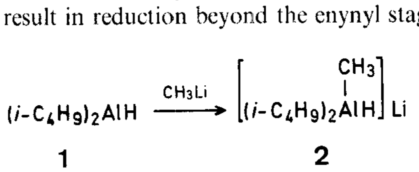
A Stereoselective Synthesis of Symmetrically Substituted *trans*-Enynes from Conjugated Diynes

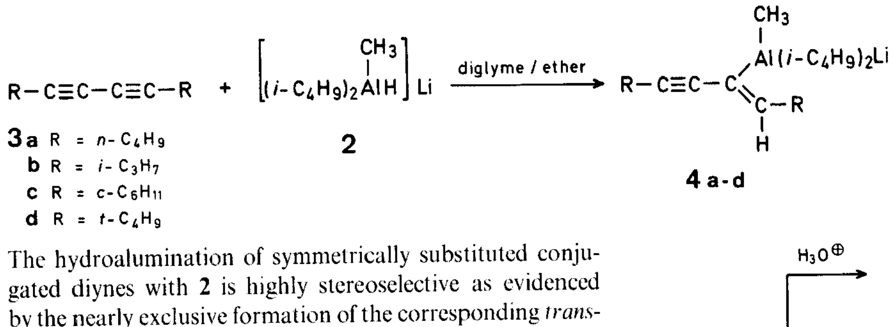
George ZWEIFEL*, Richard A. LYND, Rex E. MURRAY

Department of Chemistry, University of California, Davis, California 95616, U.S.A.

The addition of the Al—H bond of organoaluminum hydrides to disubstituted alkynes furnishes direct syntheses of reactive vinylmetallic intermediates of predictable stereochemistry. For example, the reaction of 3-hexyne with diisobutylaluminum hydride (**1**) in hydrocarbon solvent affords the (*E*)-vinylalane[1]. On the other hand, treatment of the alkyne with lithium diisobutylmethylaluminum hydride (**2**) in diglyme at 100–130° for 6–8 h produces, *via* *trans*-hydroalumination of the triple bond the corresponding (*Z*)-vinylaluminate[2].

In the course of delineating the scope of the *trans*-hydroalumination of carbon-carbon triple bonds it was observed that 5,7-dodecadiyne (**3a**) reacted at room temperature with **2** in diglyme solvent to produce the lithium enynylaluminate **4a**. This is in contrast to the elevated temperatures required for achieving hydroalumination of disubstituted monoynes[2]. The rate of hydroalumination was markedly dependent on the choice of the solvent used, decreasing in the following order: diglyme > 1,2-dimethoxyethane > tetrahydrofuran[3]. Also, it should be noted that utilization of a 50% excess of **2** over that required for monohydroalumination did not result in reduction beyond the enynyl stage.





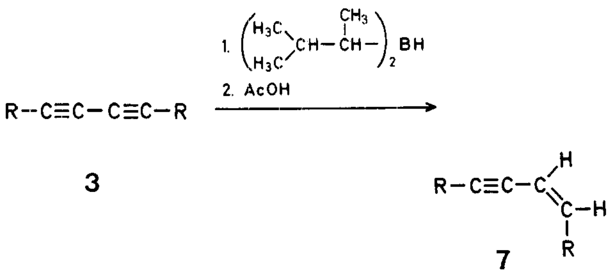
The hydroalumination of symmetrically substituted conjugated diynes with **2** is highly stereoselective as evidenced by the nearly exclusive formation of the corresponding *trans*-enynes **5** after hydrolysis of the intermediate enynylaluminates **4**. Therefore, the *trans*-monohydroalumination of substituted 1,3-diynes provides an operationally simple route to *trans*-enynes[4] from readily available precursors[5]. A summary of the yields of various *trans*-enynes obtained in the present work is given in the Table.

Table. *trans*-Enynes (**5**) Derived by Hydroalumination of Conjugated Diynes (**3**)

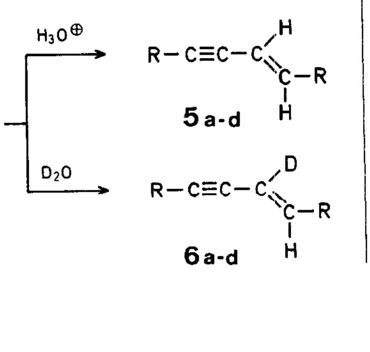
Product	R	Yield [%][a]	b.p./torr or m.p.	n_D^{21}	Molecular formula[b]
5a	*n*-C_4H_9	92 (99)	63°/1	1.4686	$C_{12}H_{20}$ (164.3)
5b	*i*-C_3H_7	89 (98)	57°/10	1.4611	$C_{10}H_{16}$ (136.2)
5c	*c*-C_6H_{11}	91 (98)	122°/1	1.5223	$C_{16}H_{24}$ (216.4)
5d	*t*-C_4H_9	80 (96)	m.p. 56°	–	$C_{12}H_{20}$ (164.3)

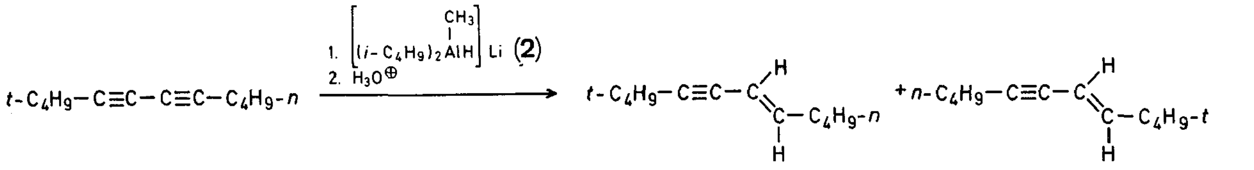
[a] Values in parentheses are the isomeric purities.
[b] The spectral and analytical data (C ±0.15%, H ±0.15%) for all compounds reported are consistant with the structures proposed.

It should be pointed out that the corresponding *cis*-enynes **7** are available *via* the monohydroboration of diynes **3** followed by protonolysis of the resultant enynylboranes with acetic acid[6].



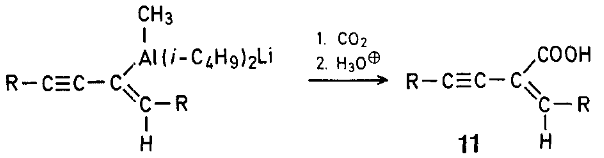
In addition to being stereoselective the *trans*-hydroalumination of symmetrical 1,3-diynes is also highly regiospecific. Thus, N.M.R. examination of the *trans*-enyne **6a** obtained after deuterolysis of **4a** (R = C_4H_9—) with D_2O revealed that at least 98% of one deuterium was attached at the internal position of the double bond. This result indicates that the aluminum preferentially adds at the sterically less hindered position of the diyne system[7]. However, the observation that the *trans*-hydroalumination of 2,2-dimethyldeca-3,5-diyne (**8**) with **2** produced, after hydrolysis, a mixture of enynes **9** and **10** indicates that the hydroaluminating agent **2** does not discriminate in its addition between the triple bonds of unsymmetrically substituted conjugated diynes.





8 9 (58%) 10 (42%)

Finally, it should be noted that the formation of enynylaluminates **4** of predictable structure *via* the hydroalumination of symmetrical 1,3-diynes with **2**, coupled with the established reactivity of the vinyl carbon-aluminum bond toward Grignard coreagents[2], points to a possible convenient synthesis of functionally substituted enynes. For example, treatment of **4** with carbon dioxide followed by work-up should afford the corresponding enynoic acids **11**.



4 11

Dicyclohexylbutadiyne (3c):

A steady stream of oxygen was passed into a well-stirred mixture of copper(I) chloride (4.0 g, 40 mmol), pyridine (75 ml) and cyclohexylacetylene (10.8 g, 100 mmol) over a period of 3 h. The exothermic reaction was controlled between 20° and 40°. To the mixture was then added crushed ice (150 g) and concentrated hydrochloric acid (100 ml). After extraction with *n*-pentane, the combined extract was washed with 6 normal sodium hydroxide solution and a saturated solution of sodium chloride. Removal of the solvent *in vacuo* afforded the diyne: yield: 10.3 g (94%); m.p. 107–108° (Lit.[8] m.p. 102°).

1,4-Dicyclohexyl-*trans*-1-buten-3-yne (5c):

Into a dry, nitrogen-flushed flask kept under a static pressure of nitrogen and containing freshly distilled diglyme[9] (16 ml) were added dropwise diisobutylaluminum hydride (5.6 ml, 30 mmol) followed by methyllithium in ether (19.5 ml, 30 mmol) while maintaining the temperature during the additions between 0° and 25°. The reaction mixture was allowed to warm up to room temperature. To the resultant milky lithium diisobutylmethylaluminum hydride was added at 25° the solid dicyclohexylbutadiyne (**3c**: 4.29 g, 20.0 mmol). The reaction mixture was stirred at 25° (water bath) for 8 h and then was added to chilled 10% sulfuric acid (50 ml) by means of the double ended needle technique[10]. After diluting the mixture with an additional 25 ml of 10% sulfuric acid, it was extracted with *n*-pentane. The combined extracts were washed sequentially with water, 10% hydrochloric acid, and a saturated solution of sodium hydrogen carbonate. After drying with magnesium sulfate, the solvent was removed *in vacuo* and the enyne product distilled; yield: 3.93 g (91%); b.p. 122°/1 torr; $n_D^{21} = 1.5223$.

$C_{16}H_{24}$	calc.	C 88.82	H 11.18
(216.35)	found	88.91	11.05

I.R. (neat): $\nu_{max} = 2208$ (—C≡C—), 954 cm^{-1} (*trans*-CH=CH—).
U.V. (*n*-hexane): $\lambda_{max} = 229$ ($\varepsilon = 20600$), 234 nm (shoulder, 18400).

^{1}H-N.M.R. (CCl_4): $\delta = 6.10$–5.07 (m, 2H, —C$\underline{H}$=C$\underline{H}$—, $J = 16$ Hz), 3.0–0.7 ppm (m, 22H).

This research was supported by the National Science Foundation through Grants 26369 and CHE76-03738.

Received: September 13, 1976

* To whom correspondence should be addressed.

[1] G. Wilke, H. Müller, *Justus Liebigs Ann. Chem.* **629**, 222 (1960).
[2] G. Zweifel, R. B. Steele, *J. Am. Chem. Soc.* **89**, 5085 (1967).
[3] Since the reaction mixtures were heterogeneous, it is conceivable that differential solubilities of **2** in the solvents used could account for the observed rates of reaction.
[4] For a recently reported synthesis of unsymmetrically 1,4-disubstituted *trans* enynes see: E. Negishi, G. Lew, T. Yoshida, *J. Chem. Soc. Chem. Commun.* **1973**, 874.
[5] H. G. Viehe, *Chemistry of Acetylenes*, Marcel Dekker, New York, 1969, p. 597.
[6] G. Zweifel, N. L. Polston, *J. Am. Chem. Soc.* **92**, 4068 (1970).
[7] A similar regiospecificity was observed in the hydroboration of 2,2-dimethyldeca-3,5-diyne with dialkylboranes[6].
[8] A. J. Hubert, *J. Chem. Soc.* **1965**, 6669.
[9] G. Zweifel, H. C. Brown, *Org. React.* **13**, 28 (1963).
[10] H. C. Brown, *Organic Synthesis via Boranes*, John Wiley & Sons, Inc., New York, 1975, p. 210.