REACTION OF 0-HYDROXYBENZYL ALCOHOL WITH ESTER AMIDES AND AMIDES OF PHOSPHOROUS ACID

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The reaction of o-hydroxybenzyl alcohol (I) with trialkyl phosphites gives the 2-oxo-2-alkoxy-1-oxa-2-phosphaindan, and the reaction proceeds via the formation of the quasiphosphonium complex and the diethyl ester of o-hydroxybenzylphosphonic acid [1, 2]. 2-Methoxymethyl-6-methylphenol reacts in a similar manner with triethyl phosphite [1]. The ester amides and amides of trivalent phosphorus acids are ambident nucleophilic reagents and, depending on the nature of the electrophile, can react either at the P atom or at the N atom [3].

In order to ascertain the conditions for progress of the reaction at the P atom and at the N atom we studied the reaction of (I) with diethyl diethylamidophosphite (II), ethyl bis(diethylamido)phosphite (III), and tris(diethylamido)phosphite (IV). Alcohol (I) is convenient for studying the reactions that proceed at the nitrogen atom, since the formed 2-diethylaminomethylphenol (V) is less reactive than (I) toward trivalent phosphorus derivatives; in general, diethylphosphorous acid does not react with (I), while it reacts with (V) at >150° [4-6].

Without a solvent the reaction of (I) with (II), (III), or (IV) proceeds with a strong exothermic effect (80-100°), and is accompanied by complete tarring. For this reason the reaction was run in a solvent, with cooling, in an inert gas stream. The progress of the reaction was checked employing IR, ³¹P NMR spectroscopy, and GLC. In order to eliminate the effect of temperature during distillation on the possible secondary transformations of the formed products the spectra and chromatograms were taken immediately after the exothermic effect and after distillation of the reaction mixtures.

When (I) was reacted with (II) we obtained and identified: (V), diethylphosphorous acid, diethyl ohydroxybenzylphosphonate (VI), diethylamine, 2-oxo-2-ethoxy-1-oxa-2-phosphaindan (VII), and ethanol.

After adding (II), the ³¹P NMR spectrum of the reaction mixture contains the signal δ_{31P} -146 ppm, which corresponds to the starting monoamidophosphite (the signal disappears after the exothermic effect), the doublet δ_{31P} -8 ppm, $J_{P,H}$ 680 Hz, which was assigned to HP(O)(OC₂H₅)₂ (is retained after the exothermic effect), and the signal δ_{31P} -30 ppm, which corresponds to ester (VI), and is retained after the exothermic effect but decreases markedly after distillation of the reaction mixture, since (VI) is transformed to (VII) [2]. The signal δ_{31P} -48 ppm in the ³¹P NMR spectrum corresponds to product (VII).

Analogous data were obtained when the reaction mixture was studied employing GLC and IR spectro-scopy.

As a result, from the presented data it follows that attack occurs at both the N atom and the P atom, with the respective formation of (V) and $HPO(OC_2H_5)_2$, and (VI) and $(C_2H_5)_2NH$, since the formation of (VII) and alcohol from (VI) during distillation is a secondary process. The obtained data make it possible to depict the process by the scheme:

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Analogous products are formed when (I) is reacted with (III) or (IV). However, these reactions have a number of specific traits. Thus, the reaction of (I) with (III) is accompanied by the disproportionation of (III). This is corroborated by the fact that the ³¹P NMR spectrum of the reaction mixture, recorded after the addition of (III), has signals with δ_{31P} -136 ppm for (III), and -147 ppm for (II); also a doublet with a constant $J_{P,H}$ 612 Hz for diethylamidoethylphosphorous acid.

In order to identify the latter compound we took the spectrum of an authentic specimen of the acid [7]; the spectrum contains an analogous doublet. Changes in the ³¹P NMR spectrum are not observed after the exothermic effect. However, after distillation there appear a doublet with $\delta_{31P} - 8$ ppm and $J_{P, H}$ 680 Hz, which corresponds to HPO(OC₂H₅)₂, and a signal with $\delta_{31P} - 118$ ppm for (IV). Similar cases of the disproportionation of amidophosphites are described in [8, 9].

In addition, a superimposition of the signals of δ_{31P} -48 ppm and of the doublet at -47 and +9 ppm, with J_{P,H} 570 Hz, is observed in the ³¹P NMR spectrum of the reaction mixture composed of (I) and (IV), which belong respectively to (VII) and bis(diethylamido)phosphorous acid, and this makes it impossible to judge when the formation of phosphaindan (VII) occurs.

As a result, the presented data show the existence of two reaction centers in amidophosphites.

EXPERIMENTAL METHOD

The ³¹P NMR spectra were taken on a KGU-4 NMR spectrometer (10.2 MHz) relative to 85% H₃PO₄. Prior to the experiments, the ester amides and triamide of phosphorous acid were distilled over sodium.

Reaction of o-Hydroxybenzyl Alcohol (I) with Diethyl Diethylamidophosphite (II). To 18.6 g of (I) in 40 ml of absolute petroleum, in a dry nitrogen stream, 29.05 g of (II) was added in drops. The mixture was stirred at 50°. At the conclusion of the addition the temperature of the mixture was kept at 50-55° for 20 min, after which the solution became homogeneous. Then samples were removed from the reaction mixture for study by IR and ³¹P NMR spectroscopy and GLC.

After removal of the solvent in vacuo the residue was distilled. Here we isolated: 1) 8 g of a low boiling fraction, which was trapped at -180° and had n_D^{20} 1.4075; 2) 7.4 g of a fraction with bp 44-70° (0.09 mm); 3) 11.2 g of a fraction with bp 72-85° (0.06 mm); 4) 9.7 g of a fraction with bp 90-112° (0.06 mm). The residue from the distillation weighed 3.7 g. From the first fraction we isolated 3.5 g of diethylamine, 1.1 g of ethanol, 1.3 g of triethyl phosphite and 1.5 g of diethylphosphorous acid with bp 64-65° (10 mm); n_D^{20} 1.4085. Found: P 22.20%. C₄H₁₁O₃P. Calculated: P 22.45%.

From the second fraction we isolated 5 g (25%) of diethylphosphorous acid with bp 64-65° (10 mm); n_D^{20} 1.4085. From the third fraction, after several distillations, we isolated 8 g (30%) of (V) with bp 68-70° (0.022 mm); n_D^{20} 1.5150. Found: N 7.41%. $C_{11}H_{17}$ NO. Calculated: N 7.82%. From the fourth fraction we isolated 3.5 g (12%) of (VII) with bp 105-107° (0.02 mm); n_D^{20} 1.5265. Found: P 15.46%. $C_9H_{11}O_3$ P. Calculated: P 15.66% (cf. [5]), and 3 g of a mixture of (VI) and (VII) with bp 107-112° (0.02 mm); n_D^{20} 1.5215. Found: P 14.65%.

Reaction of o-Hydroxybenzyl Alcohol (I) with Ethyl Bis(diethylamido)phosphite (III). To 18.6 g of (I) in 40 ml of absolute petroleum ether at $\leq 40-50^{\circ}$, 33 g of (III) was added in drops. The mixture was heated at 60° for 30 min. Then samples were removed for study by IR and ³¹P NMR spectroscopy. After removal of the solvent in vacuo the reaction mixture was distilled. Here we isolated: 1) 13 g of a low boiling fraction, which was trapped at -180° and had n_D^{20} 1.3932; 2) 7 g of a fraction with bp 30-70° (0.048 mm); 3) 11.7 g of a fraction with bp 75-85° (0.048 mm); 4) 5.5 g of a fraction with bp 100-120° (0.045 mm). Further fractional distillation was accompanied by marked decomposition and the tarry residue weighed 12.4 g.

From the first fraction we isolated 5 g of diethylamine, 1.5 g of triethyl phosphite, and 4 g of diethylphosphorous acid. From the second fraction we isolated 5.2 g (26%) of diethylphosphorous acid. From the third fraction after several distillation we isolated 7.5 g (28%) of (V). From the fourth fraction by repeated distillation we isolated 3.5 g (10.5%) of 2-oxo-2-diethylamido-1-oxa-2-phosphaindan with bp 103-105° (0.02 mm); n_D^{20} 1.5275. Found: C 58.22; H 7.59; P 13.50; N 6.32%. C₁₁H₁₆O₂P. Calculated: C 58.66 H 7.18; P 13.78; N 6.22%.

Reaction of o-Hydroxybenzyl Alcohol (I) with Tris(diethylamido)phosphite (IV). To 18.6 g of (I) in 50 ml of absolute petroleum ether was added 37.05 g of (IV) in drops at 40°. The mixture was kept at 40-50° for 30 min. Then samples were removed from the reaction mixture for study by IR and ³¹ P NMR spectroscopy. After removal of the solvent in vacuo the mixture was distilled. Here we isolated: 1) 10 g of a fraction that was trapped at -180° and has n_D^{20} 1.3870; 2) 8.5 g of a fraction with bp 46-70° (0.03 mm); 3) 13 g of a fraction with bp 75-90° (0.03 mm); 4) 8 g of a fraction with bp 115-135° (0.03 mm). Further fractional distillation was accompanied by decomposition; the tarry residue weighed 9 g. After repeated distillations we obtained 6 g of diethylamine, 5 g (17%) of bis(diethylamido)phosphorous acid [7] with bp 62-64° (0.04 mm); n_D^{20} 1.4545; 8 g (30%) (V); 4.5 g (13%) (VII) with bp 108-110° (0.03 mm); n_D^{20} 1.5280.

CONCLUSIONS

1. A study was made of the reaction of o-hydroxylbenzyl alcohol with diethyl diethylamidophosphite, ethyl bis(diethylamido)phosphite, and tris(diethylamido)phosphite.

2. It was established that in nucleophilic substitution reactions both the phosphorus atom and the nitrogen atom in the ester amides and amides of phosphorous acid can function as the nucleophilic center.

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