Nucleophilic Substitution at Silicon: Evidence for a Parallel with Addition Reactions to α,β Ethylenic Ketones

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Summary The relationship between the stereochemistry of nucleophilic substitution at Si–O and Si–F bonds and the electronic character of the attacking nucleophile (Bu^i_2AlH, $LiAlH_4$, $LiAlH_4$–4CuI, EtLi, EtMgBr, and $Et_2CuMgBr$) has been studied; those reagents which favour 1,2-addition to α-enones react with retention of configuration, whereas those which favour 1,4-addition to α-enones react with inversion.

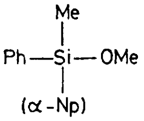
Coupling reactions of various organometallic reagents (RLi, RMgX, RNa, $LiAlH_4$) with optically active silicon compounds have been studied previously;[1,2] it was shown that the stereochemistry of nucleophilic substitutions at silicon depends on the electronic character of the nucleophile.

This hypothesis was confirmed by comparing the behaviour of some nucleophilic reagents in addition reactions with α-enones and in substitution reactions at silicon. Compounds (**1**),[1] (**2**),[2e] and (**3**)[2a] were used in this study. The results are summarized in Tables 1—3.

Table 1. Attack by nucleophiles on compound (**1**).

Nucleophile	Solvent	[α]$_D$ of product	Inversion or retention
Bu^i_2AlH[b]	Hexane	+34°	100% retn.
$LiAlH_4$[c]	Et_2O	+30°	94% retn.
$LiAlH_4$—4CuI	THF[d]	−4°	55% inv.

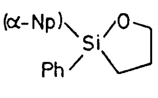
[a] The product in all cases was MePh(α-Np)SiH. [b] See ref. 3. [c] See ref. 1. [d] THF = tetrahydrofuran.



$Ph{-}Si(Me)(\alpha\text{-}Np){-}OMe$

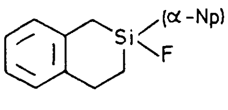
(1)

$[\alpha]_D = +16°$



(2)

$[\alpha]_D = -16°$



(3)

$[\alpha]_D = +34°$

Table 2. Attack by nucleophiles on compound (**2**).

Nucleophile	Solvent	[α]$_D$ of product	Inversion or retention[b]
Bu^i_2AlH	Hexane	+19°	Retn.
$LiAlH_4$	Et_2O	+13°	Retn.
$LiAlH_4$– 4CuI	THF	−18°	Inv.

[a] The product in all cases was $Ph(\alpha\text{-}Np)(H)Si[CH_2]_3OH$. [b] Compound (**2**) is a liquid and has not been obtained optically pure, so its maximum [α]$_D$ value is not known. Hence, % retention or inversion values cannot be given.

In all cases, those reagents (Bu^i_2AlH,[5] $LiAlH_4$,[6] RLi[7] RMgBr,[8]) which favour 1,2 addition to α-enones (charge-controlled process[9]) react with retention of configuration at

R_3Si =

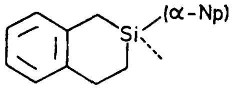


Table 3. Attack by nucleophiles on compound (**3**).

Nucleophile	Solvent	[α]$_D$ of product	Inversion or retention
Bu^i_2AlH	Hexane	+21°[a]	100% retn.
$LiAlH_4$[b]	Et_2O	0°[a]	Racemic
$LiAlH_4$-4CuI	THF	−16°[a]	80% inv.
EtLi[c]	Et_2O	+114°[d]	96% retn.
EtMgBr[e]	Et_2O	+27°[d]	61% retn.
$Et_2CuMgBr$	Et_2O	−84°[d]	84% inv.

[a] Product was R_3SiH. [b] See ref. 4. [c] See ref. 2b. [d] Product was R_3SiEt. [e] See ref. 2a.

silicon, whereas those reagents ($LiAlH_4$—4CuI,[10] R_2CuMgX[11]) which give predominant 1,4 addition (frontier-orbital controlled process[9]) react with inversion of configuration.† These results agree with our hypothesis on the change of stereochemistry with change in the electronic character of the attacking nucleophile with the same silane; hard nucleophiles prefer to attack equatorially at silicon according to a charge-controlled process, and softer reagents axially according to a frontier-orbital controlled process.

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† Cyclopent-2-enone undergoes 99% 1,2-addition with Bu^i_2AlH (ref. 5), 63% 1,2-addition with $LiAlH_4$ (ref. 6), and does not react with $LiAlH_4$-4CuI; PhCH=CHCOMe undergoes 100% 1,2-addition with Bu^i_2AlH and $LiAlH_4$, and 100% 1,4-addition with $LiAlH_4$–4CuI.

[1] L. H. Sommer, 'Stereochemistry, Mechanism and Silicon', McGraw Hill, New York, 1965.

[2] (a) R. Corriu and J. Massé, *J. Organometallic Chem.*, 1972, **35**, 5; (b) *ibid.*, 1972, **34**, 221; (c) R. Corriu and G. Lanneau, *Bull. Soc. chim. France*, 1973, 303; (d) R. Corriu and G. Royo, *ibid.*, 1972, 1490; (e) R. Corriu, C. Guérin, and J. Massé, *J. C. S. Chem. Comm.*, 1975, 75.

[3] L. H. Sommer, J. McLick, and C. M. Golino, *J. Amer. Chem. Soc.*, 1972, **94**, 669.

[4] R. Corriu and J. Massé, *Bull. Soc. chim. France*, 1969, 3491.

[5] K. E. Wilson, R. T. Seidner, and S. Masamune, *Chem. Comm.*, 1970, 213.

[6] H. C. Brown and H. M. Hess, *J. Org. Chem.*, 1969, **34**, 2206.

[7] T. Eicher, 'The Chemistry of Carbonyl Compounds', Ed. S. Patai, Interscience, New York, 1966, pp. 624–631.

[8] M. S. Karasch and O. Reinmuth, 'Grignard Reactions of Nonmetallic Substances', Prentice-Hall, Englewood Cliffs, New Jersey, 1954, pp. 196—239; H. O. House and W. F. Fisher, *J. Org. Chem.*, 1968, **33**, 949.

[9] O. Eisenstein, J. M. Lefour, C. Minot, N. T. Anh, and G. Soussan, *Compt. rend.* (*C*), 1972, **274**, 1310.

[10] E. C. Ashby, J. J. Lin, and R. Kovar, *J. Org. Chem.*, 1976, **41**, 1939.

[11] H. Rivière and P. W. Tang, *Bull. Soc. chim. France*, 1973, 2455.