

NEW METHOD OF ALKYLENE PHOSPHONATE PREPARATION

Pawel Klosinski

Center of Molecular and Macromolecular Studies
Polish Academy of Sciences
90-363 Lodz, Sienkiewicza 112, Poland

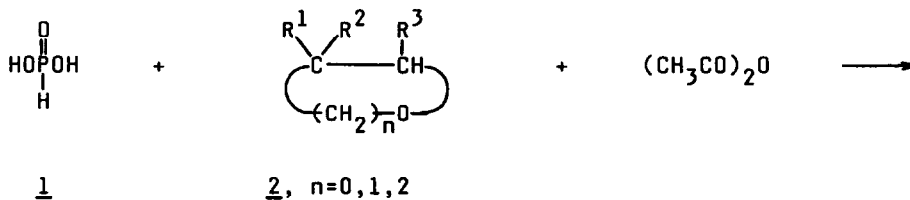
Abstract: A new method of alkylene phosphonate preparation has been elaborated, based on the reaction of the corresponding cyclic ethers and phosphonic acid in the presence of acetic anhydride.

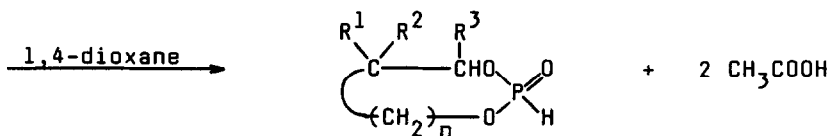
The alkylene phosphonates (1,3,2-dioxaphospholanes and 1,3,2-dioxaphosphorinanes) are important intermediates in organic and polymer chemistry, in which they are used for the preparation of poly(alkylene phosphate)s modeling the structures or/and functions of teichoic and nucleic acids.¹

Methods of alkylene phosphonates synthesis, developed up to now, are based mainly on the hydrolysis of the corresponding alkylene chlorophosphites² or on the transesterification reaction of dialkyl phosphonates with appropriate diols.³

In the course of our studies of the poly(alkylene phosphonate)s synthesis by polyaddition of phosphonic acid to dioxirane compounds we observed that parallel to polyaddition cyclization proceeds, affording 1,3,2-dioxaphospholane 2-oxides.⁴

In this paper we report on the reaction between phosphonic acid (1) and cyclic ethers (2), especially oxiranes, in the presence of acetic anhydride as a new method of alkylene phosphonates (3) preparation:





3, n=0,1,2

Phosphonic acid (1.64 g, 2.0 mmol) is dissolved in 1,4-dioxane (10 ml). To this solution, mixture of the appropriate cyclic ether (2.0 mmol) and acetic anhydride (1.89 ml, 2.0 mmol or 2.26 ml, 2.4 mmol) is added dropwise and the resulting solution is allowed to react for several hours either at r.t. or at reflux in boiling 1,4-dioxane (time and temperature given in Table 1). For oxiranes the reaction mixture is cooled with water bath and after addition of reagents left overnight. The crude products is obtained by removal of solvent and acetic acid (by-product), and then purified by vacuum distillation.

Yield of the product depends mainly on the size of the ring in cyclic ethers and on the degree of their substitution (Table 1).

Linear polymers are formed simultaneously with cyclic compounds. These linear polymers depolymerize during distillation of the reaction mixtures, back to 3. 1,3,2-Dioxaphospholane 2-oxides, especially monosubstituted in the ring, are known to undergo "spontaneous" polymerization.^{2,5} Products contain up to 20 mol% (elemental analysis, ¹H NMR) of the corresponding dialkyl phosphonates (the products of double esterification of H₃PO₃ molecule) as impurities. When the starting proportion of acetic anhydride was increased the proportion of the impurities decreased below 10%. The overall yield of the desired product was simultaneously lowered (cf. Table 1).

The reaction of 3,3-bis(chloromethyl)oxetane (2h) with 1 at approx. 100°C (reflux) afforded a mixture of the main product 3h and by-product 2,2-bis(chloromethyl)-1,3-diacetoxypropane.

The phenyloxirane (2e) yielded the required product 3e, corresponding polymer and some unidentified compounds with P-C bonds (³¹P NMR). This mixture decomposed during attempts of distillation (bath temperature 140°C). 3e prepared by hydrolysis of the 2-chloro-4-phenyl-1,3,2-dioxaphospholane behaved similarly.⁶

Products 3a+3d and 3f were obtained as mixtures of trans/cis isomers with equal proportions.

Table 1.

no	n	R ¹	R ²	R ³	Time (h) (temp.)	Yield ^a (%)	³¹ P { ¹ H} NMR ^b		b.p. (°C/torr)	Literature b.p.(°C/torr)
							<u>3</u>	poly- <u>3</u>		
<u>3a</u>	0	H	H	CH ₃	12 (r.t.)	45.2 (39.6)	22.66 21.75	7.15	55-8/0.03	66-7/0.01 ³
<u>3b</u>	0	H	H	CH ₂ Cl	12 (r.t.)	65.7 (49.4)	23.77	8.35	90-4/0.04	125-6/2.5 ³
<u>3c</u>	0	H	H	CH ₂ CH ₃	12 (r.t.)	66.2 (52.2)	22.90 22.09	7.87	62-5/0.02	new compound
<u>3d</u>	0	CH ₃	H	CH ₃	12 (r.t.)	71.7 (57.1)	20.14 ^c 19.34 18.73	6.55	60-3/0.03	67-8/0.05 ³
<u>3e</u>	0	H	H	C ₆ H ₅	12 (r.t.)	-	-	-	decomposi- tion	-
<u>3f</u>	0	H	H	CH ₂ OC ₆ H ₅	12 (r.t.)	(74.2)	23.87 23.16	8.26	154-6/0.03	new compound
<u>3g</u>	1	H	H	H	2 (reflux)	73.8	3.93	-	80-5/0.02	92-3/0.05 ³
<u>3h</u>	1	CH ₂ Cl	CH ₂ Cl	H	2 (reflux)	47.9	5.35	-	120-30/0.02 m.p.64-5°C ^d	148-50/0.02 ⁵ m.p.65°C
<u>3i</u>	2	H	H	H	3 (reflux)	20.8	10.99	-	65-70/0.05	new compound

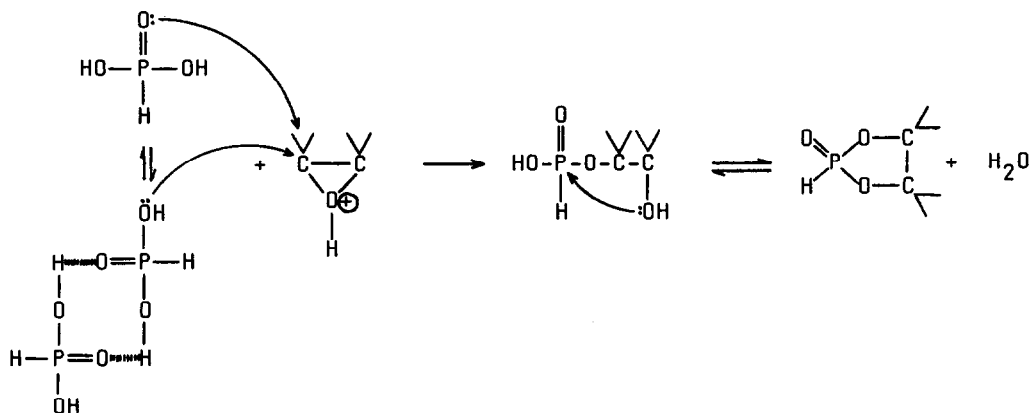
^a The yields of products obtained with 20% mol excess of Ac₂O are given in brackets.

^b Spectra recorded on Jeol-FX60 apparatus at 24.2 MHz in CHCl₃ solutions with 85% H₃PO₄ as an external standard.

^c Three stereoisomers obtained from the mixture of trans,cis-3d.

^d M.p. after crystallization from benzene:heptane.

The reaction mechanisms of the acids of phosphorus addition to the oxiranes has not been studied. Kinetic analysis has been undertaken in our laboratory ⁷ and on its basis and by analogy of carboxylic acids addition to oxiranes the mechanism similar to "borderline S_N2" is the most likely. Whether this is the monomeric or dimeric acid participating in the nucleophilic attack on the protonated oxirane might be a matter of specific reaction conditions. Once the hydroxy ester is formed, the intramolecular esterification provides the final alkylene phosphonate. Since this reaction is highly reversible, the presence of compounds reacting with water (acetic anhydride) increases the yield. These steps are shown on the scheme below:



Acknowledgement: I wish to thank Professor S. Penczek for his kind interest to this work and helpful discussions.

This work was supported by the Polish Academy of Sciences, Grant no 01.13.

References:

1. Penczek, S., Klosinski, P., Synthetic polyphosphates related to nucleic and teichoic acids in "Models of Biopolymers by Ring-Opening Polymerization", Penczek, S., Ed., CRC Press, in press.
2. Zwierzak, A., Can. J. Chem. 1967, 45, 2501.
3. Oswald, A.A., Can. J. Chem. 1959, 37, 1498.
4. Klosinski, P., Penczek, S., Macromol. Chem., Rapid Commun. 1988, 9, 159.
5. Arbuzov, B.A., Kataev, V.E., Arshinova, R.P., Gubaidukin, R.N., Izv. Akad. Nauk SSSR, Ser. Khim. 1978, 2450.
6. Biela, T., unpublished results from this laboratory.
7. Biela, T., Kubisa, P., in preparation.

(Received in UK 12 February 1990)