A Stereospecific Synthesis of Optically Active Allylsilanes†

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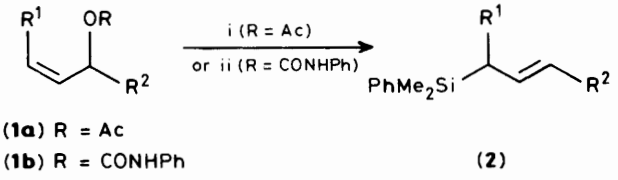
The phenyldimethylsilyl-cuprate reagent reacts with secondary allyl acetates stereospecifically *anti*, and with secondary and tertiary allyl urethanes stereospecifically *syn*; these reactions can be used to synthesise either enantiomer of an optically active allylsilane from a single enantiomer of an optically active allyl alcohol.

We reported earlier[1] that secondary allyl acetates react regiospecifically with our silyl-cuprate reagent: provided that the double bond of the allyl unit is *cis*, the silyl group is introduced with a high level of allylic rearrangement in the sense (**1a**)→(**2**). We also reported that the degree of regiospecificity is even higher when a urethane group is used (**1b**) → (**2**) and the protocol changed to a three-step sequence introduced by Goering for alkyl cuprates.[2] We now report that these reactions are stereospecifically *anti* and *syn*, respectively, and that this makes it possible for us to synthesise either enantiomer of a symmetrical or an unsymmetrical optically active allylsilane.

We expected the reaction with allyl esters to be *anti*, by analogy with our earlier work with tertiary allyl acetates,[3] and we expected the urethane reaction to be *syn* by analogy with Goering's work with alkyl cuprates.[2] These expectations are confirmed by the observations recorded in Scheme 1. The stereochemistries of the allylsilanes (**3**) and (**4**) are easily identifiable by comparison of their ^{13}C n.m.r. spectra with those reported.[4] We also checked that the tertiary allyl urethane (**5**) reacted stereospecifically *syn*: the product was the allylsilane (**6**) identical with the compound we prepared earlier.[3]

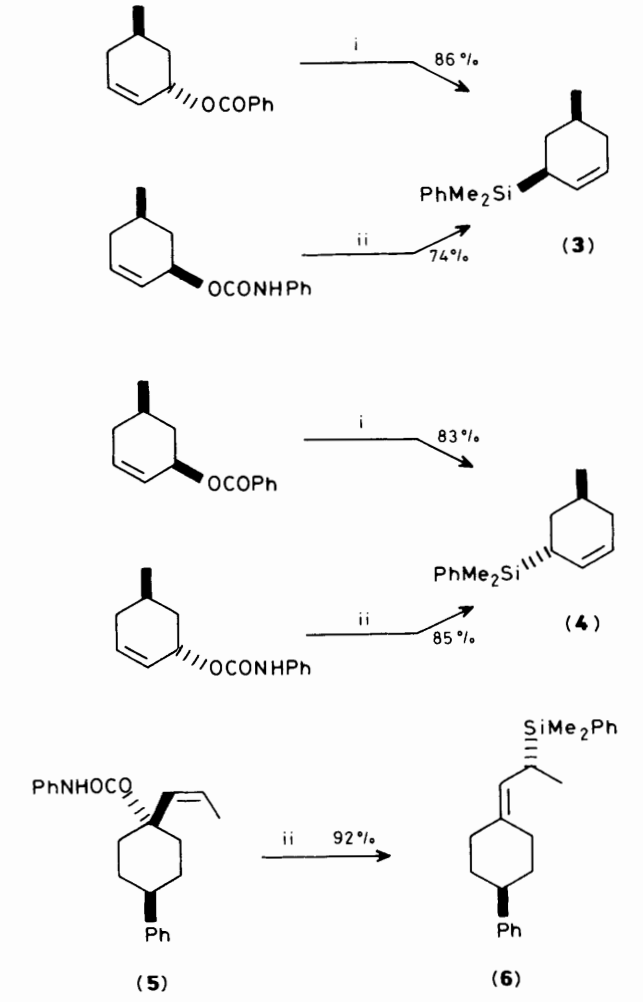
The fact that the two reactions have opposite stereochemistry makes it possible for us to prepare optically active allylsilanes in either enantiomeric series from either enantiomer of an allyl alcohol, as shown in Scheme 2. The optically active propargyl alcohol (**7**) [78% enantiomeric excess (e.e.)] was available by reduction of the corresponding acetylenic ketone using alpine borane,[5] and the conversions into the allylsilanes (**10**) + (**11**) and (**12**) took place smoothly. The former is an inseparable mixture of (*E*)- and (*Z*)-isomers (86:14), as we expected from our earlier results in the optically inactive series.[1] However, it is reasonable to assume that both isomers will have been formed stereospecifically *anti*, and the stereospecifically *anti* reaction of each with electrophiles[6] can be expected to give a single product. The fact that a mixture (**10**) + (**11**) is formed is therefore no disadvantage.[7] The enantiomeric allylsilane (**12**) is essentially pure (^1H n.m.r.).

We confirmed the stereochemistry of the allylsilanes (**10**) + (**11**) and (**12**) by reducing the double bond, converting the phenyldimethylsilyl group into a hydroxy group with retention of configuration,[8] and estimating the enantiomeric excess of the alcohols so formed [(**13**) and (**14**)] using Mosher's acid.[9] The allylsilane (**12**) straightforwardly gave (*S*)-1-phenylbutanol (**14**) of 72% e.e., indicating that the sequence of reactions from the propargyl alcohol (**7**) by way of the urethane (**9**) took place with approximately 96% *syn* stereospecificity. However, the mixture of allylsilanes (**10**) + (**11**), because (**10**) and (**11**) are of opposite chirality at the chiral centre, naturally gave (*R*)-1-phenylbutanol (**13**) of lower e.e. (52%) than the starting material. Nevertheless this value of the e.e. is in accordance with approximately 96% *anti* stereospecificity in the conversion of the propargyl alcohol (**7**) to the allylsilanes (**10**) + (**11**) by way of the benzoate (**8**). The optical purity of the enantiomeric allylsilanes can therefore be



(**1a**) R = Ac
(**1b**) R = CONHPh
(**2**)

Reagents: i, $(PhMe_2Si)_2CuLi{\cdot}LiCN$, $2PPh_3$; ii, (1): Bu^nLi, −78 °C, (2): CuI, $2PPh_3$, and (3): $PhMe_2SiLi$.



Only one enantiomer of the racemic mixture is drawn in each case.

Scheme 1. *Reagents:* i, $(PhMe_2Si)_2CuLi{\cdot}LiCN$, $2PPh_3$; ii, (1): Bu^nLi, −78 °C, (2): CuI, $2PPh_3$, and (3): $PhMe_2SiLi$.

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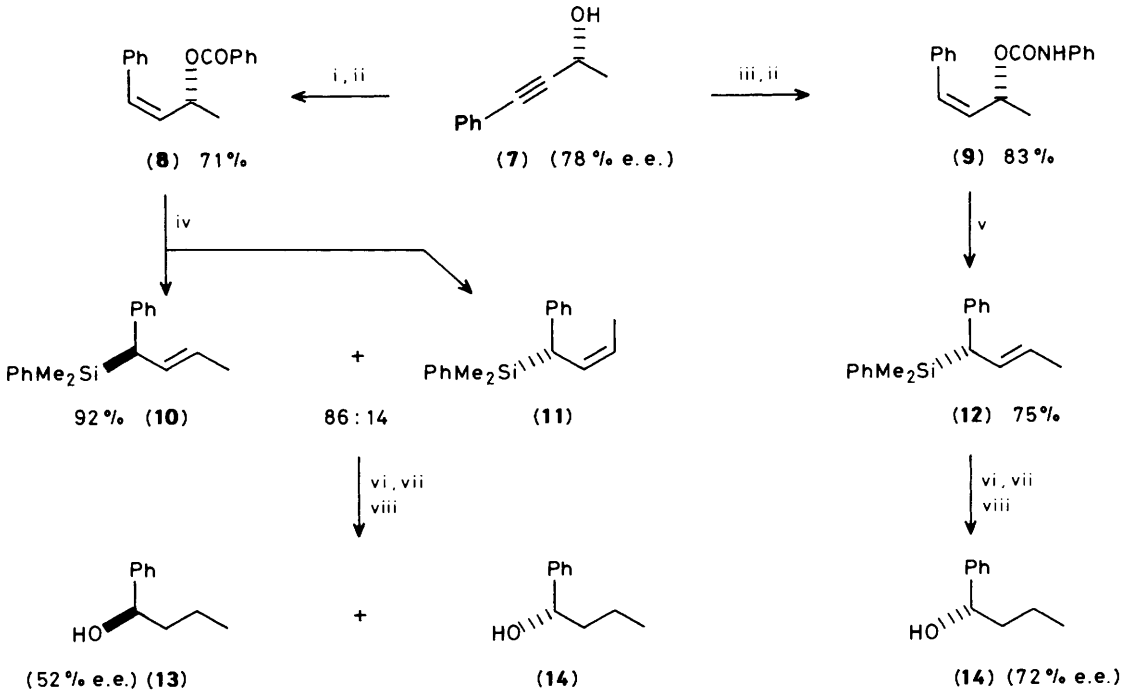

Scheme 2. *Reagents:* i, $(PhCO)_2O$, Et_3N, 4-*N*,*N*-dimethylaminopyridine (DMAP); ii, H_2/Pd/$BaSO_4$/quinoline; iii, PhNCO, Et_3N; iv, $(PhMe_2Si)_2CuLi{\cdot}CuCN$, $2PPh_3$; v, (1): Bu^nLi, −78 °C, (2): CuI, $2PPh_3$, and (3): $PhMe_2SiLi$; vi, H_2, Pd/C; vii, $BF_3{\cdot}2AcOH$; viii, *m*-chloroperbenzoic acid (MCPBA), Et_3N.

expected to reflect almost completely the optical purity of the propargyl alcohol used as starting material.

The fact that the two reactions have opposite stereochemistry is critically important to our use of allylsilanes in the control of chiral centres remote from the influence of other chiral centres, as illustrated in our synthesis of the Prelog–Djerassi lactone.[10] In that synthesis, we achieved convergence using tertiary allyl acetates and either a *cis* or *trans* double bond. Now we can be confident that convergence is possible using only the *cis* double bond and the two reactions described in this paper, one for each diastereoisomer. This means that we no longer need to use $LiAlH_4$ (to prepare the *trans* double bond from the propargyl alcohol), thus removing one of the limitations of the earlier procedure.

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