SYNTHESIS OF ALKYL- AND ARYL(o-OXYPHENOXYMETHYL) PHOSPHINIC ACIDS

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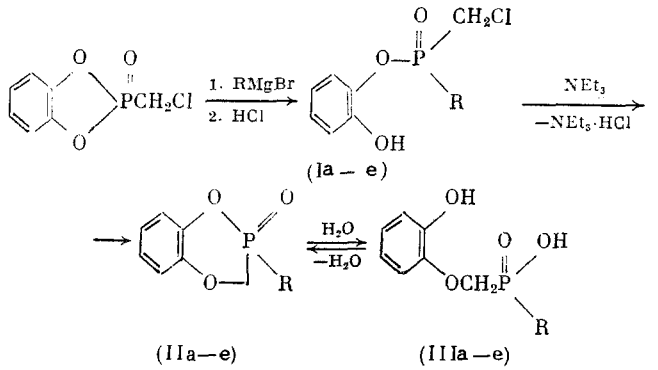
Convenient starting materials for the synthesis of phosphorus-containing podands are mono-α-phosphinylalkylated pyrocatechols [1-4], including derivatives of α-(o-oxyphenoxy)-alkylphosphonic acids [4]. The latter are also interesting as complexing agents for metal cations, in particular, rare earth elements [5].

In this work, a method for synthesis of alkyl- and aryl(o-oxyphenoxymethyl)phosphinic acids (III), having two phosphorus–carbon bonds, is described. Cleavage of 2-oxo-2-chloromethyl-1,3,2-benzodioxaphosphole by Grignard reagents (instead of NaOH [4]) with subsequent neutralization of HCl leads to o-oxyphenyl esters (Ia-e), which upon boiling in toluene in the presence of triethylamine cyclize with formation of 2-oxo-2-R-3H-1,4,2-benzodioxaphosphorines (IIa-e)



R = Et (a), Bu (b) C_8H_{17} (c), Ph (d), C_6H_4Me-*p* (e).

It should be mentioned that the Mg salt which is formed upon reaction of the Grignard reagent does not undergo intramolecular alkylation. Thus, for example, after boiling the reaction product of the starting phosphole with PhMgBr in toluene (~2 h) and subsequent acidification, only the ester (Id) (70%) was isolated. Apparently, the intermediate which arises (up to neutralization of HCl) is analogous to the product which is formed upon reaction of 2-oxo-2-phenyl-1,3,2-dioxaphospholane with PhMgBr [6], in which the Mg atom is bonded not to the phenol O atom but to the phosphoryl group.

The cyclic esters (IIa-e) are very easily hydrolyzed to the phosphinic acids (IIIa-e). Cleavage of the phosphorine ring is observed even in air and upon column chromatography of the esters (II). The compounds (III) as well as the α-(o-oxyphenoxy)alkylphosphonic acids [4] are able to eliminate water on boiling in xylene, quantitatively reverting to the phosphorines (II).

EXPERIMENTAL

NMR spectra were recorded on a Bruker CXP-200 instrument. Chemical shifts of ^1H and ^{31}P were determined relative to TMS and 85% H_3PO_4. Melting points were measured on a Boetius-PHMK instrument. Column chromatography used silica gel L 100-250 μm, and TLC, Silufol (eluting system of methylethylketone:heptane, 1:1). Yields, constants, and elemental analysis of the compounds produced are given in Table 1, NMR data, in Table 2.

o-Oxyphenylesters of Alkyl- and Aryl(chloromethyl)phosphinic Acids (Ia-e). Grignard reagent (from 94 mmoles alkyl- or arylbromide and 120 mg·at Mg in 60 ml ether) was added dropwise with stirring to 75 mmoles 2-oxo-2-chloromethyl-1,3,2-benzoxaphosphole [4] in 50 ml anhydrous THF at −15°C. The mixture was stirred for 3 h at 20°C. After addition of 100 ml

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TABLE 1. Constants, Yields, and Elemental Analyses of the Compounds

Compound	Yield,[a] %	Bp, °C (p, mm Hg) Mp, °C (solvent)	Found, %				Empirical formula	Calculated, %			
			C	H	Cl	P		C	H	Cl	P
(Ia)	57	79–80 (toluene)	46,0	5,3	15,0	12,9	$C_9H_{12}ClO_3P$	46,1	5,2	15,1	13,2
(Ib)	66	56–57 (cyclohexane)	49,9	6,0	13,6	11,6	$C_{11}H_{16}ClO_3P$	50,3	6,1	13,5	11,8
(Ic)	73	Oil[b]	56,7	7,9	10,9	9,4	$C_{15}H_{24}ClO_3P$	56,5	7,6	11,1	9,7
(Id)	70	117–119 (toluene)	54,9	4,3	12,5	10,8	$C_{13}H_{12}ClO_3P$	55,2	4,3	12,5	11,0
(Ie)	61	116–119 (toluene)	56,7	4,5	11,9	10,2	$C_{14}H_{14}ClO_3P$	56,7	4,8	12,0	10,4
(IIa)	74	103–104 subl.	54,6	5,7	–	15,5	$C_9H_{11}O_3P$	54,6	5,6	–	15,6
(IIb)	Quantitative[c]	48–49 (cyclohexane)	58,6	6,7	–	13,4	$C_{11}H_{15}O_3P$	58,4	6,7	–	13,7
(IIc)	64	Oil[b]	64,0	8,4	–	10,8	$C_{15}H_{23}O_3P$	63,8	8,2	–	11,0
(IId)	89	165 (1)[d]	–	–	–	–	$C_{13}H_{11}O_3P$	–	–	–	–
(IIe)	83[c]	190–191 (2); 82–83 (cyclohexane-ether)	64,8	4,8	–	11,6	$C_{14}H_{13}O_3P$	64,6	5,0	–	11,9
(IIIa)	Quantitative	98–100 (benzene)	50,1	6,2	–	14,0	$C_9H_{13}O_4P$	50,0	6,1	–	14,3
(IIIb)	75 e	128–130 (methylethylketone)	54,1	6,9	–	12,4	$C_{11}H_{17}O_4P$	54,1	7,0	–	12,7
(IIIc)	84 e	131–132 (methylethylketone)	60,3	8,6	–	10,2	$C_{15}H_{25}O_4P$	60,0	8,4	–	10,3
(IIId)	89 e	180–183 (alcohol)[d]	–	–	–	–	$C_{13}H_{13}O_4P$	–	–	–	–
(IIIe)	80 e	165–168 (methylethylketone)	61,0	5,4	–	10,9	$C_{14}H_{15}O_4P$	60,4	5,4	–	11,3

[a]For crystalline compounds the yields are given for products whose melting points did not differ from the analytical sample by more than 5%.
[b]R_f 0.79 (Ic), 0.50 (IIc). Yield is given for the product after chromatographic purification.
[c]For (IIb, e) the yield is indicated for starting (IIIb, e).
[d]See [4].
[e]For (IIIb-e) the yield is indicated for starting (Ib-e).

TABLE 2. ^{1}H and ^{31}P NMR Spectra (δ, ppm) for the Compounds[a]

Compound	Solvent	^{1}H NMR spectrum					^{31}P NMR spectrum
		R	CH_2P, d		C_6H_4, m	OH, s	
			δ	$^{2}J_{HP}$, Hz			
(Ia)	$CDCl_3$	1,32 d.t (3H), 2,18 q (2H)	3,67	8	6,86 (1H), 7,09 (3H)	8,13 (1H)	58,71
(Ib)	$CDCl_3$	0,97 t (3H), 1,48 m (2H), 1,71 m (2H), 2,17 m (2H)	3,62	8	6,87 (1H), 7,09 (3H)	7,83 (1H)	58,26
(Ic)	$CDCl_3$	0,90 t (3H), 1,30 m (8H), 1,45 m (2H), 1,76 m (2H), 2,17 m (2H)	3,65	8	6,86 (1H), 7,10 (3H)	7,56 (1H)	57,96
(Id)	$CDCl_3$	7,59 m (3H), 8,00 d.d (2H)	3,85 [b], 3,91 [b]	8, 9	6,81 (1H), 7,03 (2H), 7,13 (1H)	8,23 (1H)	40,33
(Ie)	$CDCl_3$	2,44 s (3H), 7,35 d.d (2H), 7,88 d.d (2H)	3,77 [b] 3,89 [b]	6, 9	6,81 (1H), 7,03 (2H), 7,12 (1H)	8,20 (1H)	41,00
(IIa)	$CDCl_3$	1,30 d.t (3H), 2,03 q (2H)	4,11 [b], 4,60 [c]	8	7,00	–	41,53
(IIb)	$CDCl_3$	0,95 t (3H), 1,48 sext (2H), 1,72m (2H), 2,05 m (2H)	4,11 [b], 4,56 [c]	8	7,02	–	40,42
(IIc)	Acetone-d_6	0,88 t (3H), 1,26 m (8H), 1,42 m (2H), 1,69 m (2H), 2,01 m (2H)	4,15 [b] 4,76 [c]	8	7,06	–	39,40
(IIe)	C_6D_6	1,90 s (3H), 6,82 d.d (2H), 7,77 d.d (2H)	3,89 [b], 4,11 [b]	7, 1	6,70 (2H), 6,93 (2H)	–	23,66
(IIIa)	$CDCl_3$	1,21 d.t (3H), 1,96 m (2H)	4,26	7	6,87	9,08 (2H)	50,88
(IIIb)	DMSO-d_6	0,98t (3H), 1,38 m (2H), 1,49 m (2H), 1,75 m (2H)	4,12	7	6,78 (3H), 7,00 (1H)	5,92 (2H)	44,16
(IIIc)	DMSO-d_6	0,86 t (3H), 1,24 m (10H), 1,53 m (2H), 1,80 m (2H)	4,14	8	6,79 (3H), 7,00 (1H)	5,55 (2H)	44,13
(IIIe)	DMSO-d_6	2,38 s (3H), 7,33 d.d (2H), 7,75 d.d (2H)	4,28	8	6,70 (1H), 6,79 (2H), 6,93 (1H)	5,15 (2H)	29,36

[a] Spectral characteristics of (IId) and (IIId) are given in [4].
[b] d.d (1H, $^{2}J_{HH}$ = 14 Hz).
[c] d (1H, $^{2}J_{HH}$ = 14 Hz).

$CHCl_3$, it was decomposed with 100 ml 5% HCl. The organic layer was dried with Na_2SO_4 and evaporated in vacuum. Recrystallization of the residue from toluene gave the esters (Id, e). Compounds (Ia-c) were isolated by column chromatography; eluent for (Ia), toluene:acetone, 10:1; for (Ib), toluene:acetone, 20:1; and for (Ic), toluene.

2-Oxo-2-alkyl(aryl)-3H-1,4,2-benzodioxaphosphorines (IIa, c, d). A mixture of 30 mmoles ester (I) and 30 mmoles NEt_3 in 50 ml toluene was boiled with stirring for 5 h, cooled, the precipitate filtered, and the solution evaporated in vacuum. Phosphorine (IIa) was obtained by recrystallization of the residue from benzene. Compound (IIc) was isolated by column chromatography (eluent, benzene). (IId) was obtained by distillation. (IIb, e), and also (IIc, d), underwent hydrolysis without isolation (see below).

Alkyl- and Aryl(o-oxyphenoxymethyl)phosphinic Acids (IIIa-e). Phosphorine (IIa, 80 mmoles) was dissolved in a mixture of benzene–$CHCl_3$, 1:1, and left in air for 3 days. The precipitate which formed was separated and recrystallized. Acids (IIIb-e) were obtained analogously from reactions of compounds (IIb-e).

Cyclization of Acids (IIIb, e) into Phosphorines (IIb, e). A suspension of 30 mmoles acids (IIIb, e) in 50 ml xylene was boiled for 4 h with a Dean–Stark trap (until cessation of water evolution). The solution obtained was evaporated in vacuum, and the residue recrystallized (IIb) or distilled (IIe).

CONCLUSIONS

Cleavage of 2-oxo-2-chloromethyl-1,3,2-benzodioxaphosphole by Grignard reagents produced pyrocatechol esters of alkyl- and aryl(chloromethyl)phosphinic acids, cyclization of which and subsequent hydrolysis lead to alkyl- and aryl(o-oxyphenoxymethyl)phosphinic acids.

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SYNTHESIS OF P, B-CONTAINING HETEROCYCLES BASED ON BIS(α,2-DIHYDROXYBENZYL)PHENYLPHOSPHINE

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Reaction of bis- and tris(α-hydroxyalkyl)phosphines and their derivatives with esters or anhydrides of boric acids in the presence of amines is a promising method for the synthesis of P,B-containing heterocycles with four-coordinate boron atoms. Using this route, 4,6-disubstituted ammonium 1,3,2,5-dioxaborataphosphorinanes and their derivatives [1-3] as well as pyridinium 1-phenyl-3,5,8-tris(trichloromethyl)-1-borata-2,6,7-trioxa-4-phosphabicyclo[2.2.2]-octane [4] have been obtained. The products were isolated in complex or salt form [1-4]. Use of aromatic o-hydroxyaldehydes opens new synthetic possibilities. This was shown in [5], where triethylammonium 1,4-diphenyl-3-(o-hydroxyphenyl)-2,8,9-trioxa-1-borata-4-phospha-6,7-benzobicyclo[3.3.1]non-6-ene (1) was obtained from phenylphosphine, salicylaldehyde, the anhydride of phenylboric acid, and triethylamine. The structure of this compound was found by

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