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Use of 1,8-Diazabicyclo[5.4.0]undec-7-ene in Preparation of Trimethylsilyl Enol Ethers and Trimethylsilylacetylenes

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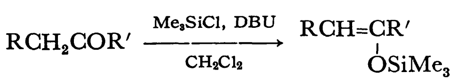
Synopsis. Trimethylsilyl enol ethers were prepared by using a combination of chlorotrimethylsilane and 1,8-diazabicyclo[5.4.0]undec-7-ene in good yields. Trimethylsilylation of acetylenes was also achieved with the same reagents in the presence of silver salt as catalyst.

Triethylamine is the most frequently used base for enol trimethylsilylation of carbonyl compounds[1] under equilibrating conditions. However, enol silylation with this base in combination with chlorotrimethylsilane requires rather vigorous conditions (refluxing in *N*,*N*-dimethylformamide for several hours),[2] and despite some modifications,[3] the yields have been less satisfactory than those with trimethylsilyl trifluoromethanesulfonate[4] or with trimethylsilyl nonafluorobutane-1-sulfonate formed *in situ*.[5,6]

Here, we wish to show that the use of 1,8-diazabicyclo-[5.4.0]undec-7-ene (DBU) as a base in combination with chlorotrimethylsilane, provides a rapid, mild, and efficient method of enol silylation of various carbonyl compounds.



$$\mathrm{RCH_2COR'} \xrightarrow[\mathrm{CH_2Cl_2}]{\mathrm{Me_3SiCl,\ DBU}} \mathrm{RCH{=}CR'(OSiMe_3)}$$

The yields are summarized in Table 1 (entry 1—15). Ketones, aldehydes, and α,β-unsaturated ketones were smoothly enol silylated at the refluxing conditions in dichloromethane. An exceptionally low yield of 3,3-dimethyl-2-trimethylsiloxy-1-butene (entry 6 in Table 1) can be ascribed to the steric crowdness of the ether which is considered to be in equilibration with the starting ketone and chlorotrimethylsilane under the presence of chloride ion.[7] It is noteworthy that the addition of silver nitrate to the reaction mixture improved the yield to 92% (entry 8). In other cases examined, the addition of silver nitrate did not show much influence on the final yields.

The poor regioselectivity of the present method is demonstrated by the silylation of 2-methylcyclohexanone (entry 3 and 4 in Table 1 and notes therein). The ratio of the two isomers did not change after prolonged reaction time (50 h).[8]

$$\mathrm{RC{\equiv}CH} \xrightarrow[\mathrm{CH_2Cl_2}]{\mathrm{Me_3SiCl,\ AgCl(cat.),\ DBU}} \mathrm{RC{\equiv}CSiMe_3}$$

In trimethylsilylation of acetylenes, strong bases such as butyl lithium[9] or Grignard reagent[10] have usually been used for the generation of acetylide anions, except for one example where monosubstituted acetylenes were heated with trialkylchlorosilanes and triethylamine in the presence of catalytic amount (0.15 mol equiv.) of copper(I) chloride at 150 °C in an autoclave for 100—120 h.[11] When the present method with DBU was applied directly to trimethylsilylation of monosubstituted acetylenes, no silylation took place despite the modifications of the reaction conditions. However, the addition of a small amount of silver salt (0.1 mol equiv.) such as silver chloride or nitrate to the reaction mixture resulted in smooth silylation in refluxing dichloromethane in good yields. They are summarized in Table 1 (entry 16—23). Because of the mildness of the reaction conditions, the present method seems to have wide applicability. The use of triethylamine in place of DBU was ineffective. In experiments with phenylacetylene, copper(I) chloride gave a less satisfactory result than[silver chloride, and zinc chloride was almost useless.

Application of the method to the formation of ketene acetals from carboxylic esters was unsuccessful.

Experimental

Commercial DBU was distilled from calcium hydride. Commercial chlorotrimethylsilane was once distilled.

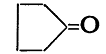
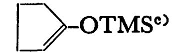
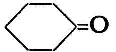
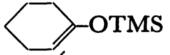
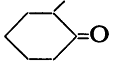
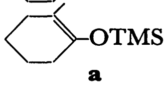
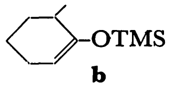
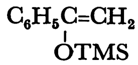
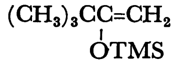
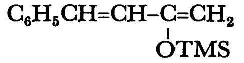
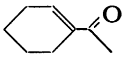
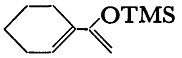
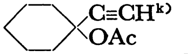
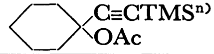
Silylation of Carbonyl Compounds. For the determination of the yield given in Table 1, chlorotrimethylsilane (0.55 mmol) was added to a stirred mixture of a ketone (0.50 mmol) and DBU (0.60 mmol) in dichloromethane (500 μl) at 40 °C. The progress of the reaction was followed by GLPC (SE-30) with the addition of an appropriate internal standard. The product was identified by comparing the retention time with that of the authentic specimen prepared by one of the reported procedures.[12]

In the experiment with silver nitrate as an additive, chlorotrimethylsilane (0.55 mmol) was added to a suspension of powdered silver nitrate (0.55 mmol) in dichloromethane and stirred for 15 min. The mixture was then warmed to 40 °C and a solution of a ketone (0.50 mmol) and DBU (0.60 mmol) in dichloromethane (300 μl) was added to this.

A typical example of the isolation experiment is as follow (entry 1, Table 1): A mixture of cyclopentanone (1.23 g, 14.7 mmol), chlorotrimethylsilane (1.76 g, 16.2 mmol), and DBU (2.68 g, 17.6 mmol) in dichloromethane (15 ml) was stirred at 40 °C for 1 h. The mixture was diluted with pentane (10 ml) and washed successively with dilute hydrochloric acid (1%) and aqueous sodium hydrogencarbonate, dried over magnesium sulfate, and distilled, giving 1-trimethylsiloxycyclopentene [1.83 g (80%), bp 85 °C (bath)/6670 Pa].

Silylation of Acetylenes. A typical example is given below (entry 23, Table 1). 1-Ethynylcyclohexyl acetate (1.054 g, 6.34 mmol) and DBU (1.16 g, 7.61 mmol) were successively added to a stirred suspension of silver chloride[13] (90.0 mg, 0.634 mmol) in dichloromethane (6.5 ml). The mixture was heated at 40 °C and chlorotrimethylsilane (0.827 g, 7.61 mmol) was added to this. After stirring for 25 h at the same temperature, the mixture was cooled, diluted with pentane (15 ml), washed successively with aqueous sodium hydrogencarbonate, hydrochloric acid (1%), and water, dried, and distilled. 1-(Trimethylsilylethynyl)cyclohexyl acetate: 1.36 g (90%), bp 149 °C (bath)/8000 Pa. NMR ($CDCl_3$) δ 0.17, [s, 9H, $-Si(CH_3)_3$], 1.4—1.8 (m, 10H, $-CH_2-$), and 2.03 (s, 3H, $-COCH_3$). Found: C, 65.40; H, 9.30%. Calcd for $C_{13}H_{22}O_2Si$: C, 65.50; H, 9.30%.

TABLE 1. SILYLATION OF CARBONYL COMPOUNDS AND MONOSUBSTITUTED ACETYLENES

Entry	Substrate	Additive (mole equiv.)	Time/h[a]	Product	Yield/%[b]
1		None	0.5	 [c]	98 (80)
2		None	1		96 (84)
3		None	2	 **a**  **b**	92[d]
4		$AgNO_3$(1.1)	2		81[e]
5	$C_6H_5COCH_3$	None	0.25	 $C_6H_5\underset{\text{OTMS}}{\underset{\vert}{C}}=CH_2$	92 (82)
6	$(CH_3)_3CCOCH_3$	None	4	 $(CH_3)_3C\underset{\text{OTMS}}{\underset{\vert}{C}}=CH_2$	57
7		None	2.5[f]		73
8		$AgNO_3$(1.1)	4		92 (80)
9		$AgNO_3$(0.1)	2		75
10	$CH_3(CH_2)_5CHO$	None	0.25	$CH_3(CH_2)_4CH=CHOTMS$	97 (85)[g]
11		None	2[h]	$CH_3(CH_2)_4CH=CHOTBDMS$[i]	(81)[j]
12	$C_6H_5CH=CHCOCH_3$	None	0.5	 $C_6H_5CH=CH-\underset{\text{OTMS}}{\underset{\vert}{C}}=CH_2$	97
13		$AgNO_3$(1.1)	0.25		92
14		None	4		84
15		$AgNO_3$(1.1)	4		82
16	$C_6H_5C{\equiv}CH$	AgCl(0.1)	24	$C_6H_5C{\equiv}CTMS$	94
17		$AgNO_3$(0.1)	24		91 (83)
18		CuCl(0.1)	24		76
19		$ZnCl_2$(0.1)	24		6
20	$CH_3(CH_2)_5C{\equiv}CH$	AgCl(0.1)	21	$CH_3(CH_2)_5C{\equiv}CTMS$	84 (62)
21	$AcOCH_2C{\equiv}CH$[k]	AgCl(0.1)	24	$AcOCH_2C{\equiv}CTMS$[l]	(84)
22	$EtCH(OAc)CH_2C{\equiv}CH$[k]	AgCl(0.1)	24	$EtCH(OAc)CH_2C{\equiv}CTMS$[m]	(89)
23	 [k]	AgCl(0.1)	25	 [n]	(90)

a) Other reaction conditions; see experimental section. b) GLPC yield. Isolated yield is given in parentheses. c) TMS =trimethylsilyl. d) **a** : **b**=63 : 37 (GLPC). e) **a** : **b**=57 : 43 (GLPC). f) HMPA was used as the solvent at 40 °C. g) E : Z=30 : 70 (GLPC). h) ClSi(*t*-Bu)Me_2 (1.1 equiv.) and DBU (1.2 equiv.) were used. i) TBDMS=*t*-butyldimethylsilyl. Bp 104 °C (bath)/930 Pa. Found: C, 68.09; H, 12.37%. Calcd for $C_{13}H_{28}OSi$: C, 68 32; H, 12.35%. j) E: Z=61 : 39. [NMR ($CDCl_3$): Olefinic proton β to oxygen appears at δ 4.98 (dt, J=11.8 and J=7.3 Hz) and 4.44 (dt, J=5.9 and J=7.1 Hz) for *E*-isomer and *Z*-isomer, respectively.]. k) The corresponding alcohol was acetylated with acetic anhydride and 4-dimethylaminopyridine. l) Bp 104 °C (bath)/9600 Pa. NMR ($CDCl_3$) δ 0.17 [s, Si $(CH_3)_3$]. Found: C, 56.30; H, 8.36%. Calcd for $C_8H_{14}O_2Si$: C, 56.43; H, 8.29%. m) Bp 136 °C (bath)/9870 Pa. NMR($CDCl_3$) δ 0.11 [s, Si$(CH_3)_3$]. Found: C, 62.03; H, 9.60%. Calcd for $C_{11}H_{20}O_2Si$: C, 62.21; H, 9.49%. n) Characterization: See experimental section.

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References

1) For recent reviews: J. K. Rasmussen, *Synthesis*, **1977**, 91; E. W. Colvin, *Chem. Soc. Rev.*, **7**, 15 (1978).

2) H. O. House, L. J. Czuba, M. Gall, and H. D. Olmstead, *J. Org. Chem.*, **34**, 2324 (1969).

3) S. Danishefsky and T. Kitahara, *J. Am. Chem. Soc.*, **96**, 7807 (1974); G. M. Rubottom and J. M. Gruber, *J. Org. Chem.*, **42**, 1051 (1977).

4) G. Simchen and W. Kober, *Synthesis*, **1976**, 259; H. Emde and G. Simchen, *Synthesis*, **1977**, 867.

5) H. Vorbruggen and K. Krolikiewicz, *Synthesis*, **1979**, 34.

6) Recently, a combination of iodotrimethylsilane and hexamethyldisilazane in pentane has been shown to provide a good silylating method: R. D. Miller and D. R. McKean, *Synthesis*, **1979**, 730.

7) Actually, when this enol ether was treated with 1 mole equivalent of DBU hydrochloride in dichloromethane at 40 °C, it gave an equilibrium mixture of a similar composition (trimethylsilyl enol ether: ketone=60 : 40) in 5 min, and the ratio did not change by prolonged heating (1 h).

8) The ratio, **a** : **b**=63 : 37, was different from the ratio, **a** : **b**=78 : 22, reported by House et al. with triethylamine in refluxing DMF (Ref. 2). This seems to be due to the difference in reaction conditions.

9) C. Eaborn, A. R. Thompson, and D. R. M. Walton, *J. Chem. Soc., B*, **1969**, 859.

10) C. Eaborn, A. R. Thompson, and D. R. M. Walton, *J. Chem. Soc., C*, **1967**, 1364.

11) G. Deleris, J. Dunogues, and R. Calas, *J. Organomet. Chem.*, **80**, C45 (1974).

12) For silyl enol ethers: Ref. 2 (entry 2, 3, and 6); 3 (entry 14); 4 (entry 1, 2, and 5); R. D. Miller and D. R. McKean, *Synthesis*, **1979**, 730 (entry 12); and D. Ladjama and J. J. Riehl, *ibid.*, **1979**, 504 (entry 10). For silylacetylenes: Ref. 11 (entry 16) and K. Uchida, K. Utimoto, and H. Nozaki, *J. Org. Chem.*, **41**, 2215 (1976) (entry 20).

13) Silver chloride precipitated by mixing aqueous silver nitrate and aqueous sodium chloride at room temperature, was washed with water and dried at 100 °C/133 Pa for 3 h.