Stereoselective Synthesis of Conjugated *trans*-Enynes Readily Convertible into Conjugated *cis,trans*-Dienes and its Application to the Synthesis of the Pheromone Bombykol

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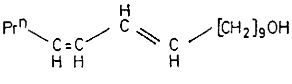
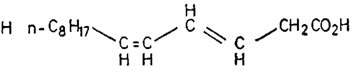
Summary Treatment of the borate complexes derived from bis-(1,2-dimethylpropyl)alkenylboranes and alkynyllithiums with iodine and sodium hydroxide produces in a highly stereoselective (> 99%) manner conjugated *trans*-enynes readily convertible into the corresponding *cis,trans*-dienes.

CERTAIN insect pheromones, such as bombykol[1] (**1**) and megatomoic acid[2] (**2**), contain a conjugated *cis,trans*-diene. The other stereoisomers are generally inactive.[3] Stereoselective syntheses of conjugated *cis,trans*-dienes or *trans*-enynes are therefore desirable. Although a stereospecific[4] method for the preparation of *trans*-enynes[5] is available, it requires a prior stereoselective[4] synthesis of the requisite alkenyl halides. A stereoselective synthesis of conjugated *cis,trans*-dienes has recently been reported.[6] However, the method appears applicable only to the synthesis of symmetrically substituted *cis,trans*-dienes. To our knowledge, there have been no stereoselective (⩾ 99%) and general methods which permit the preparation of unsymmetrically substituted conjugated *trans*-enynes or *cis,trans*-dienes.

We report here a potentially general, highly stereoselective (⩾ 99%) synthesis of conjugated *trans*-enynes which is related to the Zweifel's *cis* olefin synthesis[7] and acetylene syntheses reported recently.[8] The experimental procedures are outlined in the Scheme and the results are summarized in the Table. The development of this procedure hinges on two findings: (i) the alkynyl group reacts with iodine nearly exclusively in the presence of the alkenyl group;† (ii) the 1,2-dimethylpropyl group participates in the migration from the boron atom to the adjacent alkynyl carbon only to a minor extent (< 7%; see Table), thereby permitting the preferential coupling of the alkenyl group with the alkynyl group. The present method thus provides, for the first time, a highly stereoselective synthesis of both symmetrically and unsymmetrically substituted conjugated *trans*-enynes. G.l.p.c. examination (SE-30) of each of the reaction products listed in the Table revealed the presence of a sharp single peak (> 99%) in the region expected for the product.‡ The *trans* geometry was indicated by the i.r. (955 cm^{-1}) and ^{1}H n.m.r. spectra (J_{trans} 16 Hz). In the case of dodec-5-en-7-yne, the absence (< 1%) of the *cis* isomer was further established by g.l.p.c. using an authentic


(1)


(2)

$HC{\equiv}C[CH_2]_9OSiMe_3$

(4)

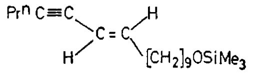

(5)

TABLE. The preparation of conjugated *trans*-enynes[a]

Enyne	Yield[b] (%)	Isomeric purity (%)	B.p. (°C) (mm)
trans-Dodec-5-en-7-yne[c]	74 (60)	>99	77—79 (1·8)
trans-1-Cyclohexyloct-1-en-3-yne[d]	71 (53)	>99	72—73 (0·15)
trans-1-Cyclohexyloct-3-en-1-yne[e]	60 (51)	>99	95—96 (0·75)

[a] The products yielded correct elemental analyses and satisfactory spectral data. [b] By g.l.p.c. (SE-30). The numbers in parentheses are isolated yields. [c] $n_D^{26.5}$ 1·4622; the yield of 2,3-dimethylnon-4-yne was 7%. [d] n_D^{25} 1·4902; the yield of 2,3-dimethylnon-4-yne was 7%. [e] $n_D^{24.5}$ 1·4969; the yield of 1-cyclohexyl-3,4-dimethylpent-1-yne was 4%.

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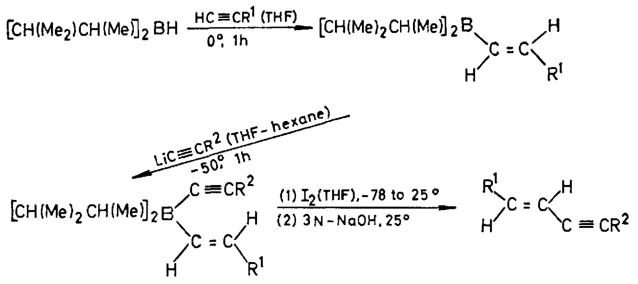
† Based on the previous results[7] the interaction of the alkenyl group with iodine would result in the formation of the *cis*-enyne rather than the *trans* isomer.

‡ In general, *cis*-enynes have shorter retention times (SF-30) than the *trans* isomers.

sample.[9] The co-distillation of boron-containing by-products with the *trans*-enynes can readily be prevented by oxidation of the reaction mixture with alkaline hydrogen peroxide before distillation.[10] Conjugated *trans*-enynes can readily be converted into the corresponding *cis,trans*-dienes by partial hydrogenation[1] or by hydroboration with bis-(1,2-dimethylpropyl)borane followed by protonolysis. Thus, the present synthesis complements the *trans,trans*-diene synthesis reported recently.[10]

In order to demonstrate the synthetic applicability of the present method, we synthesized bombykol (**1**). Undec-10-ynoic acid (**3**) was reduced with lithium aluminium hydride, and the alcohol thus obtained was converted into the trimethylsilyl ether (**4**) [74% based on (**3**)], b.p. 60—62°/0·05 mm; $n_D^{25\cdot5}$ 1·4352. The *trans*-enyne (**5**), b.p. 127—130°/0·2 mm; $n_D^{26\cdot5}$ 1·4620, was synthesized in 63% yield from (**4**) and pent-1-yne.§ A pure sample of (**5**) was converted into (**1**) by the hydroboration with an equimolar amount of bis-(1,2-dimethylpropyl)borane (0°, 1h) followed by protonolysis (isobutyric acid, reflux for 1 h after evaporation of THF) and treatment of the butyrate ester thus obtained with lithium aluminium hydride. The crude concentrated product was essentially pure (**1**). After purification by g.l.p.c. (Carbowax-20M), the identity of the product was established by comparing the spectral data, refractive index ($n_D^{26\cdot5}$ 1·4800), and g.l.p.c. retention time with those of an authentic specimen.



Scheme

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§ G.l.p.c. examination revealed the presence of several unidentified minor by-products, one of which appeared near (**5**). All these by-products were readily separable by simple fractional distillation.

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