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THE CATALYTIC ACTION OF TRIMETHYLGALLIUM ON THE REACTION OF ALKYNYLLITHIUM WITH EPOXIDES

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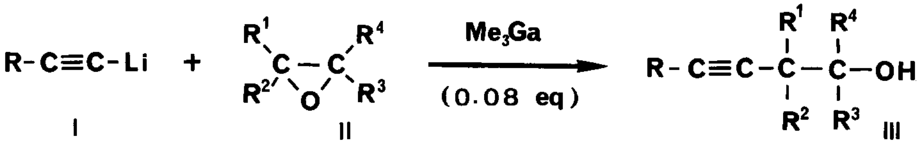
Abstract: Trimethylgallium catalyzes the reaction of 1-lithio-1-alkynes with epoxides affording 3-alkyn-1-ols in good to excellent yields.

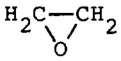
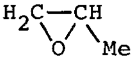
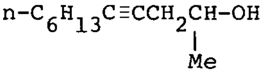
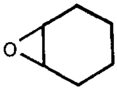
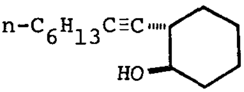
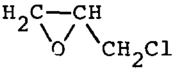
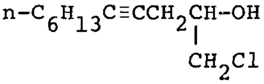
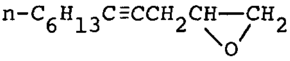
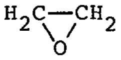
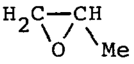
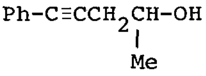
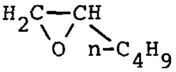
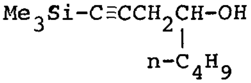
Among organic compounds of IIIB elements, organoboron and aluminium reagents have played resplendent roles in modern organic syntheses.[2-6] Organogallium compounds, on the other hand, have been little studied in this field.[7,8] In continuation of interest to the reactivities of ate complexes of boron and aluminium,[9-11] reaction of an ate complex of gallium with oxirane was examined. During the studies along this line, it has been found, as described in this paper, that the reaction of alkynyllithium with epoxides is catalyzed by trimethylgallium.



First of all, the reactivity of an ate complex prepared from trimethylgallium and 1-lithio-1-octyne with oxirane was examined.[12] Oxirane was treated with a reagent prepared from 1-lithio-1-octyne and equimolar trimethylgallium in THF-hexane. The reaction completed within 30 min at room temperature affording 3-decyn-1-ol in 95% yield. Utilizing 0.3 equiv. of trimethylgallium gave the same product in more than 90% yield after the reaction at room temperature for 1 h. These results suggested the catalytic use of trimethylgallium for the reaction of alkynyllithium with oxiranes.[13-15]

Reaction of 1-lithio-1-octyne (I, R = n-C_6H_{13}) with oxirane (II, R^1 - R^4 = H) is illustrative. To a THF-hexane solution of I (R = n-C_6H_{13}) prepared from 1-octyne (1.10 g, 10 mmol), n-BuLi (5.6 mL of 1.86 M hexane solution, 10 mmol) and 10 mL of THF, a hexane solution of trimethylgallium (1 mL of 0.8 M solution, 0.8 mmol, 8 mol% of I) was added at 0°C. To the reaction mixture maintained at 0°C, oxirane (II, R^1 - R^4 = H, 0.6 mL, 530 mg, 12 mmol) was added and the whole was stirred for 1 h at room temperature. The reaction mixture was worked up with brine and extracted with ether. The ethereal solution was washed (brine), dried

Table 1. Reaction of Alkynyllithium (I) with Epoxide (II)

Alkynyllithium I	Epoxide II	Product	Reaction Conditions °C	h	Yield[a] %	Ref.
$n\text{-}C_6H_{13}C{\equiv}C\text{-}Li$		$n\text{-}C_6H_{13}C{\equiv}CCH_2CH_2OH$	-78	6	1 (1)	18
			0	1	63 (3)	
			r.t.	1	92 (10)	
		 $n\text{-}C_6H_{13}C{\equiv}CCH_2\underset{Me}{CH}\text{-}OH$	0	2	39 (2)	19
			r.t.	1.5	87 (3)	
			r.t.	10	37^{b} (2)	16
			reflux	6	71 (12)	
		 $n\text{-}C_6H_{13}C{\equiv}CCH_2\underset{CH_2Cl}{CH}\text{-}OH$	0	2	29 (9)	20
			0	6	$64^{c,d}$	
			r.t.	6	$85^{c,e}$	21
$Ph\text{-}C{\equiv}C\text{-}Li$		$Ph\text{-}C{\equiv}CCH_2CH_2OH$	r.t.	2	99 (4)	13
		 $Ph\text{-}C{\equiv}CCH_2\underset{Me}{CH}\text{-}OH$	r.t.	2	88 (3)	22
$Me_3Si\text{-}C{\equiv}C\text{-}Li$		 $Me_3Si\text{-}C{\equiv}CCH_2\underset{n\text{-}C_4H_9}{CH}\text{-}OH$	r.t.	4	38^{f} (5)	23
			reflux	40 min	79 (18)	

[a] Yields in parentheses indicate those obtained by the reaction without Me_3Ga.

[b] Using MgBr in place of Li gave a mixture of 2-bromo-1-cyclohexanol (58%) and 1-cyclopentyl-2-nonyn-1-ol (31%).

[c] In the presence of 0.16 equiv of trimethylgallium.

[d] Reaction in Liquid ammonia gave 2-undecen-4-yn-1-ol (ref. 16).

[e] Initially produced lithium alcoholate of chlorohydrin gave epoxide at room temperature (ref. 17).

[f] Using MgBr in place of Li gave 1-trimethylsilyl-3-methyl-1-heptyn-3-ol (82%).

(Na_2SO_4), concentrated and chromatographed affording 3-decyn-1-ol (III, R = n-C_6H_{13}, R^1 - R^4 = H) in 92% yield. Other oxiranes reacted analogously with alkynyllithiums. Combinations of alkynyllithium (I), oxirane (II), product III, reaction conditions, as well as yields are summarized in Table 1.

As can be seen from Table 1, the method has following characteristics: (a) Reaction proceeds under mild conditions. (b) Alkynyl group is introduced at less substituted carbon of oxiranes. (c) Isomerization of oxiranes to carbonyl compounds is not observed. (d) Catalytic amount of trimethylgallium is sufficient in contrast to known methods using stoichiometric amount of boron or aluminium mediators.[14,15] Though the mechanism is still open, the alkylgallium catalysis will find practical uses in syntheses.[25]

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20. ^{1}H-NMR ($CDCl_3$), δ ppm, 0.90 (3H, t, J = 6.0 Hz), 1.20-1.65 (8H, m), 2.27 (2H, tt, J = 2.1, 6.9 Hz), 2.35 (1H, d, J = 6.0 Hz), 2.48 (1H, tt, J = 2.1, 7.0 Hz), 2.60 (1H, qd, J = 2.1, 7.0 Hz), 3.62 (1H, dd, J = 6.1, 11.0 Hz), 3.74 (1H, dd, J = 4.6, 11.0 Hz), 3.95 (1H, m). IR (neat), cm^{-1}, 3600-3050, 1090, 1050, 740, 700.
21. ^{1}H-NMR ($CDCl_3$), δ ppm, 0.89 (3H, t, J = 6.0 Hz), 1.15-1.62 (8H, m), 2.15 (2H, tt, J = 2.3, 7.2 Hz), 2.43 (1H, ddt, J = 5.0, 17.7, 2.3 Hz), 2.60 (1H, ddt, J = 4.6, 17.7, 2.3 Hz), 2.65 (1H, dd, J = 2.5, 4.8 Hz), 2.79 (1H, dd, J = 3.6, 4.8 Hz), 3.08 (1H, ddd, J = 2.5, 3.6, 5.0 Hz). IR (neat), cm^{-1}, 960, 930, 840, 830.
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