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Cobalt-Catalyzed Alkenylation of Zinc Organometallics

Hovsep Avedissian,[a,b] Laurent Bérillon,[a] Gérard Cahiez,[b]* and Paul Knochel[a]*

a/ Fachbereich Chemie der Philipps-Universität Marburg, D - 35032 Marburg, Germany.
b/ Département de Chimie, Ecole Supérieure de Chimie Organique et Minérale (ESCOM); 13, Boulevard de l'Hautil, F - 95092 Cergy-Pontoise, France.

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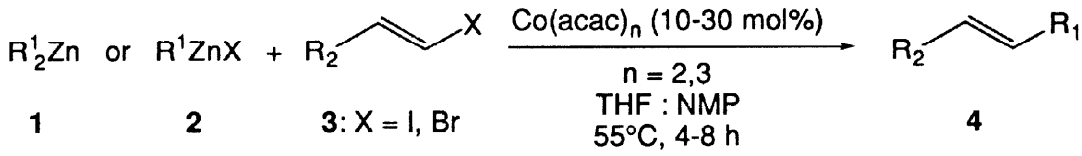
Summary: Organozinc halides and diorganozincs undergo cross-coupling reactions with either *E*- or *Z*-alkenyl iodides in the presence of catalytic amounts of $Co(acac)_2$ or $Co(acac)_3$ in THF:NMP at 55 °C leading to polyfunctional alkenes with retention of the stereochemistry of the double bond.

Transition metal catalyzed cross-coupling reactions of organozincs with unsaturated halides have been extensively studied since the discovery by Negishi of palladium catalyzed cross-coupling reactions with organozinc halides.[1] These carbon-carbon bond forming reactions have found numerous applications in the synthesis of various polyfunctional unsaturated compounds[2] and applications in combinatorial chemistry[3] have been described. Recently, we have described that cobalt salts are able to catalyze several carbon-carbon bond formations.[4,5] Herein, we wish to report a new cobalt-catalyzed cross-coupling of zinc organometallics R_2Zn (**1**) or RZnX (**2**) with alkenyl halides (**3**) leading to alkenes of type **4** in good yields with retention of the configuration of the double bond (Scheme 1).



Scheme 1

In optimization studies, we have treated (*E*)-iodooctene (**3a**) with BuZnX (X = I, Br) in the presence of various cobalt salts under several reaction conditions (Table 1 and Scheme 2). We noticed first that cobalt(II) bromide was not suited for these coupling reactions due to the formation of homo-coupling products (7,9-hexadecadiene). On the other hand, cobalt(II) acetylacetonate ($Co(acac)_2$) proves to be an efficient catalyst giving generally less than 2 % of homo-coupling. Long reaction times were observed at rt and most reactions have to be carried out at 55 °C (7 h reaction time instead of 48 h; entries 1 and 2). By increasing the amount of the cobalt salts, better yields were obtained but a leveling was reached with 20-30 mol % of catalyst (compare entries 2, 3 and 4 of Table 1). An increase of the amount of zinc reagent has a positive effect and the use of 3 equivalents of BuZnI increases the yield up to 80 % and reduces the reaction time to 3 h (see entries 3, 5 and 6). The use of $Co(acac)_3$ is also possible and leads to shorter

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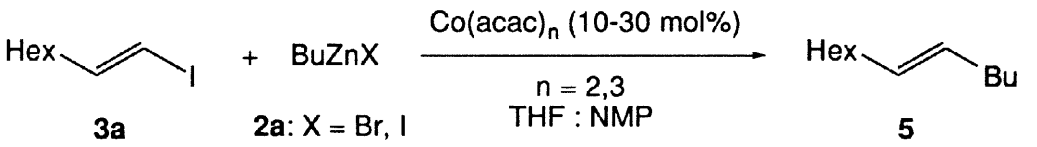
reaction times but lower yields (compare entries 3 and 7). A rate acceleration was observed when LiBr was added to the reaction mixture leading to shorter reaction times and enhanced yields allowing the performance of the reaction at rt. In the absence of LiBr, a 40 % yield is obtained at rt whereas by adding LiBr (1.2 equiv.), the reaction is complete in less than 12 h and affords the product **5** in 68 % yield (compare entries 1 and 8). Thus, starting with BuZnBr instead of BuZnI and using $Co(acac)_3$ (5 mol %) leads after 20 h at 25 °C to 65 % yield of the product **5** (entry 9). Increasing further the amount of catalyst to 10 mol % leads to 75 % of **5** (entry 10). Finally, an increase of the reaction temperature under these conditions reduces the reaction time to 0.5 h (67 % yield; entry 11). Applying these optimized conditions to octylzinc iodide (**2b**) allows to couple this alkylzinc iodide with **3a** and the functionalized (*E*)-5-chloro-1-iodopentene (**3b**) leading to *E*-alkenes **6** and **7** in 81 and 74 % as pure *E*-isomers (> 99 % *E* as shown by ^{13}C-NMR and ^{1}H-NMR spectroscopy; Scheme 3).

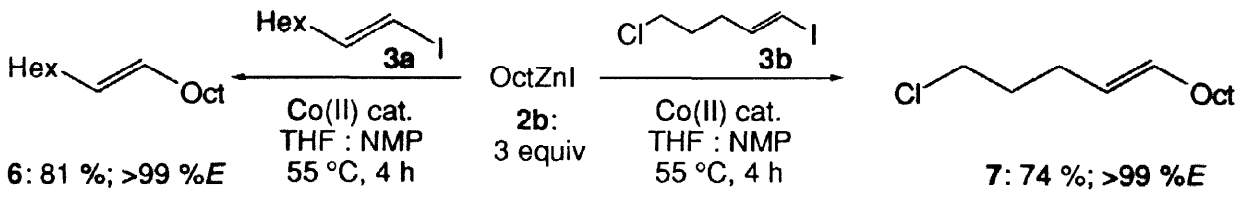


Scheme 2

Table 1. Optimization of the Cobalt-Catalyzed Cross-Coupling Reaction Between BuZnX and **3a** Leading to **5**

Entry	BuZnX X (equiv)[a]	Catalyst mol % (n)[b]	T (°C)	Reaction Time (h)	Yield (%)[c]
1	I (2)	10 (2)	25	48	40
2	I (2)	10 (2)	55	7	44
3	I (2)	20 (2)	55	12	68
4	I (2)	30 (2)	55	12	68
5	I (2.5)	20 (2)	55	8	73
6	I (3)	20 (2)	55	3	80
7	I (2)	20 (3)	55	5	60
8	I (2)	10 (2)	25	12	68[d]
9	Br (2)	5 (3)	25	20	65
10	Br (2)	10 (3)	25	5	75
11	Br (2)	10 (3)	45	0.5	67[e]

[a] BuZnI was prepared by the insertion of zinc dust in BuI, whereas BuZnBr was obtained by the reaction of BuLi with $ZnBr_2$. [b] $Co(acac)_n$; n = 2 or 3. [c] Isolated yield of analytically pure product.
[d] 1.2 Equivalents of LiBr was added. [e] Only THF was used as solvent.



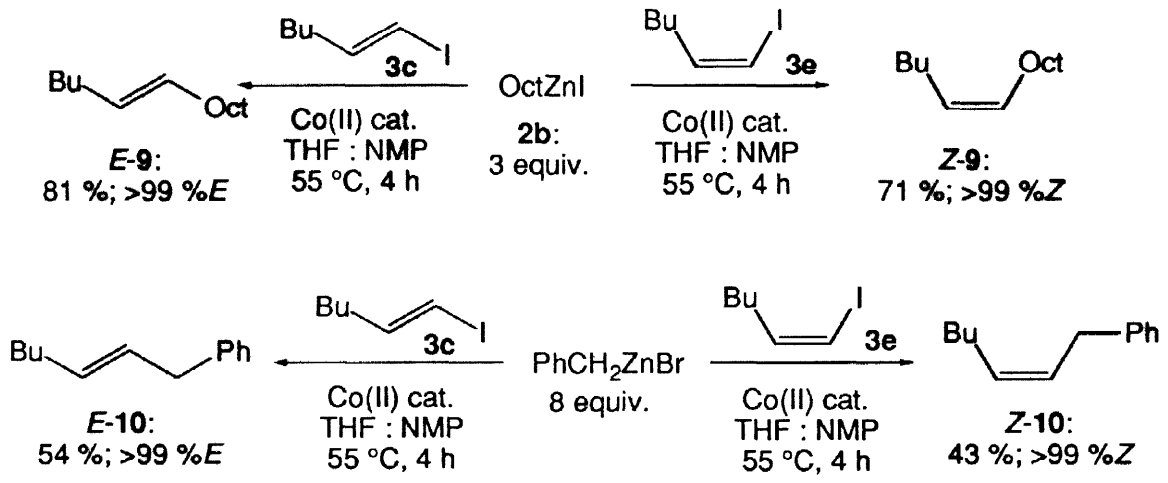
Scheme 3

Table 2. Functionalized Olefins of Type **8** Obtained by the Cobalt(II)-Catalyzed Cross-Coupling of Functionalized Organozinc Halides with Various Alkenyl Iodides in THF/NMP.

Entry	Organozinc Iodide **2**	Alkenyl Iodide **3**	Product of Type **8**	Yield (%)[a]
1	$PivO(CH_2)_3ZnI$	**3b**	PivO, Cl **8a**	77
2	$PivO(CH_2)_4ZnI$	**3b**	PivO, Cl **8b**	65
3	$AcO(CH_2)_4ZnI$	**3b**	AcO, Cl **8c**	77
4	$AcO(CH_2)_5ZnI$	**3b**	AcO, Cl **8d**	69
5	$NC(CH_2)_3ZnI$	*E*-hexenyl iodide **3c**	NC, Bu **8e**	75
6	$NC(CH_2)_2ZnI$	*E*-styryl iodide **3d**	NC, Ph **8f**	50

[a] Isolated yield of analytically pure product; > 99 % isomer as determined by ^1H- and ^{13}C-NMR spectroscopy. For a typical procedure see note 6.

The more reactive diorganozincs can be cross-coupled in some cases with bromoalkenes. Thus, the reaction of dipentylzinc with a 91:9 *E*:*Z*-mixture of 2-bromostyrene furnishes 1-phenylheptene in 70 % yield as a 91:9 *E*:*Z*-mixture of isomers. The reaction with various functionalized organozinc iodides bearing an ester or nitrile function and alkenyl iodides **3b-d** using $Co(acac)_2$ (25 mol %) in THF:NMP (55 °C, 12 h) furnishes polyfunctional *E*-alkenes of type **8** (> 99 % *E*) in 50-78 % yield (Table 2). Interestingly, these cobalt-catalyzed reactions are highly stereoselective. Thus, the cross-coupling reaction of octylzinc iodide (3 equiv.) with either *(E)* - or (*Z*)-1-iodohexene (**3c** and **3e**) furnishes either *E*- or *Z*-**9** in excellent yield (Scheme 4). Unfortunately, longer reaction times are necessary and lower yields are obtained with benzylzinc bromide which decomposes slowly under the reaction conditions. The products *E*- and *Z*-**10** are obtained with high stereoselectivity (> 99 % pure as indicated by ^1H- and ^{13}C-NMR spectroscopy).



Scheme 4

In summary, we have reported a new efficient cobalt-catalyzed cross-coupling reaction between alkenyl iodides and organozinc halides allowing the stereoselective preparation of functionalized (*E*)- or (*Z*)-alkenes.

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References and Notes

1. Negishi, E.; King, A. O.; Okukado, N. *J. Org. Chem.* **1977**, *42*, 1821. (b) King, A. O.; Okukado, N.; Negishi, E. *J. Chem. Soc., Chem. Commun.* **1977**, 683. (c) Negishi, E. *Acc. Chem. Res.* **1982**, *15*, 340.
2. (a) Erdik, E. *Tetrahedron* **1992**, *48*, 9577. (b) Quesnelle, C. A.; Familoni, O. B.; Snieckus, V. *Synlett* **1994**, 349. (c) Rossi, R.; Bellina, F.; Carpita, A.; Gori, R. *Synlett* **1995**, 344. (d) Abarbri, M.; Parrain, J. L.; Cintrat, J.-C.; Duchêne, A. *Synthesis* **1996**, 82. (e) Anderson, B. A.; Harn, N. K. *Synthesis* **1996**, 583.
3. (a) Marquais, S.; Arlt, M. *Tetrahedron Lett.* **1996**, *37*, 5491. (b) Rottländer, M.; Knochel, P. *Tetrahedron Lett.* **1997**, *38*, 1749; (c) Rottländer, M.; Knochel, P. *Synlett* **1997**, 1084.
4. (a) Devasagayaraj, A.; Knochel, P. *Tetrahedron Lett.* **1995**, *36*, 8411; (b) Reddy, C. K.; Knochel, P. *Angew. Chem.* **1996**, *108*, 1812.
5. Cahiez, G.; Avedissian, H. *Tetrahedron Lett.* preceeding paper.
6. **Typical procedure:** Preparation of (*E*)-10-chloro-6-decenyl acetate (**8d**). A dry three-necked flask equipped with a magnetic stirring bar, a thermometer and a septum was charged with $Co(acac)_2$ (320 mg, 1.3 mmol) in a 5:2 mixture of THF:NMP (7 mL) and heated to 50 °C. (*E*)-5-Chloro-1-iodo-1-pentene (**3b**) (1.15 g, 5 mmol) was added dropwise followed by 5-acetoxypentylzinc iodide (15 mmol prepared from 5-iodopentyl acetate (3.84 g, 15 mmol), zinc dust (3.9 g, 60 mmol) in THF (8 mL). The reaction mixture was stirred at 55 °C for 8 h and worked up as usually. The crude reaction oil obtained after evaporation of the solvents was purified by chromatography (hexane:ether 95:5) yielding pure unsaturated chloroester **8d** (804 mg, 69 % yield).