A New Approach to Silylated Ketones and Dicarbonyl Compounds with a Conjugated (all *E*) Diene or Triene Structure

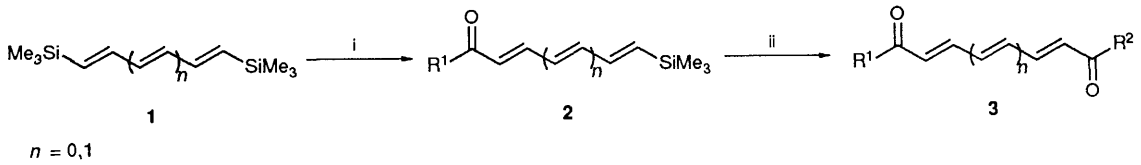
Francesco Babudri, Vito Fiandanese, Giuseppe Marchese and Francesco Naso*

Centro CNR di Studio sulle Metodologie Innovative di Sintesi Organiche, Dipartimento di Chimica, Università di Bari, via Amendola 173, 70126 Bari, Italy

Silylated ketones and dicarbonyl compounds with a conjugated diene or triene structure are obtained by electrophilic substitution reactions between (1*E*,3*E*)-1,4-bis(trimethylsilyl)buta-1,3-diene or (1*E*,3*E*,5*E*)-1,6-bis(trimethylsilyl)hexa-1,3,5-triene and acyl chlorides in the presence of aluminium trichloride.

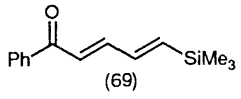
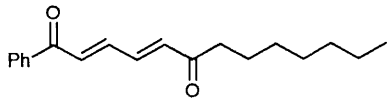
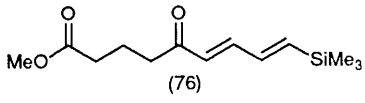
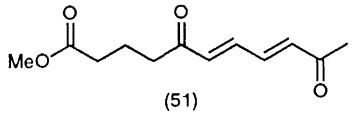
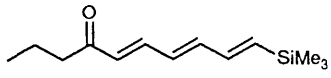
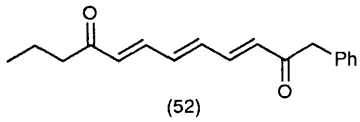
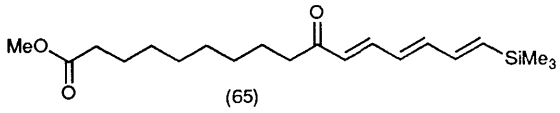
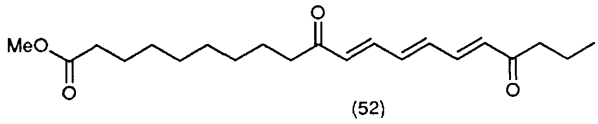
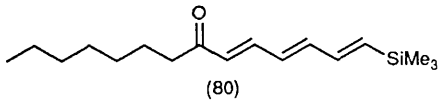
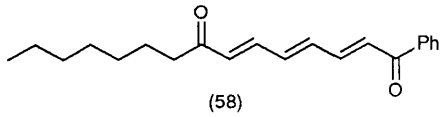
In the last decade unsaturated organosilicon compounds have been extensively studied because of their interesting potential in selective organic synthesis.[1] Thus vinyl[2] and dienyl silanes[3] have received much attention and their synthetic utility has been used in numerous carbon–carbon bond forming reactions. However, the use of the latter compounds has been mainly restricted to Diels–Alder reactions,[1b,3d] whereas examples of electrophilic substitution, which are rather common with vinyl silanes,[1a–e,2a,c,d] are rare with dienyl silanes.[3e] In the course of our previous studies on the synthesis of stereodefined alkene systems,[4] we have devised a route to 1-silylated dienes with an *E*–*E* or *E*–*Z* configuration.[5] Now we report a new synthetic approach to all *E* silylated ketones and dicarbonyl compounds with a conjugated diene or triene structure.

As depicted in Scheme 1, the crucial step of our procedure



Scheme 1 *Reagents and conditions*: i, R^1 COCl–$AlCl_3$, CH_2Cl_2, 0 °C; ii, R^2COCl–$AlCl_3$, CH_2Cl_2, 0 °C to room temp.

Table 1 Substitution products **2** and **3** from the reaction of compounds **1** with acyl chlorides in the presence of aluminium trichloride[a]

Entry substrate 1 (n = 0,1)	R^1COCl	R^2COCl	Product **2** [b, d] yield (%)	Product **3** [c, e] overall yield (%)	Time / h
1 (n = 0)	PhCOCl	—	 (69)	—	1.0
2 (n = 0)	PhCOCl	$Me(CH_2)_6COCl$	—	 (55)	17.0
3 (n = 0)	$MeO_2C(CH_2)_3COCl$	—	 (76)	—	1.0
4 (n = 0)	$MeO_2C(CH_2)_3COCl$	MeCOCl	—	 (51)	37.0
5 (n = 1)	$Me(CH_2)_2COCl$	—	 (73)	—	1.0
6 (n = 1)	$Me(CH_2)_2COCl$	$PhCH_2COCl$	—	 (52)	3.0
7 (n = 1)	$MeO_2C(CH_2)_8COCl$	—	 (65)	—	0.5
8 (n = 1)	$MeO_2C(CH_2)_8COCl$	$Me(CH_2)_2COCl$	—	 (52)	8.5
9 (n = 1)	$Me(CH_2)_6COCl$	—	 (80)	—	1.0
10 (n = 1)	$Me(CH_2)_6COCl$	PhCOCl	—	 (58)	16.0

[a] For reaction conditions see text. [b] Yields refer to products purified by distillation. [c] Overall yields of products isolated by flash chromatography and purified by crystallization. [d] All these new compounds were fully characterized by MS, IR, ^1H and ^{13}C NMR spectroscopy. [e] All these new compounds were fully characterized by IR, ^1H and ^{13}C NMR spectroscopy.

involves the highly chemoselective substitution of a trimethylsilyl group of the readily available compounds **1**, (1*E*,3*E*)-1,4-bis(trimethylsilyl)buta-1,3-diene (n = 0),[3d,6] or (1*E*,3*E*,5*E*)-1,6-bis(trimethylsilyl)hexa-1,3,5-triene (n = 1),† with acyl chlorides in the presence of aluminium trichloride to obtain silylated ketones **2**. Substitution of the second silyl group leads to the diketones **3**. As far as the first step is concerned, it is worth noting that compounds **1**, in spite of the higher number of double bonds between the two silyl groups, behave in a manner similar to (*E*)-1,2-bis(trimethylsilyl)ethene in which monoacylation has been obtained[2e] with a variety of acyl chlorides and aluminium trichloride.

In particular, we have found that in order to obtain various silylated ketones **2**, it was sufficient to react the substrate **1** with equimolar amounts of acyl chloride and $AlCl_3$ at 0 °C in CH_2Cl_2 under a nitrogen atmosphere. Only monosubstitution products were obtained, with high retention of configuration (stereoisomeric purities ≥98%), which were isolated in good yields by simple distillation. Moreover, the preparation of the dicarbonyl compounds **3** was carried out by a one-pot procedure, by just adding the other acyl chloride after completion of the first step, without isolation of the monosubstitution product.

The following procedure for the synthesis of methyl (11*E*,13*E*,15*E*)-16-trimethyl-silyl-10-oxohexadeca-11,13,15-trienoate **2** (Table 1, entry 7) and of methyl (11*E*,13*E*,15*E*)-10,17-dioxoicosa-11,13,15-trienoate **3** (Table 1, entry 8) is representative. A CH_2Cl_2 solution (8 ml) of freshly distilled methyl 10-chloro-10-oxodecanoate (1.17 g, 5.0 mmol) was added, under nitrogen, to a cold (0 °C), stirred suspension of anhydrous $AlCl_3$ (1.32 g, 10 mmol) in CH_2Cl_2 (7 ml). (It is noteworthy that when functionalised acyl chlorides were used in the first step, a molar ratio of $AlCl_3$ to acyl chloride of 2 : 1 allowed the use of shorter reaction times and led to higher yields of monosubstitution products, whereas, in the other cases, it was sufficient to use a molar ratio of $AlCl_3$ to acyl chloride of 1 : 1). The resulting mixture was stirred at 0 °C for 10 min and the clear solution obtained was transferred *via* syringe to the addition funnel of a three-necked flask, equipped with a magnetic stirrer and cooled at 0 °C, under nitrogen, which contained a CH_2Cl_2 solution (10 ml) of (1*E*,3*E*,5*E*)-1,6-bis(trimethylsilyl)hexa-1,3,5-triene **1** (n = 1) (1 g, 4.5 mmol). After complete addition at 0 °C, the mixture was stirred at the same temperature and the reaction was monitored by GLC analysis (fused silica capillary column SE 30, 30 m). After reaction completion (0.5 h), the mixture was quenched with saturated aqueous NH_4Cl and extracted with ether. The combined organic extracts were washed with water, dried over Na_2SO_4 and concentrated. The residue was purified by distillation to give 1.02 g (65% yield) of methyl (11*E*,13*E*,15*E*)-16-trimethylsilyl-10-oxohexadeca-11,13,15-trienoate (b.p. 170–172 °C, 9 × 10^{-5} mbar). The product was characterized by GC–mass-spectrometric analysis and the stereochemistry of the double bonds was ascertained from the ^{1}H NMR coupling constants between the vinylic protons.‡

In order to prepare the dicarbonyl derivative (Table 1, entry 8), the first step was carried out as described above. Then a solution of the butyryl chloride–aluminium trichloride complex [prepared as described above from 0.71 g (6.7 mmol) of butyryl chloride and 0.88 g (6.7 mmol) of $AlCl_3$] was dropped at 0 °C under nitrogen into the reaction mixture resulting from the completion of the first step. After the addition, the mixture was slowly brought to room temperature and stirred for 8 h. The same work-up procedure afforded a crude residue, which was flash chromatographed on silica gel (eluent CH_2Cl_2–Et_2O, 9.5 : 0.5). Crystallization from EtOH afforded 0.80 g of pure methyl (11*E*,13*E*,15*E*)-10,17-dioxoicosa-11,13,15-trienoate (m.p. 118–119 °C).‡ The overall yield, based upon the starting triene **1** was 52%.

This work was supported in part by Ministero della Pubblica Istruzione (Rome).

Received, 23rd July 1990; Com. 0/03323E

† (1*E*,3*E*,5*E*)-1,6-bis(trimethylsilyl)hexa-1,3,5-triene was prepared by our procedure[5] using *E*-2-trimethylsilylethenylmagnesium bromide as a reagent in both cross-coupling steps. Details of the preparation will be given elsewhere.

References

1 (*a*) E. W. Colvin, *Silicon Reagents in Organic Synthesis*, Academic Press, London, 1988; (*b*) E. W. Colvin, *Silicon in Organic Synthesis*, Butterworths, London, 1981; (*c*) W. P. Weber, *Silicon Reagents for Organic Synthesis*, Springer-Verlag, Berlin, 1983; (*d*) I. Fleming, *Chem. Soc. Rev.*, 1981, **10**, 83; (*e*) T. H. Chan and I. Fleming, *Synthesis*, 1979, 761; (*f*) B. P. Andreini, A. Carpita, R. Rossi and B. Scamuzzi, *Tetrahedron*, 1989, **45**, 5621; (*g*) E. C. Stracker, W. Leong, J. A. Miller, T. M. Shoup and G. Zweifel, *Tetrahedron Lett.*, 1989, **30**, 6487; (*h*) Y. Hatanaka, K. Matsui and T. Hiyama, *Tetrahedron Lett.*, 1989, **30**, 2403.

2 (*a*) I. Fleming, J. Dunogues and R. Smithers, *Org. React. (N.Y.)*, 1989, **37**, 57; (*b*) Y. Hatanaka and T. Hiyama, *J. Org. Chem.*, 1989, **54**, 268; (*c*) H. Westmijze, H. Kleijn and P. Vermeer, *J. Organomet. Chem.*, 1984, **276**, 317; (*d*) R. B. Miller and G. McGarvey, *J. Org. Chem.*, 1979, **44**, 4623; (*e*) J. P. Pillot, J. Dunogues and R. Calas, *Bull. Chem. Soc., Fr.*, 1975, 2143.

3 (*a*) B. Cazes, V. Colovray and J. Gore, *Tetrahedron Lett.*, 1988, **29**, 627; (*b*) T. S. Chou, H. H. Tso, Y. T. Tao and L. C. Lin, *J. Org. Chem.*, 1987, **52**, 244; (*c*) F. Sato, H. Uchiyama, K. Iida, Y. Kobayashi and M. Sato, *J. Chem. Soc., Chem. Commun.*, 1983, 921; (*d*) M. J. Carter, I. Fleming and A. Percival, *J. Chem. Soc., Perkin Trans. 1*, 1981, 2415; (*e*) K. Yamamoto, M. Ohta and J. Tsuji, *Chem. Lett.*, 1979, 713; (*f*) J. P. Pillot, J. Dunogues and R. Calas, *J. Chem. Res.(S)*, 1977, 268.

4 V. Fiandanese, G. Marchese, F. Naso, L. Ronzini and D. Rotunno, *Tetrahedron Lett*, 1989, **30**, 243; F. Naso, *Pure Appl. Chem.*, 1988, **60**, 79; V. Fiandanese, G. Miccoli, F. Naso and L. Ronzini, *J. Organomet. Chem.*, 1986, **312**, 343; V. Fiandanese, G. Marchese, F. Naso and L. Ronzini, *J. Chem. Soc., Perkin Trans. 1*, 1985, 1115; V. Fiandanese, G. Marchese, F. Naso and L. Ronzini, *J. Chem. Soc., Chem. Commun.*, 1982, 647.

5 V. Fiandanese, G. Marchese, G. Mascolo, F. Naso and L. Ronzini, *Tetrahedron. Lett.*, 1988, **29**, 3705.

6 D. Seyferth and S. C. Vick, *J. Organomet. Chem.*, 1978, **144**, 1; H. Bock and H. Seidl, *J. Am. Chem. Soc.*, 1968, **90**, 5694.

‡ *Selected spectroscopic data*: (2*E*,4*E*)-1-phenyl-5-trimethylsilylpenta-2,4-dien-1-one (entry 1): ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.13 (s, 9H), 6.46 (d, *J* 18.2 Hz, 1H), 6.77 (dd, *J* 18.2, 10.3 Hz, 1H), 6.95 (d, *J* 15.0 Hz, 1H), 7.35 (dd, *J* 15.0, 10.3 Hz, 1H), 7.40–7.60 (m, 3H), 7.88–8.00 (m, 2H): ^{13}C NMR (50.3 MHz, $CDCl_3$) δ −1.58, 125.60, 128.42, 128.57, 132.72, 138.05, 141.89, 146.33, 146.87, 191.09; IR (KBr) ν 1662, 1015, 864, 840 cm^{-1}; MS (70 eV): *m/z*(%) 230 (10, M^+), 215 (100), 157 (26), 141 (91), 115 (19), 105 (40), 77 (46), 73 (25).

(2*E*,4*E*)-1-phenyl-trideca-2,4-diene-1,6-dione (entry 2): ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.86 (br., t, 3H), 1.27 (br. s, 8H), 1.59–1.66 (m, 2H), 2.60 (t, *J* 7.0 Hz, 2H), 6.53 (d, *J* 15.2 Hz, 1H), 7.20–7.65 (m, 6H), 7.90–8.01 (m, 2H); ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 14.08, 22.60, 24.03, 29.07, 29.18, 31.66, 41.55, 128.53, 128.78, 132.20, 133.33, 136.20, 137.33, 138.73, 141.16, 189.69, 200.23; IR (KBr) ν 1688, 1657, 1023 cm^{-1}.

Methyl (11*E*,13*E*,15*E*)-16-trimethylsilyl-10-oxohexadeca-11,13,15-trienoate (entry 7): ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.07 (s, 9H), 1.26 (br. s, 8H), 1.54–1.60 (m, 4H), 2.26 (t, *J* 7.3 Hz, 2H), 2.51 (t, *J* 7.2 Hz, 2H), 3.63 (s, 3H), 6.11 (d, *J* 17.5 Hz, 1H), 6.15 (d, *J* 15.5 Hz, 1H), 6.20–6.38 (m, 1H), 6.46–6.66 (m, 2H), 7.15 (dd, *J* 15.5, 10.9 Hz, 1H); ^{13}C NMR (50.3 MHz, $CDCl_3$) δ −1.48, 24.33, 24.89, 29.06, 29.21, 34.06, 40.69, 51.46, 129.95, 130.66, 140.62, 142.11, 142.85, 143.47, 174.32, 200.73; IR (KBr) ν 1739, 1677, 1600, 1017, 867, 841 cm^{-1}; MS (70 eV): *m/z* (%) 350 (7, M^+), 335 (6), 319 (4), 277 (4), 251 (8), 207 (16), 194 (28), 179 (26), 73 (100).

Methyl (11*E*,13*E*,15*E*)-10,17-dioxoeicosa-11,13,15-trienoate (entry 8): ^{1}H NMR (200 MHz, $CDCl_3$) δ 0.91 (t, *J* 7.3 Hz, 3H), 1.27 (br. s, 8H), 1.50–1.70 (m, 6H), 2.26 (t, *J* 7.3 Hz, 2H), 2.53 (t, *J* 7.1 Hz, 4H), 3.63 (s, 3H), 6.27 (d, *J* 15.4 Hz, 2H), 6.52–6.75 (m, 2H), 7.17 (ddd, *J* 15.4, 7.1, 2.9 Hz, 2H); ^{13}C NMR (50.3 MHz, $CDCl_3$) δ 13.79, 17.64, 24.14, 24.89, 29.05, 29.18, 34.06, 41.14, 43.04, 51.46, 132.17, 132.21, 138.22, 138.25, 140.22, 174.30, 200.34, 200.40; IR (KBr) ν 1731, 1684, 1602, 1034 cm^{-1}.