

A SILYL-FUNCTIONALIZED ALKYL AZIDE, TRIMETHYLSILYLMETHYL AZIDE;
SYNTHESIS AND CYCLOADDITION REACTION TO ACETYLENIC DIPOLAROPHILES

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Thermally stable trimethylsilylmethyl azide was first synthesized from the reaction of chloromethyltrimethylsilane with sodium azide. Its use as an α -functionalized synthetic equivalent of methyl azide was demonstrated in the reaction with acetylenic dipolarophiles and the subsequent reaction of the cycloadducts with aldehydes and water in the presence of fluoride ion.

Some of fundamental organic molecules which are often gaseous, low-boiling, explosive, or toxic materials have been discouraged to be employed in organic synthesis because of their troublesome handling. As well known, the silylation of such hazardous chemicals as hydrogen cyanide, hydrazoic acid, diazomethane, etc. leads to versatile and easy-to-handle reagents (Me_3SiCN , Me_3SiN_3 , $\text{Me}_3\text{Si-CH=N}_2$, etc.) whose synthetic utility in organic synthesis has been widely achieved.¹⁾

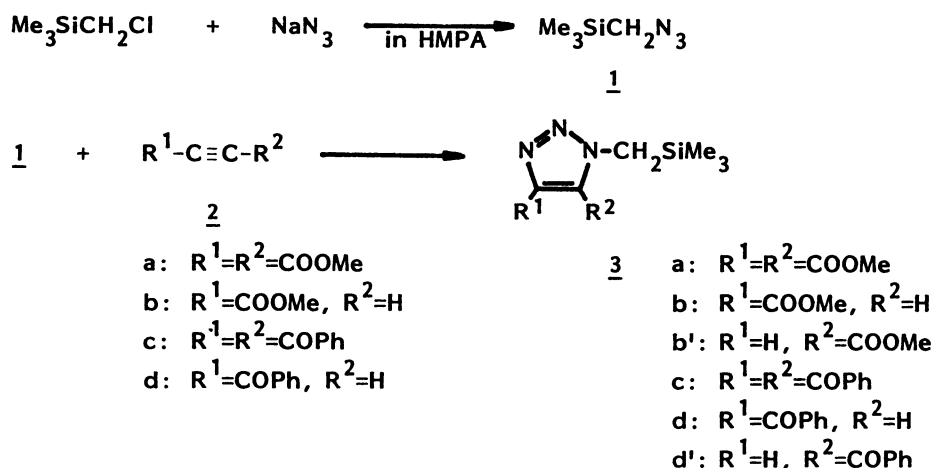
Trimethylsilylmethyl azide 1 is a silylated derivative of the simplest alkyl azide, methyl azide, that is a low-boiling (bp 20 °C at an ordinary pressure) and an explosive material.²⁾ Because of its hazardous nature, it is not surprising that the use of methyl azide in organic synthesis is rather limited.³⁾ The silyl moiety of 1 not only contributes to its thermal stability but also offers another functionality onto the α -carbon of methyl azide. It would be possible to introduce an electrophilic substituent at the α -carbon of 1 before or after its use in reactions.⁴⁾

In the present communication, we would like to report the first synthesis of thermally stable trimethylsilylmethyl azide 1 and its use as an α -functionalized synthetic equivalent of methyl azide in the cycloaddition reaction to acetylenic dipolarophiles and the subsequent reaction of the cycloadducts with several aldehydes and water in the presence of fluoride ion.

Synthesis of Trimethylsilylmethyl Azide 1. The reaction of chloromethyltrimethylsilane (0.1 mol) with sodium cyanide (0.11 mol) in hexamethylphosphoric triamide (HMPA, 30 ml) at 80 °C for 12 h, and the followed distillation under vacuum gave a colorless liquid of 1, bp 58-61 °C/80 mmHg, in 95 % yield. The IR spectrum shows characteristic absorption bands at 2100 (CN), 1250, and 850 cm^{-1} (Me_3Si) and the $^1\text{H-NMR}$ spectrum exhibits two singlet signals at 0.22 (9H, Me_3Si) and 2.82 ppm (2H, CH_2).

The silylated methyl azide 1 was found, as expected, stable enough to be handled without serious explosion.⁵⁾ When treated with lithium diisopropylamide, tetrabutylammonium fluoride, or triphenylphosphine, 1 gently decomposed with an evolution of nitrogen gas.⁶⁾

Cycloaddition Reaction of 1 with Acetylenic Dipolarophiles 2. The reaction of 1 with dimethyl



Scheme 1

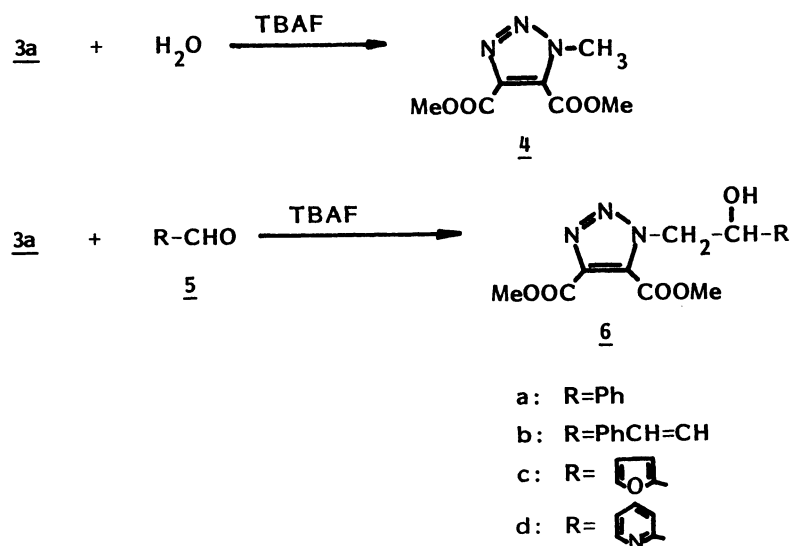
acetylenedicarboxylate 2a in benzene under reflux for 2 h gave the [3 + 2] cycloadduct 3a in a quantitative yield. Dibenzoylacetylene 2c afforded a similar cycloadduct 3c. Their structures were assigned as the 1(H)-trimethylsilylmethyltriazoles on the basis of the spectral data listed in Table 1.

In the reaction with such unsymmetrically substituted acetylenic dipolarophiles as methyl propiolate 2b and benzoylacetylene 2d, each two regioisomeric [3 + 2] cycloadducts 3b, 3b' and 3d, 3d' were obtained, respectively, also in quantitative yields. The regiochemistry was determined on the ground of the ^{13}C -NMR spectra in which the major products 3b and 3d showed the doublets of olefinic carbons upfield of those of the minor products 3b' and 3d' (Table 1).

Table 1. 1(H)-Trimethylsilylmethyltriazoles 3.

<u>3</u>	Yield (%)	mp (°C)	IR (cm ⁻¹)		MS (m/e) M ⁺					
			C=O	SiMe ₃						
<u>3a</u>	100	liquid	1730, 1720	1250, 850	271					
<u>3b</u>	100 {	76	80-81	1720	1240, 840	213				
<u>3b'</u>		24	69-71	1730	1250, 850	213				
<u>3c</u>	100	89-90	1670, 1630	1250, 850	363					
<u>3d</u>	99 {	71	79-80	1630	1240, 840	259				
<u>3d'</u>		28	liquid	1650	1240, 850	259				
<u>3</u>	¹ H-NMR (δ, ppm)				¹³ C-NMR (δ, ppm)					
	SiMe ₃	CH ₂	4-R ¹	5-R ²	SiMe ₃	CH ₂	4-C	5-C	Substituents (4-R ¹ , 5-R ²)	
<u>3a</u>	0.12s	4.13s	3.91s	3.94s	-2.47q	41.98t	139.32s	129.87s	52.55q, 53.29q (Me) 159.39s, 160.57s (CO)	
<u>3b</u>	0.15s	3.97s	3.89s	7.95s	-2.58q	42.44t	139.56s	127.82d	51.95q (Me), 161.25s (CO)	
<u>3b'</u>	0.12s	4.32s	8.01s	3.98s	-2.41q	41.80t	137.38d	127.46s	52.25q (Me), 159.28s (CO)	
<u>3c</u>	0.16s	3.85s	-	-						
<u>3d</u>	0.16s	3.95s	-	8.11s	-2.58q	42.25t	147.70s	128.84d	185.51s (CO)	
<u>3d'</u>	0.19s	4.38s	7.90s	-	-2.29q	41.91t	138.59d	132.98s	184.40s (CO)	

Substitution Reaction of 1(H)-Trimethylsilylmethyltriazoles 3. The 1(H)-trimethylsilylmethyltriazoles 3 can be regarded as the silyl-functionalized derivatives of 1(H)-methyltriazoles that are the corresponding cycloadducts of methyl azide, while few examples have been reported so far for the fluoride-induced substitution reaction of non-activated alkylsilane.⁷⁾ Some fluoride-induced reactions of the cycloadducts 3 were investigated by employing 3a and tetrabutylammonium fluoride (TBAF).



Scheme 2

A quantitative desilylation of 3a was achieved in the reaction of 3a in wet tetrahydrofuran (THF) in the presence of 10 mol % of TBAF (-78 °C and then room temperature for 12 h) giving 4.

The reaction of 3a with benzaldehyde in dry THF under nitrogen in the presence of TBAF (-78 °C and then room temperature for 15 h) gave a colorless liquid of 6a in a good yield. The structure of 6a was assigned as dimethyl 1(H)-(2-hydroxy-2-phenylethyl)triazole-4,5-dicarboxylate on the basis of the spectral data shown in Table 2.⁸⁾ The similar products 6b, 6c, and 6d were obtained, under the same conditions, in the reactions with cinnamaldehyde 5b, furfural 5c, and pyridine-2-carboxaldehyde 5d, respectively, in satisfied yields. The results are listed in Table 2.

All the new compounds obtained in this communication gave the satisfactory values of elementary analysis.

Table 2. 1-Substituted 1H-Triazoles 4 and 6.

Yield (%)	mp (°C)	IR (cm ⁻¹)		MS (m/e) M ⁺	¹ H-NMR (in CDCl ₃ , δ ppm)					
		OH	C=O		COOMe	OH	CH ₂	CH	others	
<u>4</u>	99	55-56	-	1730, 1720	199	3.94s, 3.87s	-	-	-	4.23s (NMe)
<u>6a</u>	77	liquid	3450	1730, 1720	305	3.82s, 3.86s	3.60br	4.72d	5.08t	7.25s (Ph)
<u>6b</u>	82	liquid	3420	1730, 1720	331	3.86s	3.33br	4.70br		6.08br, 6.58d (CH=CHPh)
<u>6c</u>	82	liquid	3400	1730, 1720	295	3.84s, 3.88s	3.38br	4.87d	5.08t	6.22m, 7.28m (2-furyl)
<u>6d</u>	83	liquid	3310	1730, 1720	306	3.87s, 3.92s	4.50br	4.7-5.3m		7.1-7.8m, 8.40m (2-pyridyl)

These results indicate that the azide 1 can be used as a thermally stable synthetic equivalent of methyl azide and also as an α -functionalized methyl azide.

References

- 1) As the recent reviews: I. Fleming, "Organic Silicon Chemistry," in "Comprehensive Organic Chemistry," ed by D. H. R. Barton and W. D. Ollis, Pergamon, Oxford (1979), Vol. 3, p. 539; W. C. Groutas and D. Felker, *Synthesis*, **1980**, 861; E. W. Colvin, "Silicon in Organic Synthesis," Butterworth, London (1981); W. P. Weber, "Silicon Reagents for Organic Synthesis," Springer-Verlag, Heidelberg (1983).
- 2) It has been reported that methyl azide explodes when treated with dimethyl malonate and sodium methoxide (Ch. Grundmann and H. Haldenwanger, *Angew. Chem.*, **62**, 410 (1950)) or irradiated in the presence of mercury (C. L. Currie and B. deB. Darwent, *Can. J. Chem.*, **41**, 1048 (1963)).
- 3) Methyl azide has been used in the following reactions most of which were carried out at room temperature or below, sometimes in the dark: G. P. Siuta, R. W. Franck, and R. P. Kempton, *J. Org. Chem.*, **39**, 3739 (1974); H. Quast and L. Bieber, *Tetrahedron Lett.*, **1976**, 1485; M. Regitz, W. Welter, and A. Hartmann, *Chem. Ber.*, **112**, 2509 (1979); M. S. Ouali, M. Vaultier, and R. Carrie, *Tetrahedron*, **36**, 1821 (1980).
- 4) The reaction of 1 with electrophiles in the presence of bases or fluoride ion is not described in the present communication. The results will be reported soon. See Ref. 6.
- 5) The azide 1 can be safely heated in refluxing toluene. It does not explode but burns bright when ignited or touched to a red-hot copper.
- 6) The reaction of 1 with benzaldehyde or benzophenone in the presence of lithium diisopropylamide afforded benzyl alcohol or diphenylmethanol, respectively, in good yields. On the other hand, 1 reacted with benzaldehyde and triphenylphosphine to give benzylidene(trimethylsilylmethyl)-amine in a quantitative yield.
- 7) Some examples for the fluoride-induced reaction of activated alkylsilanes such as allylsilane, benzylsilane, and α -silylacetate have been reported: E. Nakamura, M. Shimizu, and I. Kuwajima, *Tetrahedron Lett.*, **1976**, 1699; A. Hosomi, A. Shirahata, and H. Sakurai, *ibid.*, **1978**, 3043; A. Ricci, A. Degl'innocenti, M. Fiorenza, M. Taddei, and M. A. Spartera, *ibid.*, **1982**, 577.
- 8) The ^{13}C -NMR spectra of 4 and 6 are given as follows:
 - 4: 37.52 (q, N-Me), 52.68, 53.36 (each q, OMe), 130.06 (s, 5-C), 140.05 (s, 4-C), 158.71, and 160.42 ppm (each s, CO).
 - 6a: 52.49, 53.19 (each q, OMe), 56.54 (t, CH_2), 72.39 (d, CH), 131.16 (s, 5-C), 139.73 (s, 4-C), 158.87, and 160.10 ppm (each s, CO).
 - 6b: 52.60, 53.31 (each q, OMe), 55.19 (t, CH_2), 71.22 (d, CH), 126.99 (d, CH=), 131.39 (s, 5-C), 132.62 (d, =CHPh), 139.08 (s, 4-C), 159.16, and 160.28 ppm (each s, CO).
 - 6c: 53.42, 54.24 (each q, OMe), 54.77 (t, CH_2), 67.24 (d, CH), 108.48, 109.01 (each d, furyl), 132.42 (s, 5-C), 139.95 (s, 4-C), 143.60 (d, furyl), 153.37 (s, furyl), 159.89, and 161.25 ppm (each s, CO).
 - 6d: 52.55, 53.37 (each q, OMe), 55.60 (t, CH_2), 71.74 (d, CH), 131.75 (s, 5-C), 138.91 (s, 4-C), 148.54 (d, pyridyl), 157.64 (s, pyridyl), 159.16, and 160.22 ppm (each s, CO).

(Received May 11, 1983)