Silyl Phosphite Equivalents: 2,2,2-Trichloroethoxycarbonylphosphonates

By MITSUO SEKINE, HIKARU YAMAGATA, and TSUJIAKI HATA*

(*Department of Life Chemistry, Tokyo Institute of Technology, Nagatsuta, Midoriku, Yokohama* 227, *Japan*)

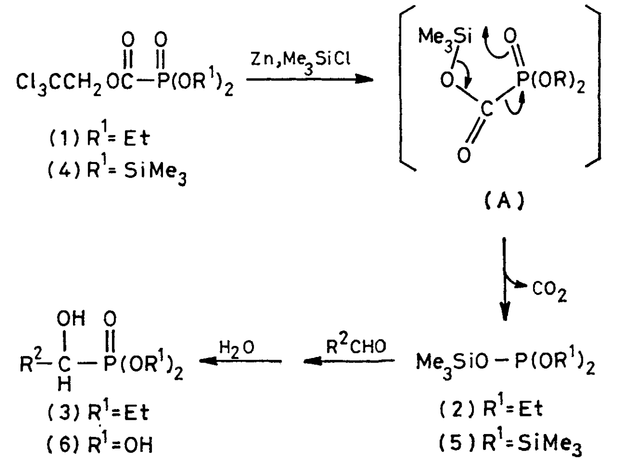
Summary 2,2,2-Trichloroethoxycarbonylphosphonates were converted directly by treatment with Zn–Me_3SiCl into silyl phosphites which *in situ* reacted with aldehydes to give α-hydroxyphosphonates in good yields.

Silyl phosphites have proved to be versatile synthetic intermediates for organophosphorus compounds.[1] They are, however, unstable towards moisture, alcohols, or carboxylic acids and hence act only as silylating agents to give unreactive five-valent phosphonates. In order to overcome the problem, suitable synthetic silyl phosphite equivalents are required.

Warren has reported that *P*-carboxyphosphonates decompose under acidic conditions with evolution of carbon dioxide to afford the phosphine oxides $[R_2P(O)H]$[2] containing an H–P bond. These compounds should easily be converted into the reactive tervalent $R_2POSiMe_3$ by simple trimethylsilylation.[1]

We report here a novel method for the generation of silyl phosphite intermediates utilizing 2,2,2-trichloroethoxycarbonylphosphonates as silyl phosphite equivalents and also describe the synthesis of α-hydroxy phosphonates by a one-flask reaction.

Diethyl 2,2,2-trichloroethoxycarbonylphosphonate (**1**) (b.p. 140—143 °C at 2 mmHg) was easily prepared in 71% yield by the Arbuzov reaction of 2,2,2-trichloroethyl chloroformate with triethyl phosphite at room temperature for 30 min. Compound (**1**) was treated with zinc powder (1·1 equiv.) in dry ether at room temperature; removal of the 2,2,2-trichloroethyl group occurred gradually, but was not complete even after a day. However, addition of trimethylsilyl chloride surprisingly accelerated the reaction and the 2,2,2-trichloroethyl group was completely removed within 2·5 h, with simultaneous elimination of carbon dioxide. This suggested that diethyl trimethylsilyl phosphite (**2**) was generated *via* a five-membered ring transition state (A) as depicted in the Scheme.



Scheme

We attempted to isolate (**2**), but it could not be obtained by distillation, probably because it was tightly bound to the zinc chloride which was simultaneously formed to form a stable complex. In order to confirm the formation of (**2**), the reaction mixture was treated with phosphate buffer (pH 6·0) and extracted with ether. The extracts were dried (Na_2SO_4), evaporated *in vacuo,* and chromatographed on silica gel to give diethyl phosphonate in 95% yield. The formation of (**2**) was further supported by the fact that α-hydroxyphosphonates (**3**) were obtained in good yields when the reaction mixture was treated *in situ* with aldehydes at room temperature for 30 min.

In a similar manner, bis(trimethylsilyl) 2,2,2-trichloroethoxycarbonylphosphonate[3] (**4**) (5 mmol) was treated with zinc powder (10 mmol) in the presence of trimethylsilyl chloride (20 mmol) at room temperature for 2 h and then with various aldehydes (6 mmol) at room temperature for 5 h. Treatment of the mixture with ethanol containing aniline (2 equiv.) led to monoanilinium salts of the unesterified α-hydroxy-phosphonic acids[3] (**6**) in good yields (see Table). In the absence of aldehydes, the monoanilinium salt of phosphonic acid was obtained in 86% yield. Tris(trimethylsilyl) phosphite (**5**) could not be isolated by distillation from the reaction mixture owing to complex formation as described in the case of (**2**). The structures of the products (**3**) and (**6**) were confirmed by their elemental analysis and n.m.r. spectra or by comparison with the authentic samples. The reactions described here might be applicable to the synthesis of more complex molecules such as nucleotide derivatives containing an α-hydroxyphosphonyl group, since all the steps can be carried out under very mild conditions.

Table. Synthesis of the α-hydroxy phosphonates (**3**) or (**6**)

	R^1	R^2	% Yield	M.p./°C
(3)	Et	Ph	84	Oil
	Et	4-$MeOC_6H_4$	62	Oil
(6)	OH	Ph	85	183—184[a]
	OH	4-$MeOC_6H_4$	68	134—136[a]
	OH	Pr^i	63	153—154[a]

[a] Monoanilinium salt.

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[1] T. Hata and M. Sekine, in 'Phosphorus Chemistry Directed Towards Biology,' Ed. W. J. Stec, Pergamon Press, New York, 1980, pp. 197—212.

[2] S. Warren and M. R. Williams, *J. Chem. Soc. B*, 1971, 618.

[3] M. Sekine and T. Hata, *J. Chem. Soc., Chem. Commun.*, 1978, 285. In this paper the solvent for the Arbuzov reaction was incorrectly reported as pyridine; the solvent used was in fact benzene.

[4] M. Sekine, I. Yamamoto, A. Hashizume, and T. Hata, *Chem. Lett.*, 1977, 485.