, and Shuki Araki Omohi College, Graduate School of Engineering, Nagoya Institute of Technology, Gokiso-cho, Showa-ku, Nagoya 466-8555

(Received January 5, 2006; CL-060009; E-mail: hirasita@nitech.ac.jp)

Allylic-type diindium reagents were prepared from 3bromo-1-iodopropene (1a), 3-bromo-1-iodo-1-phenylpropene (1b), or 2,4-diiodobut-2-en-1-ol (1c) with metallic indium, and their successive coupling with electrophiles was examined. The coupling behavior of the diindium reagents was found to depend on the electrophiles and the substituent on the diindium compounds.

Organodimetallic compounds, which contain two metalcarbon bonds in one molecule, are attractive molecules from the standpoint of synthetic reagents.<sup>1</sup> We have reported that the oxidative addition of indium to 3-bromo-1-iodopropene (1a) generates diindiopropene Ia (I'a). This compound couples with carbonyl compounds and imines, and the resulting vinylindium compounds react further with aryl, alkenyl, or allyl halide in the presence of  $Pd(PPh_3)_4$  to give linear homoallylic alcohols or amines.<sup>2</sup> The reaction courses of allylic-type diindium reagents with two electrophiles can be classified into three types, A–C (Scheme 1). We previously showed that the reaction of Ia (I'a) proceeds via type A course leading to 2.<sup>2</sup>



Scheme 1. Reaction course of allylic-type diindium.

In order to estimate the difference in reactivity between diindiopropene Ia (I'a) and allylindium sesquiiodide (III) toward electrophiles, competitive reactions were performed by using benzaldehyde (5a), sulfonimine 5b, and acetophenone (5c) as electrophiles (Table 1). It was found that the chemoselectivity of Ia (I'a) is higher than that of III. In the competitive reaction of 5a and 5b, allylindium III gave a mixture of 2a and 2b, whereas 2a was selectively obtained with diindium Ia (I'a) (Entry 1, Table 1). The results of 5b/5c indicate that diindiopropene Ia (I'a) reacts with 5b approximately seven times faster than 5c, but only twice as fast in the case of III (Entries 2 and 3).

Next, a diastereoselective allylation of imines **5d** derived from (*S*)-valine with **Ia** (**I'a**) and **III** was examined (Table 2). The reaction with **1a** afforded the allylated product with much higher selectivity (Table 2, Entry 1) than that with **III** (Entry 2). This reaction behavior of diindiopropene **Ia** (**I'a**) opens up a possibility for higher chemo- and stereoselective allylation than that with conventional allylindium reagent (**III**). Presumably, the difference between **I** and **III** may be explained by the Lewis acidity and/or the bulkiness arising from the two indium atoms on the diindiopropene.

**Table 1.** Chemoselectivity of **Ia** ( $\mathbf{I'a}$ ) and **III** toward electrophiles<sup>a</sup>

$\begin{array}{c} \textbf{Ia (I'a)} & \textbf{Y} \\ \textbf{or} & \textbf{H} \\ \textbf{In}_{l} & \textbf{In}_{l} & \textbf{Sa: } R = H, Y = O \\ \textbf{III} & \textbf{Sc: } R = Me, Y = O \end{array} \\ \begin{array}{c} \textbf{H} & \textbf{H} \\ \textbf{H} \\ \textbf{Sc: } R = Me, Y = O \end{array}$							
Ratio of Products/% <sup>b</sup>							
Entry	Solvent	Diindio	propene I	a (I'a)	Allylindiu	m sesquii	odide (III)
-		2a	2b	2c	2a	2b	2c
1	THF	100	0		63	37	_
2	THF	_	87	13	_	63	37
3	DMA		87	13		68	32

<sup>a</sup>All reactions were carried out with a half amount of the allylating agent to a 1:1 mixture of two electropliles (each 0.5 mmol) at room temperature for 17 h. <sup>b</sup>The ratio was determined on the basis of <sup>1</sup>H NMR analysis of a mixture of two products.

**Table 2.** Diastereoselective allylation of **5d** derived from (*S*)-valine

la (l'a) or III	+ Ph N 5d	CO <sub>2</sub> Me THF	Ph N C	CO <sub>2</sub> Me
Entry	Allylindium	Conditions	Yield/%	SS:RS
$1^{a}$	Ia (I'a)	rt, 44 h	54	98:2
2 <sup>b</sup>	III	rt, 36 h	100	75:25

<sup>a</sup>The reaction was carried out with In (1.5 mmol), **1a** (0.75 mmol), and **5d** (0.50 mmol). <sup>b</sup>From Ref. 3.

1h +	Y In	Ph	Туре А	Ph	Туре С	
F	H DMI	Jun	→ <sup>R</sup> +	R	~~R +	
<b>5e</b> : $R = H, Y = O$ <b>5f</b> : $R = Et, Y = O$ <b>5g</b> : $R = n-C_6H_{13}, Y = O$ <b>5h</b> : $R = c-C_6H_{11}, Y = O$ <b>5i</b> : $R = Me_2CH, Y = O$		2 ÓH		<u> о́н 4</u> о́н		
		Ph R I		Ph Type B		
		HO	+	R		
	- 2 - ,	R	3 <sup>OH</sup>	Ϋ́Η	3'	
Entry	5 (mol %)	2 (%)	3 (%)	3' (%)	4 (%)	
1	<b>5e</b> (200)	0	<b>3e</b> : 77	<b>3'e</b> : 23	0	
2	<b>5f</b> (200)	0	<b>3f</b> : 15 <sup>b</sup>	3'f: 5 <sup>b</sup>	<b>4f</b> : 30 <sup>c</sup>	
3	5g (200)	0	0	<b>3′g</b> : 9 <sup>b</sup>	4g: 30 <sup>b</sup>	
4	<b>5h</b> (200)	<b>2h</b> : 36 <sup>d</sup>	0	<b>3'h</b> : 18 <sup>e</sup>	0	
5	<b>5i</b> (50)	<b>2i</b> : 44 <sup>f</sup>	0	<b>3'i</b> : 42 <sup>b</sup>	0	
6	<b>5a</b> (50)	0	0	<b>3'a</b> : 77 <sup>e</sup>	0	
7	<b>5b</b> (50)	0	0	<b>3'b</b> : 90 <sup>g</sup>	0	

Table 3. In-mediated reaction of 1b with aldehydes and imine<sup>a</sup>

<sup>a</sup>All reactions were carried out with In (1.0 mmol), **1b** (0.50 mmol), and **5** in DMI (1,3-dimethyl-2-imidazolidinone, 1.5 mL) at room temperature for 4 h. <sup>b</sup>Diastereomeric ratio was not determined. <sup>c</sup>Two diastereomers (9:1) were found by <sup>1</sup>H and <sup>13</sup>C NMR. <sup>d</sup>*E*:*Z* = 40:60. <sup>e</sup>*Syn:anti* = <1:>99. <sup>f</sup>*E*:*Z* = 33:67. <sup>g</sup>*Syn:anti* = >99:<1.

To disclose further the reaction behavior of diindiopropene, new allylic-type diindium reagents bearing a phenyl (**1b**) or a hydroxymethyl group (**1c**) on the C<sup>1</sup> position were prepared. Prior to the reaction of **1b** with aldehydes, the existence of diindium **Ib** (**1'b**) was confirmed by the following reaction: A mixture of **1b** (0.50 mmol) and indium (1.0 mmol) in THF was stirred for 2 h. The reaction mixture was quenched with 1 M hydrochloric acid and the product was extracted with ether. The product was analyzed by GC, showing that allylbenzene was formed in 60% yield. This fact clearly indicates the formation of the diindium reagent **Ib** (**I'b**) and the protonolysis of **Ib** (**I'b**) proceeds via type **B** course.

Next, the diindium reagent **Ib** (**I'b**) was subjected to the reaction of aldehydes and it is found that the reaction courses are distinct depending on aldehydes (Table 3).

With formaldehyde (**5e**), diol **3e** was obtained in 77% yield together with **3'e** in 23% yield (Entry 1, Table 3). Propionaldehyde (**5f**) gave a regioisomer mixture of **3f** and **4f** along with a small amount of **3'f** (Entry 2). Hexanal (**5g**) gave diol **4g** and homoallylic alcohol **3'g** (Entry 3), whereas bulky aldehydes **5h** and **5i** gave no diol product but yielded homoallylic alcohols **2** and **3'** (Entries 4 and 5). With benzaldehyde (**5a**), homoallylic alcohol **3'a** was solely obtained in high yield with *anti*-selectivity (Entry 6), whereas sulfonimine **5b** gave **3'b** with *syn*-selectivity (Entry 7). As allylic indium compounds are known to be protonated at the  $\gamma$ -position, the *anti*- and *syn*-stereochemistry of **3'a** and **3'b** can be rationalized by the attack of the proton toward the resulting allylic indium compounds **IIb** from the less hindered direction with regio- and stereoselectivity (Figure 1).<sup>4</sup>

Finally, the reaction of 1c with benzaldehyde was studied and the results are shown in Table 4. In DMI, diol 2'h (type



Table 4. In-mediated reaction of 1c with benzaldehyde<sup>a</sup>

1c P		Type A OH Ph 2'h + Ph OH	ype B 3'h	H		
Entres	C - loss of	Yield/%				
Entry	Solvent	2'h (E:Z)	3'h	6		
1	DMI	72 (30:70)	15	10 <sup>b</sup>		
2	THF-H <sub>2</sub> O (1:1	) 20 (80:20)	15	45 <sup>b</sup>		
3	THF	45 (50:50) (D 64	%) <sup>c</sup> 22	trace		

<sup>a</sup>All reactions were carried out with In (1.0 mmol), **1c** (0.50 mmol), and PhCHO (0.25 mmol) in solvent (1.0 mL) at room temperature for 2 h. <sup>b</sup>E:Z ratio was not determined. <sup>c</sup>Quenched by 1 M DCl.

A) was obtained as a main product together with diol **3'h** (type B) and diene **6** (Entry 1, Table 4). In an aqueous medium, the yield of **6** was increased (Entry 2), whereas in THF **2'h** was obtained in 45% yield and **6** was scarcely observed (Entry 3). Diene **6** may come from the C<sup>1</sup> attack of benzaldehyde, followed by the elimination of InOInL<sub>2</sub> from **II'c** prior to protonolysis.

In summary, the reaction behavior of the allylic-type diindium reagents toward electrophiles was found to differ considerably depending on both the electrophiles and the substituent on the diindiopropene. The coupling of **Ib** (**I'b**) proceeded via type **B** with small electrophiles, such as proton and formaldehyde, whereas the reaction course turned to type **A** and **C** with increasing the bulkiness of electrophiles. The diindiopropene **Ic** (**I'c**) bearing a hydroxymethyl group was prone to react with benzaldehyde via type **A** leading to the corresponding linear diol.

This work was partially supported by a Grant-in-Aid for Scientific Research (No. 14340195) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

## References

- a) I. Marek, L.-F. Normant, *Chem. Rev.* 1996, 96, 3241.
  b) E. M. Flamme, W. R. Roush, *J. Am. Chem. Soc.* 2002, 124, 13644.
- a) T. Hirashita, H. Yamamura, M. Kawai, S. Araki, *Chem. Commun.* 2001, 387. b) T. Hirashita, Y. Hayashi, K. Mitsui, S. Araki, *J. Org. Chem.* 2003, 68, 1309.
- 3 T. Basile, A. Bocoum, D. Savoia, A. Umani-Ronchi, J. Org. Chem. **1994**, 59, 7766.
- 4 M. N. Paddon-Row, N. G. Rondan, K. N. Houk, J. Am. Chem. Soc. 1982, 104, 7162.