

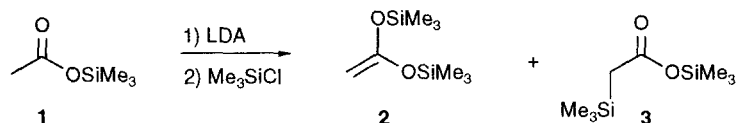
Migration of Trimethylsilyl Groups in Enolates of Silyl Esters

Paul F. Hudrlik,* Ralph R. Roberts, Da Ma, and Anne M. Hudrlik

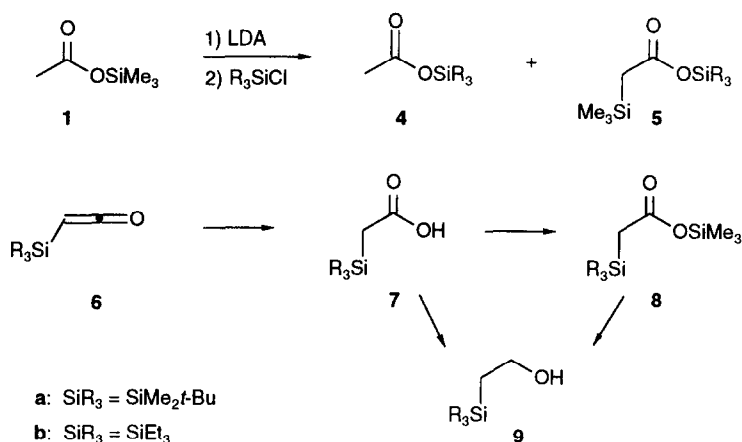
Department of Chemistry, Howard University, Washington, D. C. 20059

Abstract: The lithium enolate of trimethylsilyl acetate (**1**) undergoes a 1,3-O → C migration of the trimethylsilyl group. © 1997 Elsevier Science Ltd.

Simple ketone (and aldehyde) enolates almost invariably silylate at oxygen. Ester enolates usually silylate at oxygen, but examples of carbon silylation have also been reported.¹ Silylation of the lithium enolate of trimethylsilyl acetate (**1**) with Me₃SiCl has produced both **2** and **3**, products of O- and C-silylation, or mixtures of **2** and **3**, depending upon conditions.² Compounds of both types have been useful in synthesis. We wish to report that reactions of lithium enolates of trimethylsilyl esters (acyloxysilanes) with Et₃SiCl or *t*-BuMe₂SiCl can result in α -trimethylsilyl esters, most likely due to O → C migration of Me₃Si, complicating the interpretation of these silylation reactions, and suggesting a new interpretation to the results in reference 2b.



Treatment of trimethylsilyl acetate (**1**) with lithium diisopropylamide (LDA) in THF/ether (-78 °C, 3 h) followed by *t*-BuMe₂SiCl (-78 °C → room temp) gave a mixture of the α -Me₃Si ester **5a** and *tert*-butyldimethylsilyl acetate (**4a**)³ in a GC ratio of about 5:1.⁴ Treatment of **1** with LDA in THF for a longer time (-65 to -70 °C, 18 h) followed by *t*-BuMe₂SiCl resulted in a similar ratio of **5a** and **4a**. Distillation of the latter reaction resulted in a 52% yield of **5a**.⁵ Similarly, treatment of trimethylsilyl acetate (**1**) with LDA in THF (-78 °C, 3 h) followed by Et₃SiCl (-78 °C → room temp) gave a mixture of the α -Me₃Si ester **5b** and triethylsilyl acetate (**4b**)⁶ in a GC ratio of about 3:1. Distillation gave **5b**⁷ in 59% yield. The spectra of the crude product [from treatment of **1** with LDA in THF (-78 °C/30 min) followed by Et₃SiCl (-78 °C → room temp over 20 min)] indicated the presence of small amounts of ketene acetal (CH₂-C(OSiMe₃)(OSiEt₃)); integration of the ¹H NMR spectrum (crude doublets at δ 3.15 and δ 3.21, *J* = 1.5 Hz) was consistent with approximately a 1:5:1:1 molar ratio of silyl acetate **4b**, silyl ester **5b**, silyl ester **8b**, and silyl ketene acetal.⁸



Comparison samples of the regioisomeric esters **8a**⁹ and **8b**¹⁰ were prepared from silyl ketenes **6a**¹¹ and **6b**¹¹, respectively, by hydrolysis to the corresponding acids (**7a** and **7b**¹²), followed by treatment with Me₃SiCl/Et₃N. The structures of **7a**, **8a**, and **8b** were confirmed by reduction with LiAlH₄ to the corresponding silylethanol **9a**¹³ and **9b**¹⁴.

Both pairs of regioisomeric silyl esters (**5a**, **8a** and **5b**, **8b**) were not well separated under our GC conditions, and regioisomeric purity was verified by NMR spectroscopy. The NMR spectral data of the distilled samples are shown in Table 1. The δ 0.6 - 0.8 region of the ¹H NMR of **5b** and **8b** was particularly diagnostic. In the ¹H NMR spectrum of **5b**, no signals were observed at about δ 0.6, the center of the multiplet due to (MeCH₂)₂Si in **8b** (and in the ¹H NMR spectrum of **8b**, no signals were observed at about δ 0.75, the center of the multiplet due to (MeCH₂)₂Si in **5b**). However, in some of the crude samples of **5b** from the reaction of **1** with LDA followed by Et₃SiCl, the ¹H NMR spectra showed a small multiplet at about δ 0.6 (as well as the larger one at about δ 0.9), suggesting the possible presence of small amounts of regioisomer **8b**.

Table 1. NMR Data (CDCl₃) δ Values¹⁵

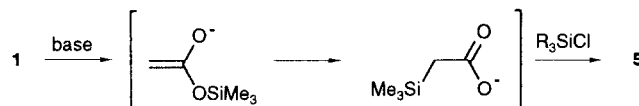
	¹ H NMR				¹³ C NMR ^a					
	Me ₃ Si	<i>t</i> -BuMe ₂ Si	Me ₃ C	RCH ₂ CO	Me ₃ Si	<i>t</i> -BuMe ₂ Si	Me ₃ C	Me ₃ C	RCH ₂ CO	C=O
4a		0.23	0.90	2.02						
5a	0.10	0.22	0.89	1.88	-4.77	-1.36	17.44	25.61	29.00	173.42
8a	0.24	0.04	0.88	1.86	-0.20	-5.91	16.77	26.14	24.97	173.85

	¹ H NMR				¹³ C NMR ^a				
	Me ₃ Si	MeCH ₂ Si	MeCH ₂ Si	RCH ₂ CO	Me ₃ Si	MeCH ₂ Si	MeCH ₂ Si	RCH ₂ CO	C=O
4b		0.75 ^b	0.95 ^c	2.03		4.41	6.37	22.54	171.61
5b	0.11	0.75 ^b	0.96 ^c	1.90	-1.41	4.59	6.52	28.86	173.35
8b	0.24	0.61 ^b	0.95 ^c	1.88	-0.25	3.59	6.98	23.83	173.79

^aAssignments of **8a**, **4b**, **5b**, and **8b** supported by APT. ^bq, *J* = 8 Hz. ^ct, *J* = 8 Hz.

The formation of the α -trimethylsilyl esters **5a** and **5b** most likely involves an intramolecular 1,3 O-C

migration of the trimethylsilyl group.^{16,17} An intermolecular silylation reaction would be expected to give trimethylsilyl α -trimethylsilylacetate (**3**) as a major product.¹⁸ Under these conditions, the triethylsilyl group does not migrate. Treatment of triethylsilyl acetate (**4b**)⁶ with LDA in THF (-78 °C, 3 h) followed by Me₃SiCl (-78 °C - room temp) gave the α -trimethylsilyl ester **5b** in 54% distilled yield.



These results demonstrate that enolate reactions of silyl esters can be complicated by rearrangements, and product assignments should be made with care. Silylation reactions of carboxylic acid dianions¹⁹ might also be complicated by similar rearrangements.

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References and Notes

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- Hudrlik, P. F.; Feasley, R. *Tetrahedron Lett.* **1972**, 1781-1784. A comparison sample was prepared from acetic acid and *t*-BuMe₂SiCl (Et₃N, THF, reflux 10 h).
- Products were isolated by filtration and concentration on the rotary evaporator without aqueous workup.
- IR (film) 1705, 1252, 1094, 857 cm⁻¹; GC/MS *m/z* (tentative assignment, relative intensity) 246 (M⁺, not visible), 231 (M⁺ - Me, 10), 189 (M⁺ - *t*-Bu, 85), 147 (100), 73 (Me₃Si⁺, 78).
- Sommer, L. H.; Pietrusza, E. W.; Whitmore, F. C. *J. Am. Chem. Soc.* **1946**, *68*, 2282-2284. A comparison sample was prepared from acetic acid and Et₃SiCl (Et₃N, THF, reflux 3 h).
- IR (film) 1704, 1252, 1096, 858, 739 cm⁻¹; GC/MS *m/z* (tentative assignment, relative intensity) 246 (M⁺, not visible), 231 (M⁺ - Me, 2), 217 (M⁺ - Et, 87), 189 (20), 175 (19), 161 (20), 147 (35), 133 (10), 119 (15), 103 ([Et₂SiOH]⁺, 100), 75 ([Me₂SiOH]⁺, 68), 73 (Me₃Si⁺, 50). See also Shchukovskaya, L. L.; Pal'chik, R. I.; Lazarev, A. N. *Doklady Chem.* **1965**, *164*, 887-890.
- The IR spectrum included a strong sharp peak at 1652 cm⁻¹. The GC/MS of the crude product showed three major peaks in the GC. The first and third corresponded to triethylsilyl acetate (**4b**) and silyl ester **5b**, respectively; the second was assigned as the silyl ketene acetal: *m/z* (tentative assignment, relative intensity) 246 (M⁺, 22), 231 (M⁺ - Me, 7), 218 (11), 189 (11), 175 (67), 147 (100), 145 (40),

- 119 (65), 86 (80), 75 ($[\text{Me}_2\text{SiOH}]^+$, 49), 73 (Me_3Si^+ , 58), 59 (56), 45 (47).
9. IR (film) 1704, 1252, 1099, 851 cm^{-1} ; GC/MS m/z (tentative assignment, relative intensity) 246 (M^+ , not visible), 231 ($\text{M}^+ - \text{Me}$, 11), 189 ($\text{M}^+ - t\text{-Bu}$, 20), 147 (100), 73 (Me_3Si^+ , 48).
 10. IR (film) 1702, 1253, 1097, 852 cm^{-1} ; GC/MS m/z (tentative assignment, relative intensity) 246 (M^+ , not visible), 231 ($\text{M}^+ - \text{Me}$, 20), 217 ($\text{M}^+ - \text{Et}$, 30), 189 (4), 175 (90), 161 (15), 147 (100), 133 (9), 119 (70), 103 ($[\text{Et}_2\text{SiOH}]^+$, 20), 87 (40), 75 ($[\text{Me}_2\text{SiOH}]^+$, 40), 73 (Me_3Si^+ , 45).
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 15. NMR spectra (^1H at 300 MHz and ^{13}C at 75 MHz) were obtained in CDCl_3 ; chemical shifts are reported in δ relative to CHCl_3 (δ 7.26) for ^1H NMR, and to CDCl_3 (δ 77.00) for ^{13}C NMR.
 16. For leading references on anionic rearrangements of silyl groups, see: (a) Brook, A. G.; Bassindale, A. R. In *Rearrangements in Ground and Excited States*, Vol. 2; de Mayo, P., Ed.; Academic Press: New York, 1980, pp. 149-227. (b) Lautens, M.; Delanghe, P. H. M.; Goh, J. B.; Zhang, C. H. *J. Org. Chem.* **1995**, *60*, 4213-4227. For base-catalyzed rearrangements of silylacetic acids to give acyloxysilanes, see: (c) Brook, A. G.; Anderson, D. G.; Duff, J. M. *J. Am. Chem. Soc.* **1968**, *90*, 3876-3877. For recent examples of 1,3 O - C silyl migrations, see: (d) Baudrillard, V.; Plé, G.; Davoust, D. *J. Org. Chem.* **1995**, *60*, 1473-1474. (e) He, H.-M.; Fanwick, P. E.; Wood, K.; Cushman, M. *J. Org. Chem.* **1995**, *60*, 5905-5909.
 17. Thermal and Lewis acid-catalyzed rearrangements of silyl ketene acetals to α -silyl esters are known. Since these reactions are very slow at room temperature in the absence of Lewis acids or high pressures, they are unlikely to be important pathways in our reactions. Raucher and Schindele reported that these reactions are not accelerated by the presence of either $t\text{-BuMe}_2\text{SiCl}$ or $\text{PhCH}_2\text{NEt}_3^+\text{Cl}^-$ (Raucher, S.; Schindele, D. C. *Synth. Commun.* **1987**, *17*, 637-646). The formation of acyloxysilanes (**4a** and **4b**) may have been due to partial hydrolysis of silyl ketene acetals.
 18. The reaction of trimethylsilyl bromoacetate with $\text{Zn}/t\text{-BuMe}_2\text{SiCl}$ gave a mixture of products containing **3**, consistent with an intermolecular silylation reaction: Nietzschmann, E.; Böge, O.; Tzschach, A. *J. Prakt. Chem.* **1991**, *333*, 281-284.
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