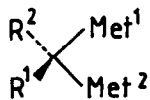


## SYNTHESIS AND REACTIVITY OF GEM-DIMETALLIC ORGANIC COMPOUNDS. PART 1.

P. Knochel\* and J.F. Normant

Laboratoire de Chimie des Organo-éléments, tour 44  
Université P. & M. Curie, 4 place Jussieu 75252 PARIS Cédex 05 France

*Summary* - A number of gem-dimetallic compounds 4a-i have been prepared by carbometallation of an alkenyl organometallic derivative of Mg, Li or Al by an allylic zinc bromide. The 1-magnesia-1-zincaalkenes 4a-b react smoothly with various aldehydes in the presence of  $\text{BF}_3 \cdot \text{OEt}_2$  to furnish (E)-1,5-dienes in high yields and high isomeric purity.



Gem-dimetallic organic compounds of type 1 are of theoretical, structural and synthetic interest. The diboraalkanes<sup>1</sup>, the 1,1-dialuminaalkanes<sup>2</sup> as well as some 1,1-dimagnesia<sup>3</sup>-, 1,1-dizinka<sup>4</sup>-, 1,1-dilithia<sup>5</sup>- and 1,1-dipotassia<sup>6</sup>- alkanes are known, but only a few synthetic applications of these reagents have been reported<sup>1-6</sup>. In 1971, M. Gaudemar<sup>7</sup> reported the addition of allyl zinc bromide on propenyl-, iso-propenyl-, pentenyl-, 1-propylvinyl- Grignard reagents which led to 1-magnesia-1-zincaalkenes with yields of 24%, 26%, 58% and 36% respectively. This interesting approach to gem-dimetallic reagents has never been emphasized since then, and we decided to test its scope and limitations. We have found that a wide range of 1,1-dimetallic compounds are available in high yields by carbometallation of alkenyl organometallics of magnesium, lithium and aluminium by allylic zinc bromides using similar reaction conditions as M. Gaudemar<sup>7</sup>. The addition of a 1.5M THF solution of an allylic zinc bromide<sup>8</sup> 2 to a 0.5M THF solution of diverse alkenyl-magnesium bromides<sup>9</sup> 3 gives, after 0.75-3hr stirring at 35°, the gem-dimetallic species<sup>10</sup> 4 in good yield (58-93%) ; see scheme 1 and table 1. An alkenyllithium like 3e reacts also well, but in this case the reaction has to be carried out at 5° due to the lower stability of the 1-lithia-1-zincaalkene 4h which decomposes slowly at room temperature (see entry 8 of table 1). Preliminary studies<sup>11</sup> show that an alkenylaluminium compound is also able to add an allylic zinc bromide in fair yield (see entry 9). Treatment of the dimetallic compounds 4a and 4h with  $\text{D}_3\text{O}^+/\text{D}_2\text{O}$  gives the corresponding 1,1-dideuterated alkenes (100% deuteration).

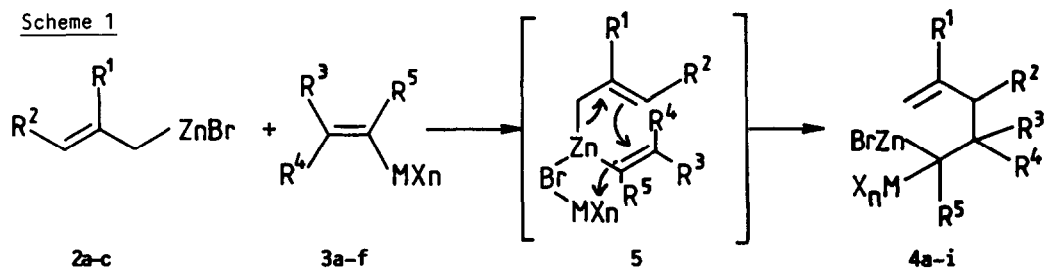


Table 1 - Addition of the allylic zinc bromides **2a-c** to the vinylic organometallic compounds **3a-3f** in THF leading to the 1,1-dimetallic reagents **4a-4i**

Entry	allylic zinc bromide	R <sup>1</sup>	R <sup>2</sup>	alkenylmetallic compound	MX <sub>n</sub>	R <sup>3</sup>	R <sup>4</sup>	R <sup>5</sup>	Product	Reaction time (h)	Yield (%) <sup>a</sup>
1	<b>2a</b>	H	H	<b>3a</b>	MgBr	H	C <sub>6</sub> H <sub>13</sub>	H	<b>4a</b>	0.75	93
2	<b>2b</b>	Me	H	<b>3a</b>	MgBr	H	C <sub>6</sub> H <sub>13</sub>	H	<b>4b</b>	0.75	92
3	<b>2c</b>	H	Me	<b>3a</b>	MgBr	H	C <sub>6</sub> H <sub>13</sub>	H	<b>4c</b>	2.5	82 <sup>b</sup>
4	<b>2a</b>	H	H	<b>3b</b>	MgBr	H	H	SiEt <sub>3</sub>	<b>4d</b>	1.75	90
5	<b>2c</b>	H	Me	<b>3b</b>	MgBr	H	H	SiEt <sub>3</sub>	<b>4e</b>	3	83
6	<b>2a</b>	H	H	<b>3c</b>	MgBr	Ph	H	H	<b>4f</b>	1	58
7	<b>2a</b>	H	H	<b>3d</b>	MgBr	Me	Me	H	<b>4g</b>	2	69 <sup>c</sup>
8	<b>2a</b>	H	H	<b>3e</b>	Li	H	C <sub>6</sub> H <sub>13</sub>	H	<b>4h</b>	15 <sup>d</sup>	90
9	<b>2a</b>	H	H	<b>3f</b>	AlEt <sub>2</sub>	C <sub>6</sub> H <sub>13</sub>	H	H	<b>4i</b>	1 <sup>e</sup>	71

(a) the yields are those of isolated alkenes obtained after hydrolysis of the dimetallic species **4**. All reactions were performed on a 10-20mmol scale.

(b) this compound is a 7:3 mixture of two diastereoisomers ; the starting alkenyl Grignard reagent used was a 9:1 mixture of Z,E isomers.

(c) in this case **4g** was quenched with Me<sub>3</sub>SnCl. The yield indicated is that of the flash-chromatographically purified 2,2-dimethyl-5-pentenyl-trimethylstannane (compare with the following publication).

(d) this reaction has to be performed at 5°.

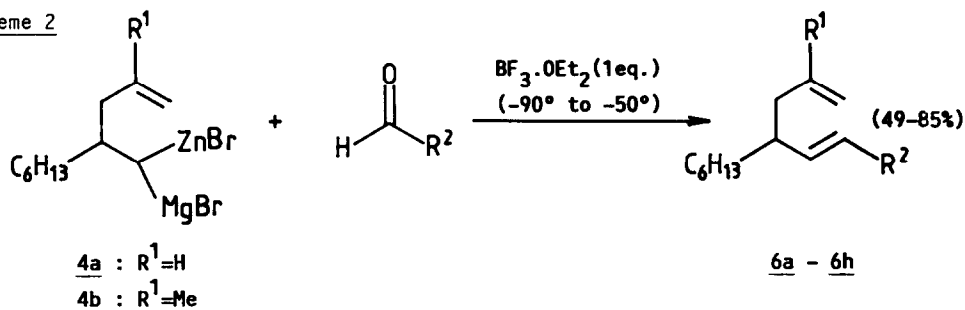
(e) In this case 1.75eq. of allyl zinc bromide is used.

The alkenyl magnesium reagent can be substituted in various positions (see entry 1-7 of table 1). If the vinylic magnesium bromide **3** is β,β'-disubstituted (R<sup>3</sup> and R<sup>4</sup> are different from H), then the addition reaction is less efficient (see entry 7). Addition of 1-trimethylsilylvinyl magnesium bromide leads to the "trimetallic species" **4d** and **4e** which have a carbon bearing formally three different metals (Zn, Mg, Si) ; see entries 4 and 5. We suppose that the carbometallation proceeds first by the formation of the mixed allyl-vinyl-zinc compound **5** (see scheme 1) which then undergoes a (3,3) sigmatropic rearrangement (a process which can be called a "metalla-Claisen" reaction) leading to the 1,1-bimetallic species **4**<sup>10</sup>. This reaction occurs under milder conditions than the carbometallation

of alkenes<sup>12,13</sup> with allylic organometallic compounds (M=ZnR,MgX) which would give the same products after hydrolysis.

We find now that the 1- magnesia -1-zincaalkenes 4 react with a number of organic substrates<sup>14</sup> leading to useful transformations. Addition of 1.1equiv. of  $\text{BF}_3 \cdot \text{OEt}_2$ <sup>15</sup> to a cooled solution ( $-90^\circ$ ) of the bimetallic species 4a or 4b ( $\approx 0.2\text{M}$  in THF), followed by the addition of 1.1equiv. of an aldehyde, warming up of the reaction mixture to  $-50^\circ$  in 15min. and stirring the resultant solution 45min. at  $-50^\circ$  to  $-60^\circ$  furnishes after hydrolysis the 1,5-dienes 6a-6h in good yields and good stereoisomeric purity (E/Z ratio generally over 90/10) ; see scheme 2 and table 2.

Scheme 2



**Table 2** : Synthesis of the 1,5-dienes 6a-6g and of the 1,5,7-triene 6h through the addition of the 1-magnesia-1-zincaalkenes 4a and 4b to aldehydes in the presence of  $\text{BF}_3 \cdot \text{OEt}_2$

Entry	Dimetallic reagent	$\text{R}^2\text{CHO}$	Product	$\text{R}^1$	$\text{R}^2$	b.p. (% torr)	E:Z <sup>b</sup>	Yield (%) <sup>a</sup>
1	<u>4a</u>	PhCHO	<u>6a</u>	H	Ph	102°/0.05	99:1	78
2	<u>4a</u>	EtCHO	<u>6b</u>	H	Et	105°/13	95:5	61
3	<u>4a</u>	PentCHO	<u>6c</u>	H	Pent	86°/0.1	94:6	75
4	<u>4a</u>	isPrCHO	<u>6d</u>	H	isPr	56°/0.1	99:1	75
5	<u>4b</u>	isPrCHO	<u>6e</u>	Me	isPr	64°/0.1	98:2	79
6	<u>4a</u>	$(\text{CH}_3)_2\text{CHCH}_2\text{CHO}$	<u>6f</u>	H	$(\text{CH}_3)_2\text{CHCH}_2$	66°/0.1	88:12	85
7	<u>4a</u>	tertBuCHO	<u>6g</u>	H	tertBu	53°/0.1	99:1	49 <sup>c</sup>
8	<u>4a</u>	Ph-CH=CH-CHO	<u>6h</u>	H	Ph-CH=CH-	-	92:8	58

(a) the yields given are those of distilled or chromatographically purified materials. All spectroscopic data (I.R.,  $^1\text{H-NMR}$  and  $^{13}\text{C-NMR}$ ) are compatible with the structures indicated.

(b) the E:Z ratio is determined by  $^{13}\text{C-NMR}$ .

(c) the reaction mixture is warmed up to  $-20^\circ$  after addition of  $\text{BF}_3 \cdot \text{OEt}_2$  and pivalic aldehyde

The reaction shows a good chemoselectivity since ketones like 3-pentanone or ethyl levulinate do not react ; a sterically hindered aldehyde like pivalic aldehyde (see entry

7 of table 2) does not react at low temperature and the reaction mixture has to be warmed up to  $-20^{\circ}$ . On the contrary, aromatic aldehydes are very reactive since benzaldehyde is the only aldehyde that reacts with **4a** in the absence of  $\text{BF}_3 \cdot \text{OEt}_2$  (although the yield and the stereoselectivity are lower : 47% ; E:Z ratio (92:8)). (E)-Cinnamaldehyde reacts with **4a** smoothly and leads to the (E,E)-1,5,7 triene **6h** in fair yield and with a 92:8 isomeric purity of the newly formed double bond (see entry 8 of table 2).

We continue actively our study on the synthesis and on the reactivity of these 1,1-dimetallic organic compounds. Its extension to hetero substituted vinylic and allylic partners is also examined.

#### Acknowledgements :

We thank Madame Monique Baudry for the synthesis of various starting materials, the Vieille Montagne Company for a generous gift of zinc of high purity and the C.N.R.S. for financial support (U.A. 473).

#### References and notes :

- H.C. Brown and G. Zweifel, *J. Am. Chem. Soc.* **83**, 3834 (1961) ; G. Zweifel and H. Arzoumanian, *Tetrahedron Lett.* 2535 (1966) ; G. Cainelli, G. Dal Bello and G. Zubiani, *Tetrahedron Lett.* 4315 (1966) ; H.C. Brown in *Organic Synthesis Today and Tomorrow*, Editors B.M. Trost and C.R. Hutchinson, Pergamon Press (1981) p. 135.
- G. Wilke and H. Müller, *Ann.* **629**, 222 (1960) ; G. Zweifel and R.B. Steele, *Tetrahedron Lett.* 6021 (1966)
- F. Bertini, P. Grasselli, G. Zubiani and G. Cainelli, *Tetrahedron*, **26**, 1281 (1970) ; J.W. Bruin, G. Schat, O.S. Akkerman and F. Bickelhaupt, *J. Organomet. Chem.* **288**, 13 (1985)
- J.J. Eisch and A. Piotrowski, *Tetrahedron Lett.* **24**, 2043 (1983)
- a/ A. Maercker, M. Theis, A.J. Kos and P. von R. Schleyer, *Ang. Chem.* **95**, 755 (1983) ; *Ang. Chem. Int. Ed. Engl.* **22**, 733 (1983) ; A. Maercker and R. Dujardin *Ang. Chem.* **96**, 222 (1984) ; *Ang. Chem. Int. Ed. Engl.* **23**, 224 (1984) ; A. Maercker and R. Dujardin, *Ang. Chem.* **97**, 612 (1985) ; *Ang. Chem. Int. Ed. Engl.* **24**, 571 (1985) ; b/ H. Kawa, B.C. Manley and R.J. Lagow, *J. Am. Chem. Soc.* **107**, 5313 (1985)
- E.M. Kaiser, F.E. Henoch and C.R. Hauser, *J. Am. Chem. Soc.* **90**, 7287 (1968)
- M. Gaudemar, *Compt. Rend. Acad. Sc. Paris, Série C*, **273**, 1669 (1971) ; Y. Frangin and M. Gaudemar, *Compt. Rend. Acad. Sc. Paris, Série C*, **278**, 885 (1974) ; M. Bellasoued, Y. Frangin and M. Gaudemar, *Synthesis*, 205 (1977)
- M. Gaudemar, *Bull. Soc. Chim. France*, 974 (1962)
- Trisubstituted alkenyl organometallics like 1-cyclooctenylmagnesium bromide did not add allylzinc bromide, even under forcing reaction conditions.
- The real structure of these dimetallic species is certainly more complex than the one indicated on formula 4 (dimeric species can be considered : compare with ref. 5b). However this formulation of 4, deduced from the reaction stoichiometry, allows us to rationalize the properties of these species (see also the following publication).
- The addition of allylic zinc bromides to alkenyl boron and aluminium compounds is currently under study in our laboratory : we have observed that allylic aluminium bromide  $((\text{C}_3\text{H}_5)_3\text{AlBr}_2)$  and the in situ generated  $((\text{C}_3\text{H}_5)_3\text{Al} \cdot \text{AlMe}_3)$  do not react with alkenyl magnesium derivatives under our standard reaction conditions.
- H. Lehmkuhl, *Bull. Soc. Chim. France (II)*, 87 (1981) and references cited.
- Even the intramolecular version of the carbometallation of alkenes by allylic magnesium bromides requires rather severe reaction conditions : W. Oppolzer in *Selectivity - a Goal for synthetic Efficiency - Workshop Conferences Hoechst/Volume 14* edited by W. Bartmann and B.M. Trost p. 135-167 (1984) Verlag Chemie.
- The 1-magnesia-1-zincaalkenes are less reactive than Grignard reagents ; thus compounds **4** ( $\text{MXn}=\text{MgBr}$ ) do not react with ketones, esters, anhydrides or various iodo derivatives (with or without  $\text{Pd}^{\circ}$  catalysis and  $\text{Ni}^{\circ}$  catalysis affords no clean reaction), vinylic sulfones,  $\alpha, \beta$  unsaturated esters,  $\text{Me}_3\text{SiCl}$ . For other reactions of reagents **4** see the following publication.
- A number of other Lewis- acids has been tested :  $\text{TiCl}_4$ ,  $\text{TiCl}_4(\text{OisPr})_2$ ,  $\text{Cp}_2\text{TiCl}_2$ ,  $\text{B}(\text{OMe})_3$ ,  $\text{BBu}_3$ ,  $\text{SnCl}_4 \cdot \text{THF}$  ; none of these shows the activity of  $\text{BF}_3 \cdot \text{OEt}_2$  as promoter in the synthesis of 1,5 dienes.

(Received in France 20 December 1985)