Switching of the Reaction Pathway for [1,2]/[1,4]- and [2,3]-Wittig Rearrangements of 3-Aryl-2-propenyl Propargyl Ethers

Kenji Hayakawa, Ayumi Hayashida, and Ken Kanematsu*

Institute of Synthetic Organic Chemistry, Faculty of Pharmaceutical Sciences, Kyushu University 62, Maidashi, Higashi-ku, Fukuoka 812, Japan

3-Aryl-2-propenyl propargyl ethers (1) undergo the [1,2] (and [1,4]) sigmatropic rearrangement periselectively on treatment with Bu^{n}Li at $-78\,^{\circ}$C, whereas the silylated derivatives (2) perform exclusively the [2,3]-Wittig rearrangement.

The sigmatropic rearrangements of α-metallated allyl ethers (the Wittig rearrangements)[1] are of current interest for their versatile applications to organic synthesis.[2—5] However, in contrast to the well-documented synthetic utility of the [2,3]-Wittig rearrangement,[2—4] the [1,2]-Wittig rearrangement has gained less attention due to the general lower yields of this reaction.[5] The control elements of the periselectivity of these anionic rearrangements also need to be investigated. Herein, we report on a highly periselective anionic [1,2]/[1,4]-sigmatropic rearrangement of 3-aryl-2-propenyl propargyl ethers (1) as well as a remarkable effect of the silyl-substituent for switching of reaction pathway.

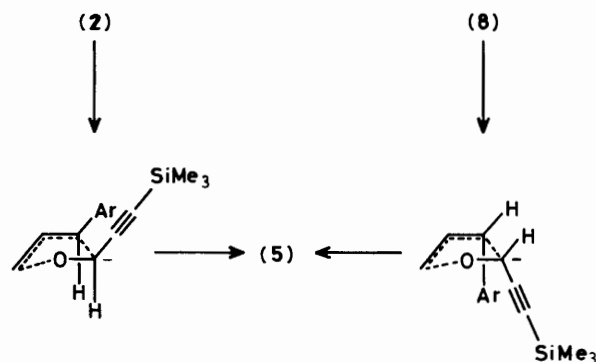During the course of our studies on the base-catalysed pericyclic reactions of various propargyl ethers,[6] we found an efficient sigmatropic rearrangement of the dianions of 3-aryl-2-propenyl propargyl ethers (1; R = aromatic) with unusual periselectivity, *i.e.* it only underwent the [1,2] (and [1,4]) sigmatropic rearrangement, although the [2,3] sigmatropic rearrangement is much more common to this class of compound, *e.g.* (1; R = H or alkyl).[3,7] Thus, treatment of
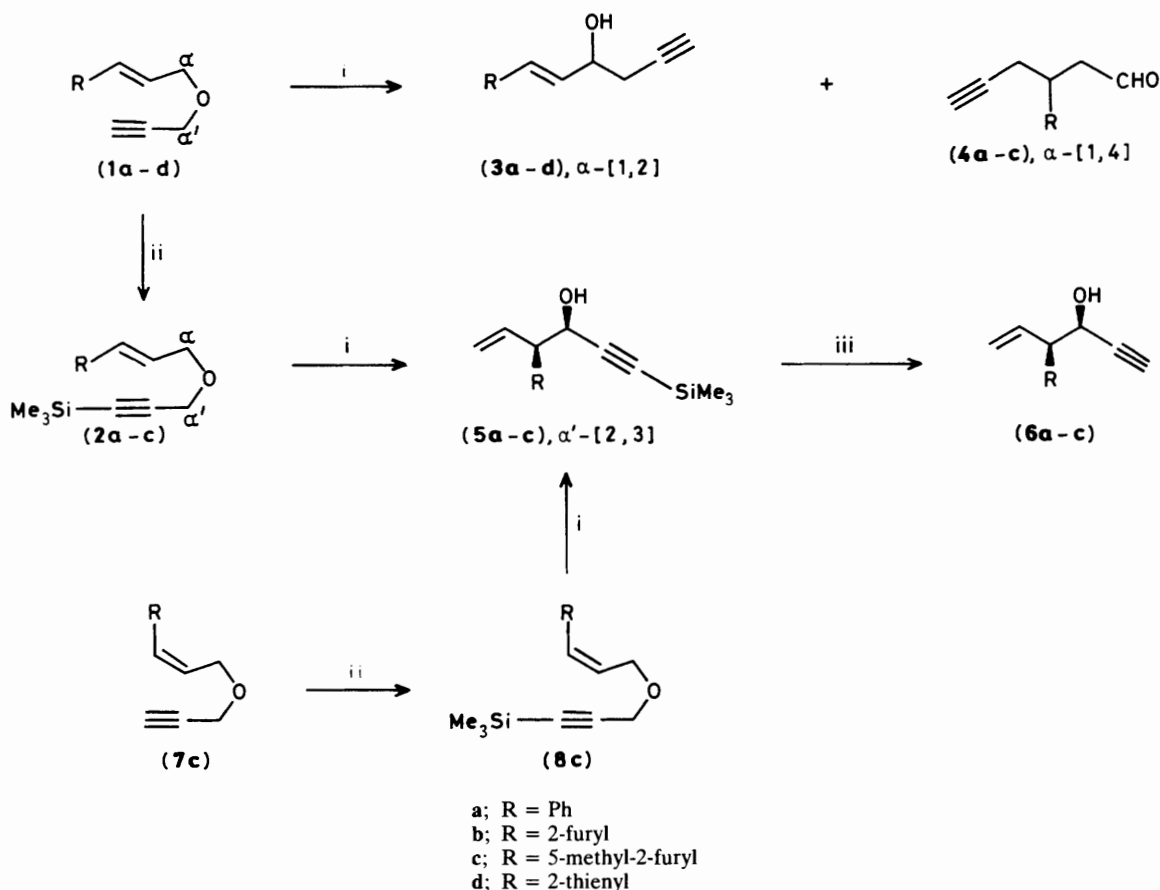
Scheme 1. *Reagents and conditions*: i, Bu^{n}Li (2.3 equiv.), THF, −78 °C; ii, Bu^{n}Li (1.0 equiv.), THF, −78 °C, then chlorotrimethyl-silane (3.0 equiv.); iii, CsF, MeOH–H$_2$O (9:1), room temp.

(E)-cinnamyl propargyl ether (1a) with 2.3 equiv. of Bu^{n}Li in tetrahydrofuran (THF) at −78 °C resulted in a rapid reaction to give the [1,2] rearrangement product (3a) (67%)† and the [1,4] rearrangement product (4a) (13%)† (Scheme 1). Both sigmatropic rearrangements were considered to arise from the α-lithiated (1a) (α-[1,2] and α-[1,4]) presumably due to the increased stabilization of the α-carbanion through conjugation with the aromatic ring. Similarly, (E)-ethers (1b—d) and the (Z)-ether (7c), prepared from (E)-3-(5-methyl-2-furyl)acrylate by photochemical *trans/cis* isomerization, followed by LiAlH$_4$ reduction and propargylation, only underwent the α-[1,2] (and α-[1,4]) sigmatropic rearrangements (Table 1).

In sharp contrast, the similar base-treatment of the silylated (E)-ethers (2a—c), prepared from (1a—c) [Bu^{n}Li (1 equiv.), Me$_3$SiCl, −78 °C], resulted in exclusively the α'-[2,3] sigma-tropic rearrangement in a high degree of *erythro* selectivity

---

† All new compounds gave satisfactory analytical and spectral data. For example, (3a): i.r. ν_{max} 3380, 3280, 2160 cm^{-1}; ^{1}H n.m.r. δ (CDCl$_3$) 6.64 (d, *J* 16.0 Hz, 1H), 6.20 (dd, *J* 16.0, 6.0 Hz, 1H), 4.40 (m, 1H), 2.49 (dd, *J* 6.0, 3.0 Hz, 2H), 2.05 (t, *J* 3.0 Hz, 1H).

(4a): i.r. ν_{max} 3280, 2360, and 1730 cm^{-1}; ^{1}H n.m.r. δ 9.71 (t, *J* 1.5 Hz, 1H), 3.47 (m, 1H), 2.91 (m, 2H), 2.53 (dd, *J* 6.5, 3.0 Hz, 2H), 2.00 (t, *J* 3.0 Hz, 1H).

(6a): i.r. ν_{max} 3400, 3280, and 2100 cm^{-1}; ^{1}H n.m.r. δ 6.18 (ddd, *J* 17.9, 10.4, 8.2 Hz, 1H), 5.27 (dm, *J* 10.4 Hz, 1H), 5.23 (dm, *J* 17.9 Hz, 1H), 4.59 (dd, *J* 6.5, 2.1 Hz, 1H), 3.60 (dd, *J* 8.2, 6.5 Hz, 1H), 2.44 (d, *J* 2.1 Hz, 1H), 2.09 (br s, D$_2$O-exchange, 1H); high resolution mass spectrum for C$_{12}$H$_{12}$O calc. *m/z* 172.0888, found 172.0914.

Scheme 2

(>95%, 270 MHz ^{1}H n.m.r.)[8]‡ to give (5a—c)† in good yields (Table 1). Interestingly, the (Z)-ether (8c), prepared from (7c), also underwent the *erythro*-selective α'-[2,3] sigmatropic rearrangement to give the same product as (E)-(2c) [(5c)] (Scheme 1), suggesting a preference for the *cis*-relationship of the aromatic ring and propargyl group in the α'-[2,3] transition

---

‡ It is well established that the proton of *erythro* isomers attached to the C–OH group in 2-alkyl-3-hydroxycarbonyl compounds resonates at lower fields than those in *threo* isomers. In addition, the coupling constants (*J ca.* 3.0—6.5 Hz) of the *erythro* isomers appear smaller than those in the *threo* isomers (*J ca.* 7.0—9.0 Hz).

Table 1. Bu^nLi catalysed rearrangement of (1), (2), (7), and (8).[a]

Compound	Product, % Yield[b]		
	(3), [1,2]	(4), [1,4]	(5),[c] [2,3]
(1a)	67	13	
(1b)	64	16	
(1c)	54	22	
(1d)[d]	19	—	
(2a)			85
(2b)			53
(2c)			62
(7c)	67[e]	12	
(8c)			73

[a] All reactions were carried out in THF at $-78\,^\circ C$ using 2.3 equiv. of Bu^nLi (30 min—1 h). [b] Isolated yields. [c] 95% *Erythro* by the 270 MHz ^1H n.m.r. analysis. [d] A large amount of the starting material (~70%) was recovered unchanged, even with 3 equiv. of Bu^nLi. [e] $E/Z = 2:1$.

states regardless of the alkene geometry of the starting materials (Scheme 2). The clean-cut change of persiselectivity between (1) [or (7)] and (2) [or (8)] may be mainly attributed to the α'-carbanion stabilizing effect (vinylagous α-effect) of silicon in (2) and (8), since the similar reaction of 2-butynyl (E)-3-(5-methyl-2-furyl)-propenyl ether gave a 1:2 mixture of α-[1,2] and α'-[2,3] rearrangement products.

Desilylation (CsF, $MeOH-H_2O$, r.t.) of (5a—c) afforded almost quantitative yields of (6a—c),† a formal α'-[2,3] sigmatropic rearrangement product of (1) (Scheme 1).

The above results provide a new method to control periselectivity in the base-catalysed sigmatropic rearrange-ments of (1). Indeed, the [1,2] products thus obtained may serve as the useful synthetic intermediates for the synthesis of the natural product secofuranoeremophilane.[9]

References

1 V. Scholkopf, *Angew. Chem., Int. Ed. Engl.*, 1970, **9**, 763; T. Nakai and K. Mikami, *Chem. Rev.*, 1986, **86**, 885.

2 W. C. Still and A. Mitra, *J. Am. Chem. Soc.*, 1978, **100**, 1927; W. C. Still, J. H. McDonald, III, D. B. Collum, and A. Mitra, *Tetrahedron Lett.*, 1979, 593.

3 T. Nakai, K. Mikami, S. Taya, and Y. Fujita, *J. Am. Chem. Soc.*, 1981, **103**, 6492; K. Mikami, S. Taya, Y. Fujita, and T. Nakai, *J. Org. Chem.*, 1981, **46**, 5447.

4 J. A. Marshall, J. Lebreton, B. S. Dettoff, and T. M. Jenson, *Tetrahedron Lett.*, 1987, **28**, 723; J. A. Marshall and J. Lebreton, *ibid.*, p. 3323.

5 V. Rautenstrauch, G. Buchi, and H. Wuest, *J. Am. Chem. Soc.*, 1974, **96**, 2576; B. H. Lee, A. Biswas, and M. J. Miller, *J. Org. Chem.*, 1986, **51**, 106; S. L. Schreiber and M. T. Goulet, *Tetrahedron Lett.*, 1987, **28**, 1043.

6 K. Hayakawa, M. Yodo, S. Ohsuki, and K. Kanematsu, *J. Am. Chem. Soc.*, 1984, **106**, 6735; K. Hayakawa, Y. Yamaguchi, and K. Kanematsu, *Tetrahedron Lett.*, 1985, **26**, 2689; Y. Yamaguchi, K. Hayakawa, and K. Kanematsu, *J. Chem. Soc., Chem. Commun.*, 1987, 515.

7 N. Sayo, F. Shirai, and T. Nakai, *Chem. Lett.*, 1984, 255; K. Mikami, T. Maeda, and T. Nakai, *Tetrahedron Lett.*, 1986, **27**, 4189.

8 C. H. Heathcock, C. T. Buse, W. A. Kleschick, M. C. Pirrung, J. E. Sohn, and J. Lampe, *J. Org. Chem.*, 1980, **45**, 1066.

9 K. Hayakawa, F. Nagatsugi, and K. Kanematsu, *J. Org. Chem.*, 1988, **53**, 860.