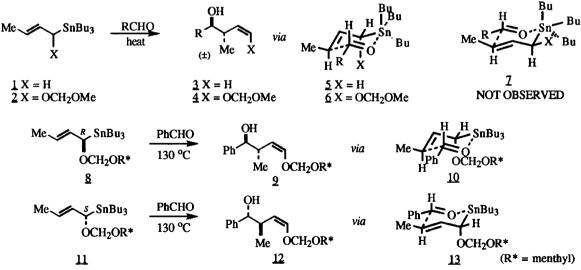# Aspects of remote asymmetric induction using allylstannanes

J. S. Carey, T. S. Coulter, D. J. Hallett, R. J. Maguire, A. H. McNeill, S. J. Stanway, A. Teerawutgulrag, and E. J. Thomas*
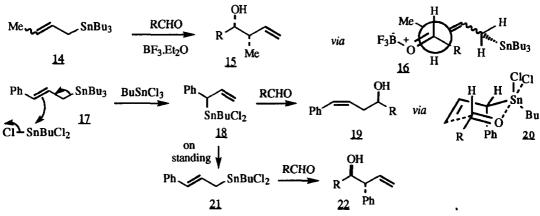
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Abstract: Transmetallation of allylstannanes with heterosubstituents at the 4-, 5- and 6-positions using tin(IV) halides generates allyltin trihalides which react with aldehydes to give homoallylic alcohols with excellent 1,5-, 1,6- and 1,7-asymmetric induction. Preliminary investigations indicate that imines prepared from butyl glyoxalate react with the allyltin trichloride prepared from 4- and 5-benzyloxypent-2-enyl-tributylstannanes with useful 1,5-asymmetric induction.
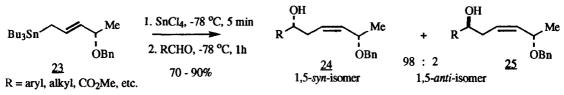
(*E*)-But-2-enyltributylstannane **1** reacts with aldehydes on heating to give *anti*-1-substituted 2-methylbut-3-enols **3** *via* concerted processes involving cyclic, chair-like, transition states **5** (1). 1-Alkoxybut-2-enyl-stannanes **2** give 4-alkoxy-1,2-*anti*-3,4-*cis*-but-3-en-1-ols **4** showing that the 1-substituent in the stannane prefers to adopt the axial position in the transition state **6** since reaction *via* transition state **7**, in which the 1-substituent is equatorial, would give rise to *trans*-alkenes, which are not observed (2). The (1*R*)- and (1*S*)-1-alkoxybut-2-enylstannanes **8** and **11** therefore react with the *Si*- and *Re*-faces of benzaldehyde to give the (1*S*,2*S*)- and (1*R*,2*R*)-products **9** and **12**, *via* transition states **10** and **13**, with excellent stereoselectivity (3).

1 X = H
2 X = OCH₂OMe

3 X = H
4 X = OCH₂OMe

5 X = H
6 X = OCH₂OMe

7
NOT OBSERVED

8

9

10

11

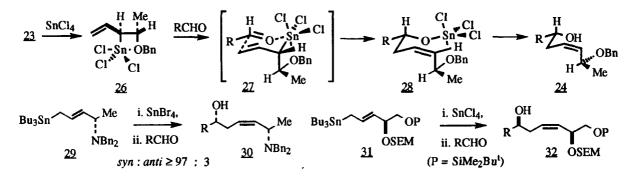**12**

13   (R* = menthyl)

In the presence of boron trifluoride diethyl etherate, both (*E*)- and (*Z*)-but-2-enylstannanes **14** react with aldehydes at -78 °C to give predominantly *syn*-products **15** *via* the open-chain process **16** in which the rate acceleration is due to co-ordination of the aldehyde by the Lewis acid (4). Other Lewis acids effect transmetallation of allylstannanes to generate more reactive allylmetal species which then react with the aldehyde. For example, treatment of 3-phenylprop-2-enylstannane **17** with butyltin trichloride generates (1-phenylprop-2-enyl)butyltin dichloride **18** which can be trapped with aldehydes to give 1-substituted (*Z*)-4-phenylbut-3-en-1-ols **19**, *via* the cyclic transition state **20** in which the 1-phenyl substituent is axial. On standing, **18** rearranges to its 3-phenyl-isomer **21** which reacts with aldehydes to give *anti*-products **22** (5).
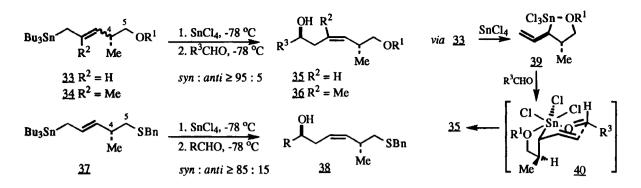
The 4-benzyloxypen-2-enylstannane 23 was found to exhibit only low diastereofacial selectivity in reactions with aldehydes at 150 °C and in the presence of boron trifluoride diethyl etherate (6). However, treatment of the stannane 23 with tin(IV) chloride followed after 5-10 min. by the addition of an aldehyde gave rise to the formation of 1-substituted *syn*-5-benzyloxy-(3Z)-hex-3-en-1-ols 24 with excellent stereoselectivity (7).
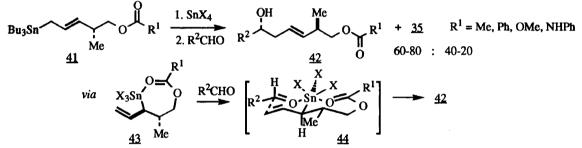

The selective formation of the 1,5-*syn*-isomer 24 is consistent with a stereoselective transmetallation of the stannane 23 to generate the allyltin trichloride 26 in which the electron deficient tin is co-ordinated to the benzyloxy substituent. This allyltin trichloride then reacts with the aldehyde *via* the cyclic, chair-like transition state 27 in which the group α to the tin is axial, *cf.* 6. This preference establishes the stereochemistry at the newly formed chiral centre relative to the chiral centre derived from the stannane and establishes the Z-geometry of the alkene (7). 1,5-*syn*-Products were also obtained with useful stereoselectivity from the 4-dibenzylamino and 4,5-disubstituted pent-2-enylstannanes 29 and 31 (8,9).
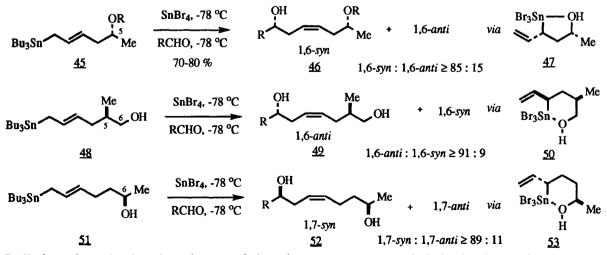

The scope of remote stereochemical control using allylstannanes with heteroatom substituents was studied. Treatment of 5-alkoxy- and 5-alkylthio-4-methylpent-2-enylstannanes 33, 34, and 37 with either tin(IV) chloride or tin(IV) bromide generated an intermediate which reacted with aldehydes with useful *anti*-1,5-stereoselectivity (10-12). This stereoselectivity was observed for 5-substituted stannanes with benzyloxy, *p*-methoxybenzyloxy, methoxymethoxy, and 2-trimethylsilylethoxymethoxy substituents and similar, albeit slightly reduced, stereoselectivity was observed for the corresponding 5-hydroxy- and 5-*tert*-butyl-dimethylsilyloxystannanes (13). The geometry of the double-bond of the stannane, particularly in the case of the 2,4-dimethylpent-2-enylstannane 34, was found to be unimportant. The stereoselectivity of these reactions is consistent with the stereoselective formation of an allyltin trihalide, e.g. 39 which reacts with aldehydes *via* the six-membered, cyclic, transition state 40 in which the group α to tin is axial and controls the facial selectivity of the reaction with the aldehyde.

Bu₃Sn OR¹ 1. SnCl₄, -78 °C OH R² via **33** Cl₃Sn-OR¹ SnCl₄

33 R² = H
34 R² = Me

syn : anti ≥ 95 : 5

35 R² = H
36 R² = Me

39 Me

R³CHO

Bu₃Sn SBn 1. SnCl₄, -78 °C OH **35** ← **40**
37 2. RCHO, -78 °C

syn : anti ≥ 85 : 15

38

In contrast, 5-acyloxypent-2-enylstannanes **41** were found to give more of the *anti*-(*E*)-hex-3-en-1-ols **42** in reactions with aldehydes promoted by either tin(IV) bromide or chloride although the stereoselectivity was not high enough to be useful. Perhaps the allyltin trihalides **43** in which the carbonyl oxygen is co-ordinated to the tin are involved. These may then react with aldehydes *via* transition states **44** in which the group α to tin is equatorial (14).

Bu₃Sn O R¹ 1. SnX₄ OH Me O R¹ + **35** R¹ = Me, Ph, OMe, NHPh
41 Me 2. R²CHO **42** O

60-80 : 40-20

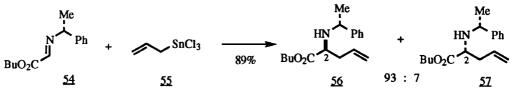*via* X₃Sn **43** Me R²CHO **44** → **42**

5-Hydroxy- and 5-methoxyhex-2-enyltributylstannanes **45** (R = H, Me) react with aldehydes after transmetallation with tin(IV) bromide to give the *syn*-1,6-products **46** (R = H, Me) with useful 1,6-asymmetric induction consistent with the participation of the allyltin tribromide **47** in which the vinyl and methyl groups are *cis* disposed about the five-membered ring (15). Lower stereoselectivities were obtained with bulkier groups on the oxygen and with tin(IV) chloride. 1,6-*anti*-Stereoselectivity was observed for the 5-methyl-6-hydroxyhex-2-enylstannane **48** and 1,7-*syn*-stereoselectivity for the 6-hydroxyhept-2-enylstannane **51** (16,17). In both cases the stereoselectivity is consistent with transmetallation of the allylstannane to generate an allyltin tribromide in which the electron deficient tin is co-ordinated by the oxygen to form a six-membered ring with both the vinyl and methyl substituents equatorial. Subsequent reaction with the aldehyde involves a chair-like transition state with the group α to tin axial.

Bu₃Sn OR SnBr₄, -78 °C OH OR + 1,6-*anti* *via* Br₃Sn—OH
45 Me RCHO, -78 °C R Me **47** Me
70-80 % 1,6-*syn* **46**

1,6-*syn* : 1,6-*anti* ≥ 85 : 15

Bu₃Sn Me OH SnBr₄, -78 °C OH Me OH + 1,6-*syn* *via* Br₃Sn Me
48 RCHO, -78 °C R 1,6-*anti* **49** **50** O H

1,6-*anti* : 1,6-*syn* ≥ 91 : 9

Bu₃Sn Me OH SnBr₄, -78 °C OH Me + 1,7-*anti* *via* Br₃Sn Me
51 RCHO, -78 °C R 1,7-*syn* OH **52** **53** O H
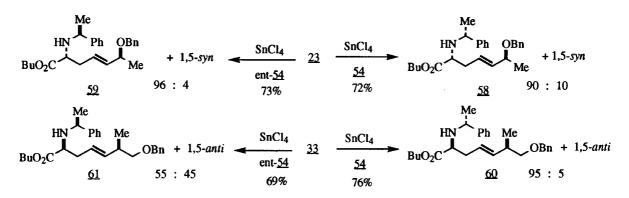
1,7-*syn* : 1,7-*anti* ≥ 89 : 11

Preliminary investigations have been carried out into remote asymmetric induction in reactions between imines and allylstannanes. Both boron trifluoride diethyl etherate and titanium(IV) chloride catalyse reactions

between imines and allylstannanes (18), but for the remote asymmetric induction it was necessary to develop conditions for reactions between allyltin trihalides and imines. Simple imines did not react with prop-2-enyltin trichloride **55** at -78 °C. However, the imine **54** prepared from butyl glyoxalate and (*R*)-1-phenylethylamine reacted with the prop-2-enyltin trichloride to give the 2-(*R*)-pentenoate **56** with excellent stereoselectivity. This selectivity is the opposite from that observed using allyl-9BBN, and establishes the intrinsic facial preference of the imine **54** in reactions with allyltin trichlorides (19).

The intermediate generated by treatment of the (4*S*)-4-benzyloxypent-2-enylstannane **23** with tin(IV) chloride reacted with both the (*R*)- and (*S*)-imines **54** and ent-**54** with excellent stereoselectivity in favour of the 1,5-*anti*-products **58** and **59** although the selectivity was slightly better when this *anti*-selectivity was matched with the intrinsic selectivity of the imine. With the 5-benzyloxy-4-methylpent-2-enylstannane **33** (R^1 = Bn; R^2 = H), this matching and mis-matching were more apparent and useful selectivity was only obtained when the 1,5-*syn*-preference of the stannane was matched with the intrinsic bias of the imine (19).

The selective formation of (*E*)-alkenes in reactions of the alkoxyallylstannanes **23** and **33** with imines contrasts with the formation of (*Z*)-alkenes in reactions with aldehydes and may be indicative of open-chain transition states, although both open-chain and cyclic processes can be devised which are consistent with both the imine facial selectivity and the 1,5-stereoselectivity. Present work is concerned with the application of this chemistry to the synthesis of complex natural products and the use of other allylmetal reagents (20).

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