

Preliminary communication

CONCERNING REVERSAL OF DIASTEREOSELECTIVITY IN THE BF_3 PROMOTED ADDITION OF CROTYL-ORGANOMETALLIC COMPOUNDS TO ALDEHYDES

YOSHINORI YAMAMOTO* and KAZUHIRO MARUYAMA

Department of Chemistry, Faculty of Science, Kyoto University, Kyoto 606 (Japan)

(Received December 7th, 1984)

Summary

The addition of a mixture of benzaldehyde and $\text{BF}_3 \cdot \text{OEt}_2$ to crotyl-organometallic reagents $\text{C}_4\text{H}_7\text{MLn}$ (**1**) ($\text{M} = \text{Cu}, \text{Cd}, \text{Hg}, \text{Tl}, \text{Ti}, \text{Zr}$ and V) produces predominantly the *erythro* homoallyl alcohol as well as the α -adduct, while without $\text{BF}_3 \cdot \text{OEt}_2$ the *threo* isomer is formed preferentially.

A recent communication by Reetz and Sauerwald [1] on the reversed diastereoselectivity in BF_3 -mediated reactions of crotyltitanium reagents with aldehydes has prompted us to report our own findings [2] in this area. When we found that the BF_3 -mediated reaction of crotyltrialkyltins with aldehydes proceeds in a stereoconvergent manner to produce *erythro* homoallyl alcohols predominantly and proposed an antiperiplanar transition state [3,4], we anticipated that a similar reaction of other crotyl-organometallic compounds may exhibit selective inversion from *threo* to *erythro* by BF_3 coordination to aldehydes (eq. 1).

We therefore examined the reaction of benzaldehyde with several crotyl-metals in the presence and in the absence of $\text{BF}_3 \cdot \text{OEt}_2$. The results are summarized in Table 1.

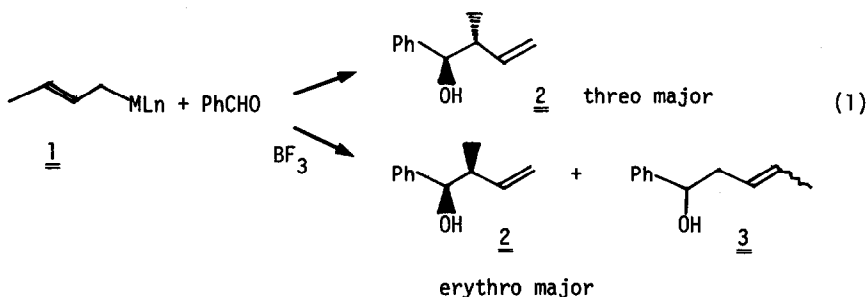


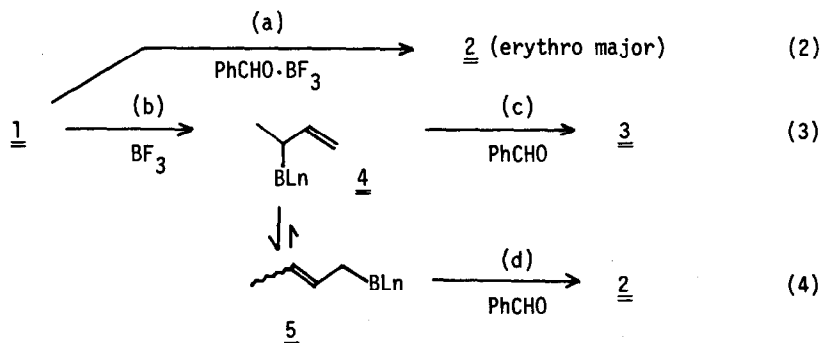
TABLE 1

SELECTIVE INVERSION FROM *threo* TO *erythro* ^a

Entry	1 (MLn)	with BF ₃		without BF ₃	
		γ-adduct (2) <i>erythro/threo</i>	ratio γ/α	α-adduct (3) <i>trans/cis</i>	<i>erythro/threo</i>
1	MgCl	48/52	70/30	60/40	48/52
2	ZnBr	56/44	81/19	65/35	56/44
3	B 	30/70	100/—	—	30/70
4	Cu ^b	98/2	35/65	57/43	48/52
5	CdI ^c	60/40	57/43	65/35	50/50
6	HgI ^c	70/30	65/35	75/25	34/66
7	TlI ^c	98/2	50/50	65/35	50/50
8	TiCl ₂ Cl	55/45	80/20	60/40	20/80
9	ZrCp ₂ Cl	96/4	34/66	50/50	19/81 ^d
10	VCp ₂ Cl	70/30	65/35	70/30	43/57

^a A mixture of PhCHO (1 mmol) and BF₃·OEt₂ (2 mmol) in dry ether (1 ml) was added at -78°C to the crotylmethyl reagent (1.1 mmol) in ether (or in ether/THF), except where otherwise indicated, and the reaction was quenched at 0°C. The reagent was prepared in situ by addition of crotylmagnesium chloride (1.1 mmol) to MLn (1.1 mmol) (ZnBr₂ in THF, CuI in ether, CdI₂ in ether, HgI₂ in ether, TlI₂ in ether, TiCp₂Cl₂ in ether, ZrCp₂Cl₂ in THF and VCp₂Cl₂ in ether). The product ratio and yield were determined by GLC and ¹H NMR spectroscopy. The structure determination was made by comparison with authentic samples [3]. Total yields are almost quantitative except for entries 5, 7 and 10, where also small amounts of PhC(O)CH(CH₃)CH=CH₂ were formed presumably due to the Meerwein-Ponndorf oxidation. ^b The reagent was made at -30°C, and PhCHO·BF₃ was added at this temperature. ^c The reagent was made at 0°C and PhCHO was added at 0°C. ^d Data from Y. Yamamoto and K. Maruyama, *Tetrahedron Lett.*, 22 (1981) 2895.

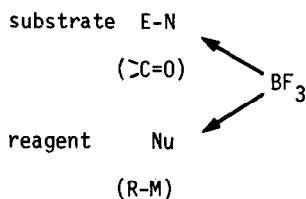
The *erythro/threo* ratio in the reaction of Mg, Zn, and B is not influenced by the presence of BF₃ (entries 1–3). Reversal of the diastereoselectivity is observed in the reactions of Cu, Cd, Hg, Tl, Ti [5], Zr, and V (entries 4–10). Especially, the use of BF₃ in the reactions of Cu, Tl, and Zr causes very predominant formation of the *erythro* isomer. Furthermore, the α-isomer **3** is formed as a by-product, and sometimes as the major product, if BF₃ is used. Without BF₃ the γ-isomer is obtained in an essentially quantitative yield [6]. The inversed regioselectivity may be explained by transmetalation via an S_E2' process (path b) followed by a rapid reaction with benzaldehyde (path c) [7] (eq. 3).



If such a transmetallation process is involved, the γ/α isomer ratio should depend on the addition sequence of BF_3 . The addition of 1 equiv. of BF_3 to crotylmagnesium chloride at -78°C followed by the addition of benzaldehyde produced 30% of the γ -adduct (*erythro/threo* = 75/25) and 70% of the α -adduct (*trans/cis* = 64/36) (cf. entry 1). Allylic rearrangement from 4 to 5 followed by the reaction with benzaldehyde (path d) again produces 2 (eq. 4). In fact, when the mixture of 1 equiv. of $\text{BF}_3 \cdot \text{OEt}_2$ and crotylmagnesium chloride, prepared at -78°C , was allowed to warm up to room temperature and then cooled to -78°C , a similar reaction with benzaldehyde gave exclusively the γ -adduct (*erythro/threo* = 39/61).

We also examined the reaction of isobutyraldehyde (6) to investigate whether in the BF_3 mediated reaction of an aliphatic aldehyde besides the γ -adduct some α -adduct is also formed. The reaction of crotyl- ZrCp_2Cl with 6- BF_3 produced 98% of the γ -adduct (*erythro/threo* = 60/40) [8] along with 1% of the α -adduct (*trans/cis* = 1/1). A similar reaction of crotyl- SnBu_3 , our original reaction in this series, gave 99% of the γ -adduct (*erythro/threo* = 96/4) along with 0.2% of the α -isomer. Consequently, the γ/α ratio is highly dependent upon the structure of the aldehyde, the metal (M), and the reaction conditions, owing to the complex competitive processes (eqs. 2–4). Until now it is not possible to clarify whether 2 is produced via eq. 2 or eq. 4. However, when the formation of the α -isomer can be neglected, the reversed diastereoselectivity must occur via an antiperiplanar transition state (path a, eq. 2).

In conclusion, reversal of the diastereoselectivity from *threo* to *erythro* is observed for a wide range of crotylmagnesiums with relatively low Lewis acidity. Furthermore, the use of BF_3 often induces reversal of the regioselectivity, which is ascribed to the fact that BF_3 can interact with both nucleophilic sites (Scheme 1). The $\text{E}-\text{N} \cdot \text{BF}_3$ interaction produces predominantly the γ -*erythro* isomer, and the $\text{Nu} \cdot \text{BF}_3$ interaction preferentially the α -isomer. A similar double function of Lewis acids has been observed recently with several reagents and reactions, e.g. $\text{RCu} \cdot \text{BF}_3$ [9], $\text{R}_2\text{CuLi} \cdot \text{BF}_3$ [9], $\text{RLi} \cdot \text{BF}_3$ [10], allylsilane $\cdot \text{TiCl}_4$ [11], and silyl enol ether $\cdot \text{TiCl}_4$ [12].



Scheme 1

SCHEME 1

References

- 1 M.T. Reetz and M. Sauerwald, J. Org. Chem., 49 (1984) 2292.
- 2 Presented orally at the post ICOS-IV Kyoto symposium, August 1982.
- 3 Y. Yamamoto, H. Yatagai, Y. Naruta and K. Maruyama, J. Am. Chem. Soc., 102 (1980) 7107; Y. Yamamoto, H. Yatagai, Y. Ishihara, N. Maeda and K. Maruyama, Tetrahedron, 40 (1984) 2239.
- 4 The synclinal transition state geometry is proposed for the intramolecular reaction; S.E. Denmark and E.J. Weber, Helv. Chim. Acta, 66 (1983) 1655. For the reaction of crotylsilane $\cdot \text{BF}_3$, see T. Hayashi, H. Ito and M. Kumada, Tetrahedron Lett., 23 (1982) 4605.

- 5 There is lack of agreement with Reetz or Sato in the Ti case (entry 8); F. Sato, K. Ikeda, S. Ijima, H. Moriya and M. Sato, J. Chem. Soc. Chem. Commun., (1981) 1140. The difference may be due to the solvent; ether in our case and THF in their cases.
- 6 This means that 1, prepared in situ from crotylmagnesium chloride and MLn, does not take an α -metallyl geometry but possesses a crotyl structure.
- 7 Y. Yamamoto, N. Maeda and K. Maruyama, J. Chem. Soc. Chem. Commun., (1983) 742; Y. Yamamoto and K. Maruyama, J. Org. Chem., 48 (1983) 1564. Another possibility for the inverted regioselectivity is that enhanced electrophilicity at the carbonyl center, caused by coordination of BF_3 , may force 1 to react at the α -position.
- 8 Without BF_3 , *erythro/threo* = 88/12 (Table 1, footnote d).
- 9 Y. Yamamoto, S. Yamamoto, H. Yatagai, Y. Ishihara and K. Maruyama, J. Org. Chem., 47 (1982) 119.
- 10 M. Yamaguchi and I. Hirao, Tetrahedron Lett., 24 (1983) 391; M.J. Els, J.E. Wrobel and B. Ganem, J. Am. Chem. Soc., 106 (1984) 3693.
- 11 A. Hosomi and H. Sakurai, Tetrahedron Lett., 17 (1976) 1295.
- 12 T. Mukaiyama, K. Banno and T. Narasaka, J. Am. Chem. Soc., 96 (1974) 7503.