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Reaction of zirconacyclopentadienes with electrophiles such as benzaldehyde, methyl methacrylate and 1-bromo-2-butyne after treatment with RLi

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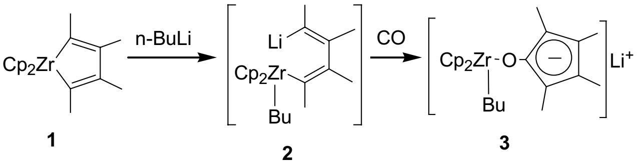
Abstract—Zirconacyclopentadienes reacted with electrophiles after treatment with alkyllithium. For example, the reaction with benzaldehyde after treatment with methyllithium to give a nucleophilic addition product of a dienyl moiety to aldehyde, dienylcarbinol, in a moderate yield. Similar reaction of a zirconacyclopentadiene using butyllithium with methyl methacrylate afforded a Michael addition product in a good yield. Treatment of zirconacyclopentadienes with *n*-BuLi followed by 1-bromo-2-butyne gave a mono-propargylated diene derivative in 95% yield after hydrolysis. When propargyl chloride was treated with *n*-BuLi first and then added to zirconacyclopentadienes, penta-substituted benzene derivatives were formed in high yields.

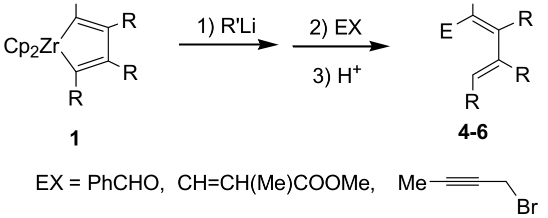
Recently we have reported that reaction of zirconacyclopentadienes **1**[1] with CO proceeded in the presence of *n*-BuLi.[2] In this reaction, we proposed the formation of a dienyllithium derivative **2** as an intermediate, which in turn reacts with CO to give a cyclopentadienyloxyzirconocene anion derivative **3** (Scheme 1). The cyclopentadienyloxyzirconocene **3** could be clearly observed by NMR study. However, unfortunately, the formation of a dienyllithium derivative **2** was not observed by NMR.

In this letter we would like to report an evidence for the formation of nucleophilic species in the reaction of zirconacyclopentadienes with electrophiles such as benzaldehyde, methyl methacrylate and 1-bromo-2-butyne after treatment with RLi.



Scheme 1.

It is well known that zirconacyclopentadienes react with aldehydes in the presence of $AlCl_3$.[3,4] Without any additives they are not nucleophilic enough to react with an aldehyde directly. However, when zirconacyclopentadiene **1a** was treated with MeLi at −78 °C followed by the reaction with benzaldehyde at −40 °C for 1 h, compound **4** was obtained in 40% yield after hydrolysis (Eq. 2). This reaction did not proceed at −78 °C and the yield was low at 0 °C. This result clearly shows that the dienyl moiety of zirconacyclopentadiene became nucleophilic and reactive towards aldehyde when it was treated with MeLi.[5]



(1)

Keywords: Alkyllithium; Dienyllithium; Zirconate; Addition reaction; Nucleophilic addition; Zirconacyclopentadiene.

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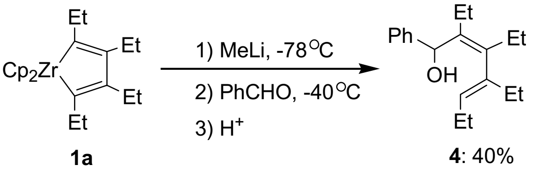
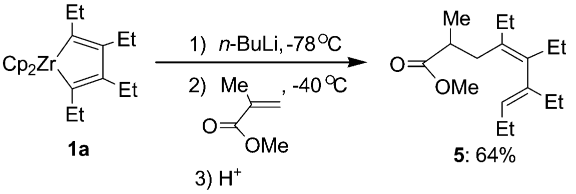


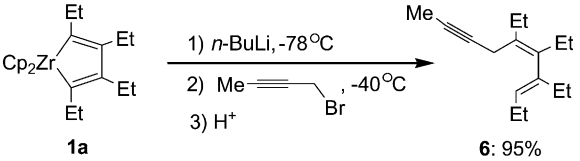
1a **4**: 40% (2)

Similar nucleophilic addition reaction could be observed when **1a** was treated with *n*-BuLi at −78 °C and with methyl methacrylate at −40 °C. As shown in Eq. 3, the tetraethyldiene moiety was added to the double bond of methyl methacrylate to give **5** in 64% yield after hydrolysis.



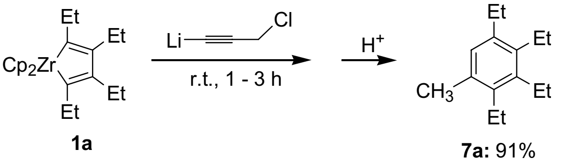
1a **5**: 64% (3)

Similarly, the reaction of zirconacyclopentadiene with *n*-BuLi followed by 1-bromo-2-butyne afforded mono-propargylated diene derivative in 95% yield after hydrolysis.



1a **6**: 95% (4)

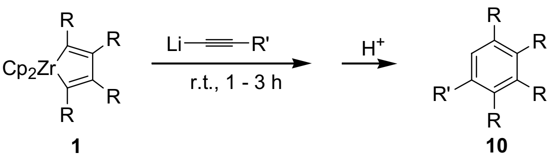
We have reported that zirconacyclopentadienes reacted with propargyl halides in the presence of CuCl to afford benzene derivatives.[6] In this case with CuCl, the carbon–carbon bond formation proceeded at the carbon–carbon triple bond of propargyl chlorides. There was no propargylation product. The reaction with *n*-BuLi reported here is in sharp contrast to the reaction with CuCl. The carbon–carbon bond formation occurred at the propargylic carbon and the mono-propargylated diene derivatives were obtained after hydrolysis. This clearly shows that a hard nucleophile was formed when zirconacyclopentadienes were treated with RLi.



1a **7a**: 91% (5)

Surprisingly, pretreated propargyl chloride with *n*-BuLi 3-chloro-1-lithioprop-1-yne led to the excellent penta-substituted benzene formation as shown in Eq. 5.[7,8] Deuterolysis and iodinolysis instead of hydrolysis gave **8a** and **9d** in 96% and 62% yield, respectively. This indicates that in the final stage a zirconium-containing four-membered ring is formed. The results are summarized in Table 1.

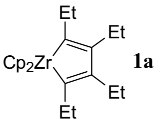
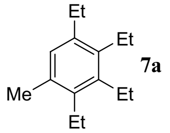
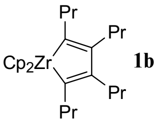
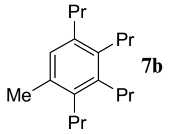
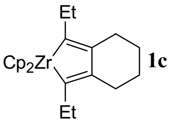
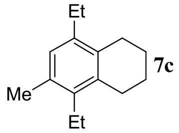
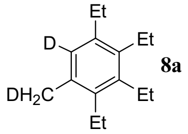
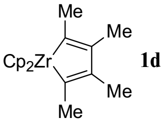
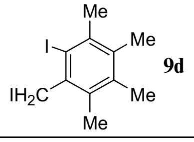
We have found that the reaction of zirconacyclopentadienes with alkynyl lithium which afforded penta-substituted benzene derivatives as shown in Eq. 6.[9] Dumond and Negishi also reported similar results.[10]

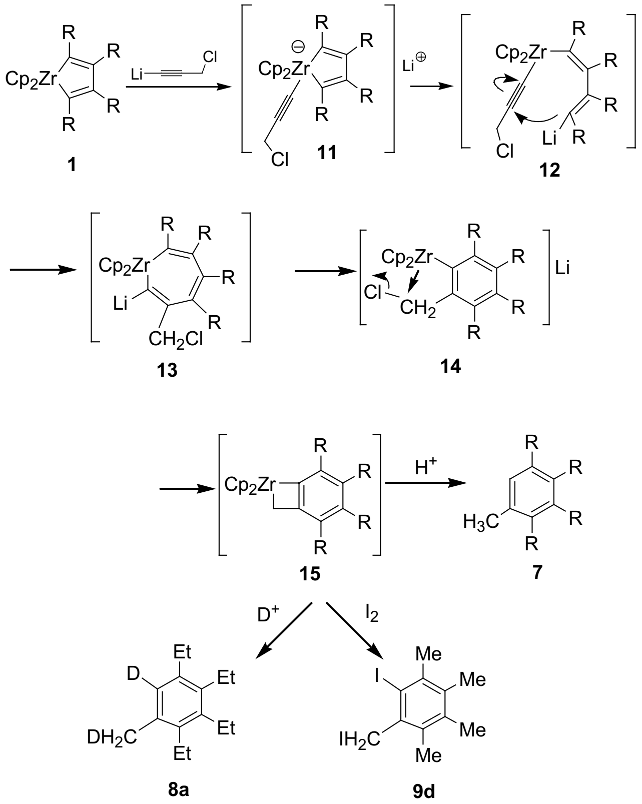


1 **10** (6)

The formation of the penta-substituted benzene shown in Eq. 5 is related to the similar examples[11–14] utilizing an alkynyl lithium[10] in terms of their reaction mechanisms. A possible mechanism is shown in Scheme 2. The lithiated propargyl chloride coordinates to zirconium of a zirconacyclopentadiene to give a zirconium ate complex **11**.[15] The ring opening of the zirconacyclopentadiene occurs and a dienyllithium **12** is formed. The intramolecular addition of the dienyllithium moiety of **12** to the carbon–carbon triple bond of the alkynyl moiety gives a zirconacyclopentadiene **13**. The reductive elimination of **13** and the following reaction of 'Cp_2Zr' with an aryllithium afford a zirconium ate complex **14**. The nucleophilic attack of **14** to benzyl chloride gives product **15**. Further investigation is in progress.

Table 1. Formulation of penta-substituted benzene derivatives by the reaction of zirconancylopentadienes with 3-chloro-1-lithioprop-1-yne

Zirconacyclopentadiene		Product	Yield (%)
 **1a**	H^+	 **7a**	91
 **1b**	H^+	 **7b**	82
 **1c**	H^+	 **7c**	81
1a	D^+	 **8a**	96
 **1d**	I_2	 **9d**	62



Scheme 2.

Although we must await further investigation for the structure of the zirconium species, it is clear that the treatment of a zirconacyclopentadiene with alkyllithium afforded a nucleophilic dienyl species, which provides novel type of reactions of zirconacyclopentadienes.

Supplementary data

Supplementary data associated with this article can be found, on the online version, at doi:10.1016/j.tetlet.2004.10.030.

References and notes

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