Substituent-Selective Mixed-Dihalogenation of Unsymmetrical Zirconacyclopentadienes

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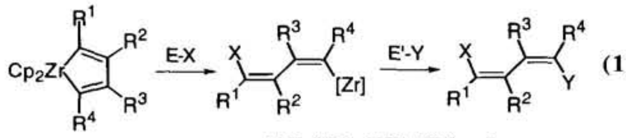
Reactions of zirconacyclopentadienes with halogenation reagents such as NCS, NBS and I_2 were highly substituent-selective. Mixed-dihalogenated 1,3-diene derivatives were obtained in one pot in good to high yields with high selectivities.

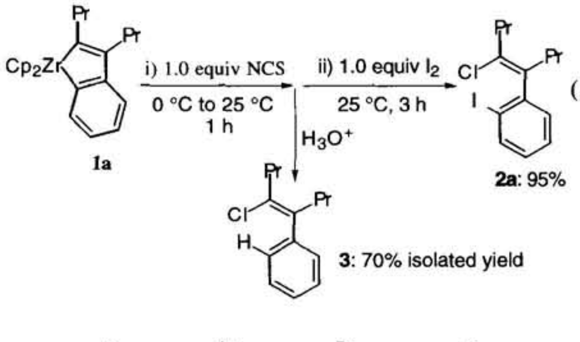
Substituent-selective reaction is one of the difficult but attractive targets in organic and organometallic chemistry. Since we developed a highly selective and convenient preparative method of unsymmetrical zirconacyclopentadienes from two different alkynes,[1,2] we have investigated the substituent-dependent reactions of two zirconium-sp^2 carbon bonds. Recently we reported a substituent-selective β,β'-carbon-carbon bond cleavage reaction of unsymmetrical zirconacyclopentadienes.[3] In this paper, we would like to report a highly substituent-selective halogenation reaction of unsymmetrical zirconacyclopentadienes. This reaction can provide 1,4-mixed-dihalo-1,3-dienes with high selectivities (eq. 1).[4]

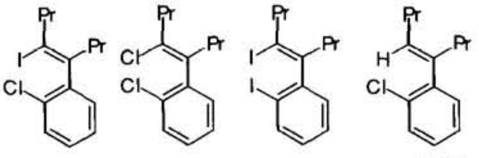


$R^1 \neq R^4$

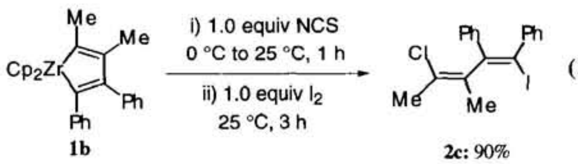
E-X, E'-Y : NCS, NBS, or I_2;
[Zr]: zirconocene moiety

In a typical reaction as shown in eq. 2, *N*-chlorosuccinimide (NCS, 1.0 mmol) was added to a THF solution of zirconaindene **1a**[1f] (1 mmol) prepared *in situ* at 25 °C. After stirring the reaction mixture at 25 °C for 3 h, I_2 (1 mmol) was added to it at 25 °C. The reaction completed within 1 h at 25 °C, affording the mixed-dihalo product **2a** in 95% yield. It is very interesting that the mixed halogenation proceeded in one-pot and that the above reaction resulted only in the formation of **2a** with a perfect selectivity. Formation of its isomer **4** was not detected at all. Homo-dihalogenation products, **5** from the first halogenation reagent (NCS) and **6** from the second reagent (I_2), were not formed. Hydrolysis of the reaction mixture of **1a** and NCS with 3N HCl instead of addition of I_2 afforded the monochlorinated product **3** in 70% isolated yield with a perfect selectivity. No formation of the isomer **7** was detected.





4: 0% **5**: 0% **6**: 0% **7**: 0%



Unsymmetrically substituted monocyclic zirconacyclopentadiene **1b**[1b] reacted with at first 1.0 equiv of NCS and then with I_2 in one-pot with an excellent selectivity to afford the mixed dihalo-1,3-diene derivative **2c** in 90% yield (eq. 3). Other dihalodienes were negligible (<1%).

It should be pointed out that iodo-1,3-diene derivatives are relatively unstable and should be stored in a freezer.

Results of mixed-dihalogenation of zirconacyclopentadienes are summarized in Table 1. In all cases, perfect or excellent selectivities for the formation of mixed dihalo-1,3-diene derivatives were achieved. All the products were isolated in good to high yields. It is noteworthy that the first chlorination or bromination proceeded at the sp^2 carbon with an alkyl substituent for **1a-c**. The sp^2 carbon with the phenyl group or the benzene ring attached to zirconium did not react at all with NCS or NBS under the conditions used here. These results show that the halogenation of unsymmetrical zirconacyclopentadienes is highly substituent-dependent.[5]

In the case of symmetrical zirconacyclopentadienes with alkyl substituents (**1d** and **1e**),[6] the two Zr-C bonds were also differentiated, forming mixed-dihalogenation products **2f** and **2g** in 97% and 96% yields, respectively.[7]

As shown in Table 1, the first halogenation reagent should be either NBS or NCS. Use of I_2 as the first halogenation reagent followed by the second one (NBS or NCS) did not lead to the formation of the desired mixed dihalogenation products (**9** or **10**). Diiodide **8** was exclusively obtained in over 90% yield (eq.4). This could be explained by *in situ* generation of NIS from the halide exchange reaction between the Zr-I moiety of the intermediate and NBS or NCS.[5b,8] The reactive NIS thus formed

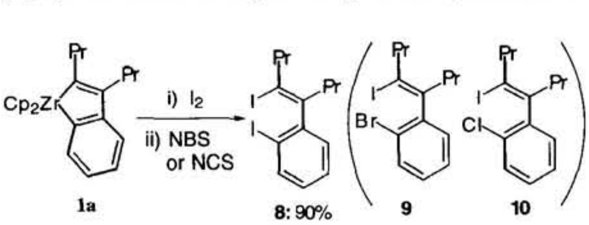
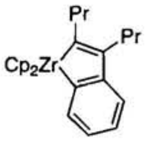
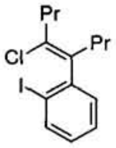
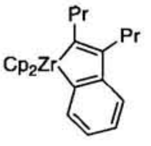
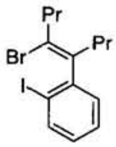
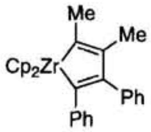
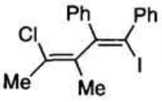
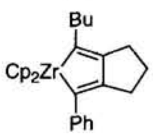
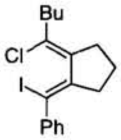
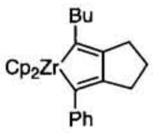
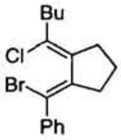
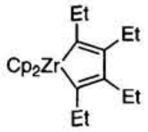
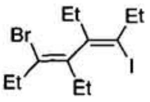
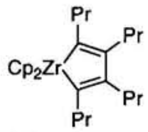
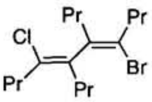


Table 1. Substituent-selective Mixed-dihalogenation of Zirconacyclopentadienes

Zirconacyclo-pentadiene **1**		1st Reagent[a]	2nd Reagent[b]	Product **2**		Yield/%[c]	Other dihalodienes /%[d]
	**1a**	NCS	I_2		**2a**	95 (77)	0
	**1a**	NBS	I_2		**2b**	(81)	0
	**1b**	NCS	I_2		**2c**	90 (68)	<1
	**1c**	NCS	I_2		**2d**	(66)	0
	**1c**	NCS	NBS		**2e**	(57)	0
	**1d**	NBS	I_2		**2f**	97 (60)	2
	**1e**	NCS	NBS		**2g**	96 (73)	0

[a] 1.1 equiv of NBS, 1.0 equiv of NCS, 0 °C to r.t., 1 h. [b] 1.0 equiv., r.t., 1-3 h. [c] GC yields. Isolated yields are given in parentheses. [d] Amount of homodihalogenation products of the 1st reagent or the 2nd reagent.

iodonates the reaction intermediate to produce diiodide **8** rather than **9** or **10**.

References and Notes

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