

Reactions of Phosphorodiamidous Acid Esters with α -Halocarbonyl Compounds

L. K. Sal'keeva, M. T. Nurmaganbetova, O. Sh. Kurmanaliev, and T. Kh. Gazizov

Buketov Karaganda State University, Karaganda, Kazakhstan

Received February 14, 2001

Abstract—Reactions of ethyl and *tert*-butyl phosphorodiamidites with chloroacetone, bromoacetone, and α -chloroethyl acetate were studied. The reaction pathway is determined by the structure of the intermediate quasiphosphonium compound responsible for the formation of the Arbuzov product as well as for the occurrence of the anomalous reaction yielding vinyl phosphate.

It is known that the reactions of trialkyl phosphites with alkyl and acyl halides [1, 2] and of phosphoramidous [3] and phosphorothious [4] acid esters with alkyl halides yield phosphonates. Phosphoramidous acid esters react with acyl halides by two pathways: with the formation of the Arbuzov products and with substitution of the amide group of phosphite with the halogen atom of acyl halide [5]. Reactions of phosphorothious acid esters with acyl halides yield exclusively the products of substitution of alkylthio group by the halogen atom [6]. Formation of phosphonates agrees with the scheme of the Arbuzov reaction and is beyond doubt. At the same time, the majority of researchers consider that, in the mechanism of substitution with the preservation of phosphorus coordination, the role of the nucleophilic center of the P(III) derivative is played by the heteroatom bound to phosphorus and having an unshared electron pair. On the whole, the reaction follows the scheme of four-centered electron transfer (pathway 1, Scheme 1) [5] or occurs via the formation of an onium intermediate followed by substitution of the onium group by the counterion of the system (pathway 2) [7]. Studies of the reactions of phosphorus amides and phosphoramidous acid esters with anhydrides and acyl halides [8] showed that the products of substitution can be formed also through the P-acylated intermediate (pathway 3a²). If the species responsible for formation of substitution products with the preservation of the phosphorus coordination were the product of acylation by the heteroatom, the yield of the substitution products would, apparently, increase in going from phosphorothious to phosphorous and then to phosphoramidous acid esters, simultaneously with an increase in the basicity of the heteroatom. However, as shown in [3–6], in the transformations under consideration this rule is not obeyed. If the Arbuzov re-

action and the substitution proceed through the same P-acylated derivative, then the yields of the products of these reactions should be determined by the properties of the intermediate. The shift of the equilibrium in the quasiphosphonium intermediate toward the ionic form should favor the formation of the Arbuzov products (the species responsible for the occurrence of the second stage of the Arbuzov reaction is the ionic form of the quasiphosphonium compound [9]), and, vice versa, shift of the equilibrium toward the pentavalent form of the intermediate should favor the formation of P(III) compounds. Artificial alteration of the dealkylation rate (stage 3b) should also considerably affect the process direction. With the aim to elucidate the mechanism of the reaction of phosphorothious and phosphoramidous acid esters with acyl halides, we have previously studied these reactions under different conditions influencing the state of the quasiphosphonium compound. These studies were based on the fact that polar solvents [9] and also passing from acyl chlorides to acyl iodides (low-basic anions in quasiphosphonium compounds are ionized more readily [10]) favor the formation of the ionic form of the intermediate. Also, it is known that the *tert*-butyl group is very rapidly eliminated in the second stage of the Arbuzov reaction [11, 12]. The results of our previous studies show [13, 14] that the direction of the reactions of phosphorous, phosphorothious, and phosphoramidous acid esters is determined by the properties of quasiphosphonium compounds. These reactions can be described by a common scheme (Scheme 1, pathway 3) including the formation of a P-acylated intermediate (Scheme 1).

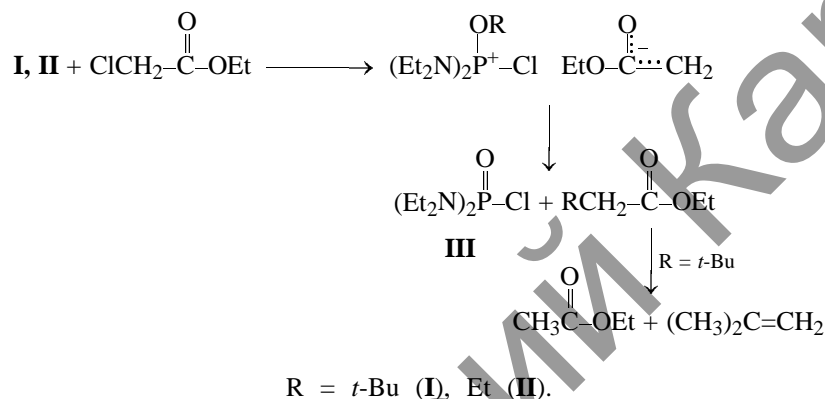
Proceeding with studies in this direction, we examined the reactions of phosphoramidous acid esters with α -halocarbonyl compounds. Published data

We believe that vinyl phosphate **IV** is formed in these reactions by the scheme of the Perkow reaction (pathway *1a*). Formation of phosphorodiamidic halide **III** presumably involves the attack of the electron-deficient halogen atom of α -halocarbonyl compound by the phosphorus atom of phosphite (pathway *2a*). Anion exchange (pathways *1b*, *2b*), apparently, can occur also.

To confirm the presumed mechanism of the reactions of phosphoramidous acid esters with α -halocarbonyl compounds, it is interesting to study the re-

action with α -halocarboxylates, in particular, with ethyl α -chloroacetate. According to published data [16], alkyl phosphorodiamidites react with alkyl chloroacetates to give exclusively the Perkow products, namely, the corresponding vinyl phosphates. We have studied the reactions of *tert*-butyl and ethyl phosphorodiamidites with ethyl chloroacetate. We found that these reactions occur at 80–85°C within 1–2 h and yield phosphorodiamidic chloride (δ_p 26 ppm) as the only phosphorus-containing product. The reaction pathway is described by Scheme 3.

Scheme 3.



Our experimental data also show that the direction of reactions of phosphoramidous acid esters with α -halocarbonyl compounds is determined by the properties of the quasiphosphonium intermediates. In detail, with bromoacetone used instead of chloroacetone, the yield of the Arbuzov product increases, because the anions of low basicity (in our case, Br^-) are more readily ionized, which facilitates the formation of the ionic form of the intermediate. Also, *tert*-butyl phosphorodiamidite forms the Arbuzov product as the major or the only product, because the second stage of the $\text{S}_{\text{N}}1$ reaction is accelerated.

EXPERIMENTAL

The ^{31}P NMR spectra were taken on a custom-made KGU-4 spectrometer (10.2 MHz) against external 85% phosphoric acid. The ^1H NMR spectra were recorded on a Varian T-60 spectrometer (60 MHz) against external TMS. The IR spectra were measured on a UR-20 spectrometer in liquid films.

Reaction of *tert*-butyl tetraethylphosphorodiamidite with chloroacetone. Chloroacetone, 6.9 g, was added to 18.6 g of phosphite **I**, and the resulting mixture was heated at 85–90°C for 2–3 h with sim-

ultaneous distillation of acetone (2.7 g, 61%). Elimination of isobutylene was observed. Distillation of the reaction mixture gave 9.4 g (55.2%) of tetraethylphosphorodiamidic chloride, bp 71–72°C (0.07 mm), d_4^{20} 1.0682, n_D^{20} 1.4680, δ_p 26 ppm [published data [17]: bp 68–70°C (0.05 mm), n_D^{20} 1.4648, d_4^{20} 1.0680], and 3.7 g (24.8%) of 1-methylvinyl tetraethylphosphorodiamidate, bp 58–59°C (0.05 mm), n_D^{20} 1.4580, d_4^{20} 1.0120, δ_p 12 ppm [published data [18]: bp 124–128°C (8 mm), n_D^{20} 1.4520, d_4^{20} 0.9920]. IR spectrum, ν , cm^{-1} : 1640 (C=C), 1260 (P=O).

Reaction of ethyl tetraethylphosphorodiamidite with chloroacetone was performed similarly. Phosphite **II**, 11.0 g, and chloroacetone, 4.6 g, gave tetraethylphosphorodiamidic chloride **III** and 1-methylvinyl tetraethylphosphorodiamidate **IV** in a 1:3 ratio.

Reaction of phosphite **I with bromoacetone.** Bromoacetone, 3.4 g, was added at a temperature from –20 to –10°C to 6.2 g of phosphite **I**. Considerable heat evolution was observed, and 450 ml (80.4%) of isobutylene was released. Distillation of the reaction mixture gave 5.0 g of tetraethylphosphorodiamidic bromide, δ_p 19 ppm. Its structure was proved by independent syntheses. The reaction of tetraethyl-

phosphorodiamidic bromide with 2 equivalents of diethylamine gave hexaethylphosphorotriamide with δ_p 23 ppm (published data [19]: δ_p 23.5 ppm). Oxidation of ethyl phosphorodiamidite with molecular bromine yields phosphorodiamidic bromide with δ_p 19 ppm.

Reaction of ethyl tetraethylphosphorodiamidite with bromoacetone was performed similarly. Phosphite **II**, 11.0 g, and 6.8 g of bromoacetone gave tetraethylphosphorodiamidic bromide (δ_p 19 ppm) and 1-methylvinyl tetraethylphosphorodiamidate (δ_p 14 ppm) in a 1:2 ratio.

Reaction of tert-butyl tetraethylphosphorodiamidite with ethyl chloroacetate. A mixture of 12.4 g of phosphite **I** and 6.1 g of ethyl chloroacetate was heated on a water bath for 1.5 h; 4.1 g (93.2%) of ethyl acetate was released, bp 75–76°C, n_D^{20} 1.3780, d_4^{20} 0.924. Published data: bp 76–78°C, n_D^{20} 1.3728, d_4^{20} 0.901 [20]. IR spectrum, ν , cm^{-1} : 1740 (C=O). Distillation of the reaction mixture gave 8.8 g (78%) of tetraethylphosphorodiamidic chloride **III**, bp 68–70°C (0.05 mm), n_D^{20} 1.4648, d_4^{20} 1.0680, δ_p 26 ppm.

Reaction of ethyl tetraethylphosphorodiamidite with ethyl chloroacetate was performed similarly. Phosphite **II**, 5.5 g, and 3.05 g of ethyl chloroacetate gave 5.7 g (82%) of tetraethylphosphorodiamidic chloride (δ_p 26 ppm) and 4.8 g (84.2%) of ethyl butyrate.

REFERENCES

1. Arbuzov, A.E., *Izbrannye trudy po khimii fosfororganicheskikh soedinenii* (Selected Works on Chemistry of Organophosphorus Compounds), Moscow: Nauka, 1976, p. 559.
2. Gazizov, T.Kh., Belyalov, R.U., and Pudovik, A.N., *Zh. Obshch. Khim.*, 1982, vol. 52, no. 4, p. 776.
3. Razumov, A.I., *Tr. Kazan. Khim.-Tekhnol. Inst.*, 1957, no. 23, p. 201.
4. Kabachnik, M.I., Pudovik, A.N., and Batyeva, E.S., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1987, no. 8, p. 1871.
5. Antokhina, L.A. and Alimov, P.I., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1971, no. 4, p. 806.
6. Al'fonsov, V.A., Zamaletdinova, G.U., Batyeva, E.S., and Pudovik, A.N., *Izv. Akad. Nauk SSSR, Ser. Khim.*, 1982, no. 6, p. 1386.
7. Hudson, R.F. and Searle, R.J.G., *Chimia*, 1966, vol. 20, p. 117.
8. Hargis, J.H. and Mattison, G.A., *J. Org. Chem.*, 1981, vol. 46, no. 8, p. 1597.
9. Gazizov, T.Kh., *Cand. Sci. (Chem.) Dissertation*, 1969.
10. Nesterov, L.V. and Aleksandrova, I.A., *Zh. Obshch. Khim.*, 1980, vol. 50, no. 1, p. 36.
11. Gusev, Yu.K., Chistokletov, V.N., and Petrov, A.A., *Zh. Obshch. Khim.*, 1977, vol. 47, no. 1, p. 45.
12. Gazizov, T.Kh., Chugunov, Yu.V., and Pudovik, A.N., *Dokl. Akad. Nauk SSSR*, 1987, vol. 294, no. 6, p. 1382.
13. Gazizov, T.Kh., Sal'keeva, L.K., Gafurov, E.K., and Kazantsev, A.V., *Zh. Obshch. Khim.*, 1988, vol. 58, no. 5, p. 1155.
14. Gazizov, T.Kh., Sal'keeva, L.K., Gafurov, E.K., and Kazantsev, A.V., *Zh. Obshch. Khim.*, 1988, vol. 58, no. 4, p. 944.
15. Abramov, V.S. and Il'ina, I.A., *Dokl. Akad. Nauk SSSR*, 1960, vol. 132, no. 4, p. 823.
16. Abramov, V.S. and Il'ina, I.A., *Dokl. Akad. Nauk SSSR*, 1964, vol. 155, no. 1, p. 112.
17. Abramov, V.S. and Il'ina, N.A., *Zh. Obshch. Khim.*, 1971, vol. 41, no. 1, p. 100.
18. Pudovik, A.N. and Chebotareva, E.G., *Zh. Obshch. Khim.*, 1958, vol. 28, no. 9, p. 2492.
19. Kormachev, V.V., *Laboratornyi praktikum po khimii fosfororganicheskikh soedinenii* (Practical Course of Chemistry of Organophosphorus Compounds), Cheboksary: Cheboksar. Gos. Univ., 1975, p. 52.
20. Rabinovich, V.A. and Khavin, Z.Ya., *Kratkii khimicheskii spravochnik* (Concise Chemical Handbook), Leningrad: Khimiya, 1978, p. 189.