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A REGIOCONTROLLED SYNTHESIS OF ALLYLSTANNANES[1]

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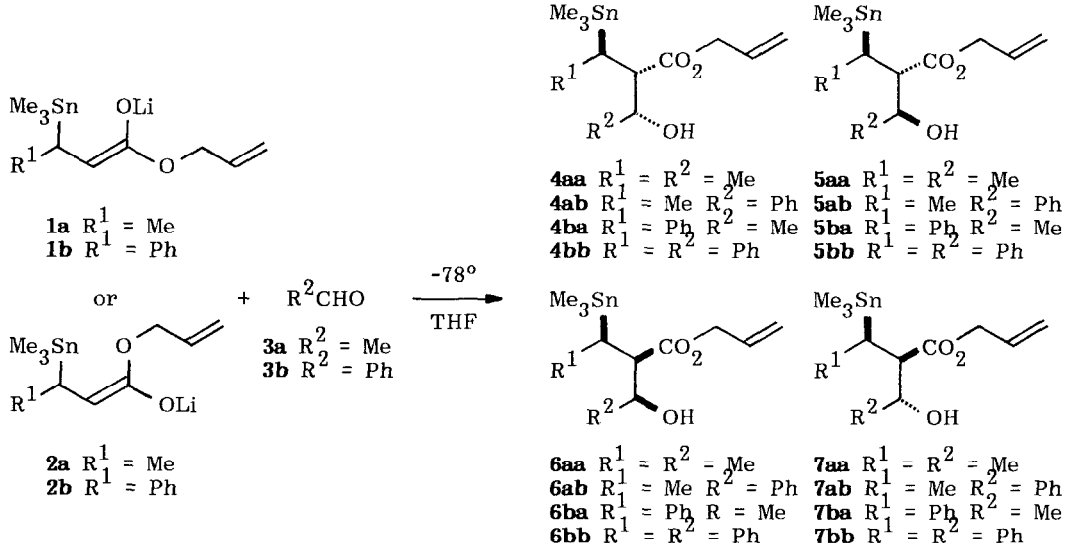
Summary Lithium β-stannylenolates react with aldehydes with moderately high stereoselectivity, and the products can be converted stereospecifically into allylstannanes with a cis or trans double bond; the allylstannanes are stable with respect to 1,3 allylic shift in non-polar solvents.

We reported recently that β-silyl enolates react with aldehydes with high stereoselectivity and that the products of these aldol reactions can be converted stereospecifically into allylsilanes.[2] We now report that the corresponding reactions in the tin series can be used to prepare unsymmetrical allylstannanes with complete regiocontrol.



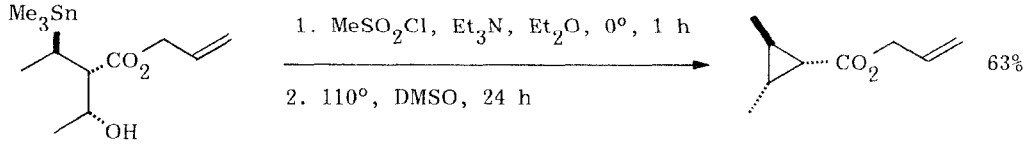
Trimethyltin-lithium[3] reacted with allyl crotonate and allyl cinnamate to give the enolates **1**, and treatment of these enolates with acetaldehyde **3a** or benzaldehyde **3b** gave the aldol products **4-7**, in the proportions shown in table 1 as those of the direct reaction. Alternatively, protonation of the enolates **1** and regeneration with lithium diisopropylamide gave the geometrically isomeric enolates **2**, and addition of acetaldehyde or benzaldehyde gave the same aldol products **4-7**, but in different proportions, shown in table 1 as those of the indirect reaction. The major products are the isomers **5** from the direct reaction and the isomers **4** from the indirect reaction.

Table 1 Diastereoselectivity in the Aldol Reaction of β-Stannylenolates

Enolate	Aldehyde	Route	Yield %	Proportions of Diastereoisomers[a] 4%	5%	6%	7%
1a	**3a**	direct	98	23[b]	54[b]	5[b]	23[b]
2a	**3a**	indirect	84	80	15[b]		
1a	**3b**	direct	84	21	57		22
2a	**3b**	indirect	98	61	39[b]		
1b	**3a**	direct	82	29[b]	58[b]		13
2b	**3a**	indirect	70	77[b]	23[b]		
1b	**3b**	direct	75	14	69[c]		17[d]
2b	**3b**	indirect	61	81	19[c]		

[a]Estimated by isolation, except where otherwise stated. [b]These isomers were not separable from each other; the proportion of each was estimated by ^{1}H NMR spectroscopy. [c]This isomer crystallised, m.p. 67-68°C. [d]This isomer crystallised, m.p. 95-96°C.

The stereochemistry of the enolates was inferred by analogy with the corresponding reactions in the silicon series and supported by the different selectivity shown in the direct and indirect reactions. The stereochemistry between C-1 and C-2 of the aldol products was likewise expected to bear a close similarity to the silicon series, since alkylation of β-stannylenolates is known to give the products of attack anti to the stannyl group.[4,5] The aldol stereochemistry between C-2 and C-3 was assigned by the conversions described below. Finally, the conversion of the aldol product **4aa** into the cyclopropane **8**, in a sequence which we have shown takes place with inversion of configuration at both the tin and hydroxyl bearing carbons,[4,6] confirms the relationship from C-1 to C-3. The stereoselectivity is noticeably less than in the silicon series, but the general trends are the same, including the somewhat greater selectivity in the indirect sequence.



4aa **8**

We purified each of the major adducts **4** and **5** free of their diastereoisomers, except for **4ba** and **5ba**, which could be purified only to the extent that the former was a 77:23 mixture with **5ba** and the latter was a 67:33 mixture with **4ba**. We converted the purified esters to the corresponding carboxylic acids **9** and **10** using the methyl-cuprate reagent,[7] and induced the anti decarboxylative elimination reaction using dimethylformamide dimethylacetal,[8] just as we had in the silicon series.[2] In this way we prepared the allylstannanes **11** and **12**, respectively, in the yields listed in table 2.

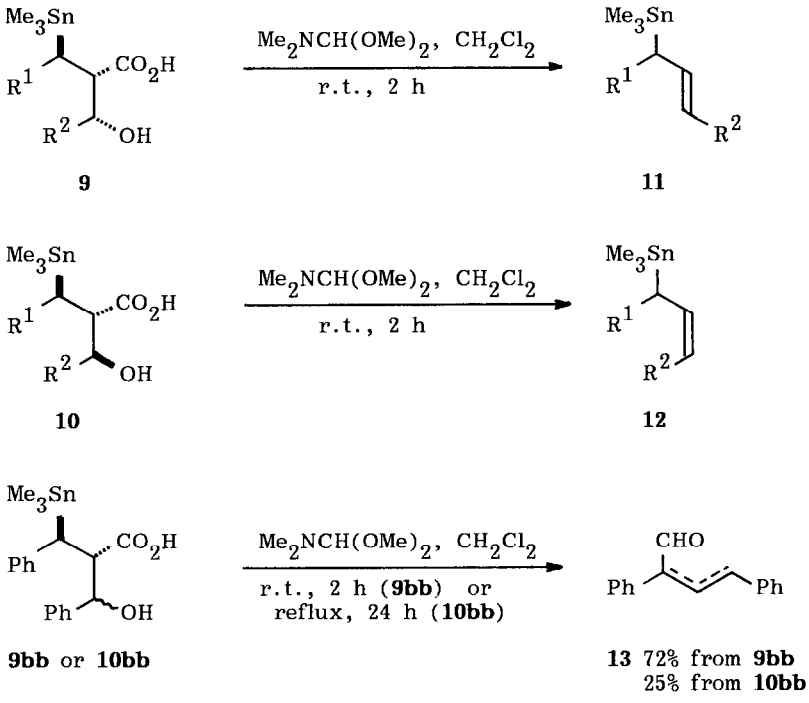


Table 2 Synthesis of Allylstannanes by anti Decarboxylative Elimination of the Aldol Products

Aldol Ester	Yield[a] %	Acid	Yield %	Allyl-stannane	Yield %
4aa	67	**9aa**	96	**11aa**	73
4ab	59[b]	**9ab**	86	**11ab**[c]	64
4ba	70[b]	**9ba**	96	**11ba**[c]	87
4bb	49	**9bb**	96	-	
5aa	52	**10aa**	92	**12aa**	78
5ab	47[d]	**10ab**	67	**11ab**[e]	41
5ba	71[d]	**10ba**	93	**12ba**[e]	68
5bb	51	**10bb**	94	-	

[a]Of pure aldol, except where otherwise stated, after chromatography of the mixture on SiO_2, eluting with EtOAc-light petroleum (b.p. 60-80°), 1:8. [b]This is still a mixture (77:23) with **5ba**. [c]This is still a mixture (76:24) with **12ba**. [d]This is still a mixture (67:33) with **4ba**. [e]This is still a mixture (68:32) with **11ba**.

In the purely aliphatic series (**aa**), the reactions were uneventful. In the purely aromatic series (**bb**), the product was a mixture of unsaturated aldehydes **13**, which presumably came from the reaction of the allylstannanes **11bb** and **12bb** with dimethylformamide dimethylacetal. In the mixed series, the hydroxyacids **9ba**, **9ab** and **10ba** were uneventful, except that the latter pair started as mixtures of diastereoisomers, and hence gave mixtures of geometrically isomeric allylstannanes in the same ratios as those of the starting materials. However,

the isomer **10ab** required heating (24 h at reflux) and gave the trans allylstannane **11ab** instead of the cis.

When we started this work, we had no certainty that the allylstannanes would be regiostable with respect to 1,3 allylic shift; indeed the likelihood was that they would not be stable to any significant extent.[9] Most of the known unsymmetrical allylstannanes have the stannyl group at a primary position, which is presumably the thermodynamically more stable position for it to be. However, a recent paper by Jephcote and Thomas[10] has shown that a stannyl group at the more substituted end of an unsymmetrical allylstannane is reasonably stable in that position in non-polar solvents. We find the same: the cis-allylstannane **12aa** is largely unchanged in refluxing deuterochloroform after 5 days, when we can expect cis-trans isomerisation to accompany any 1,3 allylic shift. In perdeuterobenzene, the half-life at reflux is about 4 days, but this is an uncharacterised decomposition rather than isomerisation. Only in deuteromethanol can we measure the half-life for cis-trans isomerisation, which is approximately 18 h at 65 ^{o}C. The presence of a phenyl group lowers the barrier to 1,3 shift: the loss of stereocontrol in the preparation of **12ab**, where we got **11ab** instead, is probably caused by 1,3 shifts, and the half-life for the conversion of **12ba** to **11ab** is approximately 24 h in deuterochloroform at room temperature.

Thus, we have a general synthesis of unsymmetrical allylstannanes, and these compounds are stable enough with respect to allylic shift to be potentially useful regiospecific carbon nucleophiles, somewhat more reactive than the corresponding allylsilanes. Finally, the synthesis of the cyclopropane **8** illustrates another application of the stereoselective aldol reactions of β-stannylenolates.

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