SYNTHESIS AND ^1H AND ^{31}P NMR SPECTRAL CHARACTERISTICS OF 2-SUBSTITUTED AND 2,2-DISUBSTITUTED 5-PHENYL-5-THIO-1,3,5-DIOXAPHOSPHORINANES

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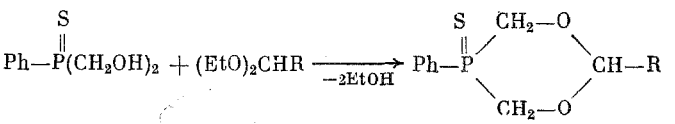
Bis(α-hydroxyalkyl)phosphines readily form heterocycles upon treatment with various electrophilic and nucleophilic reagents [1] but such reactions for their derivatives are extremely rare. Treatment of phenyl(benzyl)bis(α-hydroxybenzyl)phosphine oxides with PhCHO and methylbis(hydroxymethyl)phosphine oxide with paraformaldehyde led respectively to 5-phenyl(benzyl)-5-oxo-2,4,6-triphenyl-1,3,5-dioxaphosphorinanes [2, 3] and to 5-methyl-5-oxo-1,3,5-dioxaphosphorinane [4]. 4,6-Disubstituted-5-phenyl-5-oxo-1,3,2,5-dioxaboraphosphorinane [5] was obtained from phenylbis(α-hydroxyalkyl)phosphine oxides and phenylboric anhydride. In the presence of tertiary amines phenylbis(α-hydroxyalkyl)phosphine oxides, sulfides and selenides with isobutyl diphenylborate gave ammonium 5-phenyl-5-oxo(thio, seleno)-1,3,2,5-dioxaborataphosphorinanes with substituents in positions 4 and 6 [6-8].

It is known that orthoesters, acetals, and ketals are more active towards reaction with bis(α-hydroxyalkyl)phosphines than are esters, aldehydes, and ketones. Thus phenylbis(hydroxymethyl)phosphine does not react with aldehydes or ketones on heating [9] but under the same conditions is converted to substituted 5-phenyl-1,3,5-dioxaphosphorinanes by $HC(OEt)_3$, acetals, and ketals [10, 11]. It was therefore of interest to introduce these reagents into the reactions with bis(α-hydroxyalkyl)phosphines. We have already shown that phenylbis(hydroxymethyl)phosphine sulfide reacts with $PhCH(OEt)_2$ to form 2,5-diphenyl-5-thio-1,3,5-dioxaphosphorinane [12].

The reactions of bis(α-hydroxyalkyl)phosphines and derivatives with acetals and ketals led correspondingly to 2-substituted and 2,2-disubstituted 1,3,5-dioxaphosphorinanes. 2,2-Dialkyl(diaryl)substituted 5-phenyl-1,3,5-dioxaphosphorinanes were obtained from phenyl(hydroxymethyl)phosphine and ketals. However, reactions with acetals occurred principally at the P atom and it was not possible [11] to prepare 2-alkyl(aryl) substituted 5-phenyl-1,3,5-dioxaphosphorinanes. The nucleophilicity of the P atoms is lowered in derivatives of phenylbis(hydroxymethyl)phosphine and it might be expected in this case that both types of compound would be formed.

In this paper we have studied the reactions of phenylbis(hydroxymethyl)phosphine sulfide (PHPS) with acetals and ketals. Reaction with the diethyl acetals of furfural, cinnamaldehyde, p-methoxy and p-ethoxybenzaldehydes and 3-ethoxybutyraldehyde at 140-180°C without solvent was carried out until completion of distillation of the evolved EtOH. In all cases 2-substituted 5-phenyl-5-phenyl-5-thio-1,3,5-dioxaphosphorinanes were produced



R =  (I), PhCH=CH (II), C_6H_4OMe-*p* (III), C_6H_4OEt-*p* (IV).

In the case of the diethylacetal of 3-ethoxybutyraldehyde three molecules of EtOH were eliminated and an unsaturated substituent at position 2 produced.

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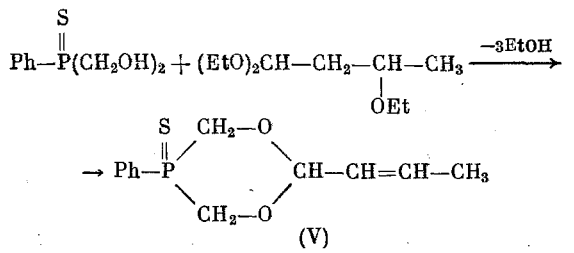
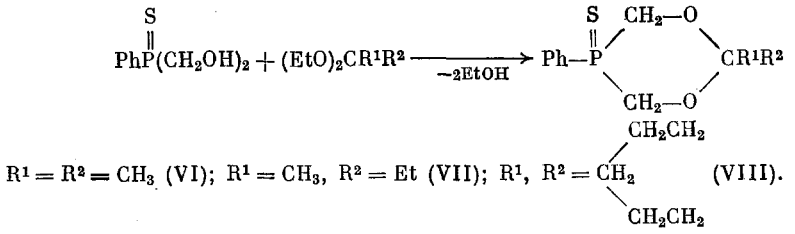


(V)

In this series the most ready and complete reaction was that with cinnamaldehyde diethylacetal giving a fully crystalline product which was pure according to ^{31}P NMR spectral data.

Reaction of PHPS with the diethylketals of acetone, ethylmethyl ketone and cyclohexanone also proceeds without solvent at 140-180°C to give 2,2-disubstituted 5-phenyl-5-thio-1,3,5-dioxaphosphorinanes.



$R^1 = R^2 = CH_3$ (VI); $R^1 = CH_3$, $R^2 = Et$ (VII); R^1, $R^2 = CH_2CH_2CH_2CH_2CH_2$ (VIII).

^{31}P NMR spectra data showed the yield of VI to be virtually quantitative.

The IR spectra of I-VIII showed the absence of absorption in the 3100-3600 cm^{-1} region. The signal for the P atom in the ^{31}P NMR spectra lies at higher field than for PHOS, this shift normally being observed on cyclization. Elemental analytical data was in agreement with the proposed structure and the PMR spectral parameters supported cyclization.

Compounds I-V and VII can exist as stereoisomers differing in the substituent orientation on the P and C atoms. V and VIII are a mixture of conformers. The three dimensional structure was determined by PMR spectroscopy and the NMR spectral parameters are given in Table 1.

The spectra of the ring methylene protons show a pattern characteristic of an $(AB)_2X$ coupled system where A and B are the axial and equatorial protons 4 and 6 and X is the P atom. The non-equivalence of these methylene protons points to a predominantly chair conformation of the six membered ring with change in orientation of the substituents on P and C atoms with inversion. The similarities in the spin-spin coupling constants (J_{AX} or J_{BX}) throughout the series indicates a common orientation of the P-Phenyl substituent.

The orientation of the P-Phenyl was established by comparison of the PMR spectra of I-VIII with the model compounds 5-phenyl-5-thio-1,3,5-dioxaphosphorinane (J_{AX} = −6.8, J_{BX} = 0.0 Hz [9]) and 2,5-diphenyl-5-thio-1,3,5-dioxaphosphorinane (J_{AX} = −7.1, J_{BX} = −0.6 Hz [12]). Dipole moment data showed that the phenyl in the model compounds occurred in the axial position and the good agreement in spin-spin couplings (J values) between the model and investigated compounds suggested that the P-Phenyl in I-VIII also occupies an axial position. An equatorial orientation of the phenyl in 5-phenyl-5-thio-1,3,5-dioxaphosphorinanes leads to a $^2J_{PH}$ value in the range 13-15 Hz [13]. The ^{31}P chemical shifts in the model compounds were 8 ppm [9, 12].

Comparison of chemical shifts in the ^{31}P NMR spectra of I-VIII (Table 1) and the model compounds allows determination of the substituent orientation on the C atom in I-V and VII. There was a marked difference for the 2-substituted and 2,2-disubstituted compounds. In the latter, one of the substituents is axial. Consequently the substituent in I-V is orientated equatorially. This is confirmed by the absence of substituent effects on the chemical shifts in the series I-V, being the same as the unsubstituted compound. The stereoisomers of VII have the same orientation of the P substituent but differ in the C substituent. The signal for the stereoisomer with the smaller sterically demanding axial substituent lies at higher field.

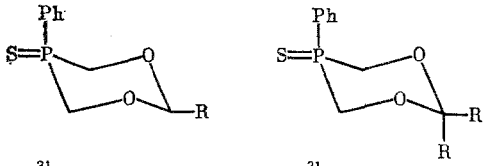
TABLE 1. NMR Spectral Data for I-VIII (δ, ppm; J, Hz)

Compound	Solvent	$\delta^{31}P$	δ_A	δ_B	$-J_{AX}$	$-J_{BX}$
(I)	CCl_4	8	4.58	4.47	7.1	0.6
(II)	CCl_4	8	4.58	4.47	7.1	0.9
(III)	CCl_4	8	4.64	5.54	6.4	1.6
(IV)	C_6H_6	8	4.28	4.18	6.4	1.6
(V)	CCl_4	8	4.42	4.30	7.1	0.9
(VI)	CCl_4	22	4.25	4.36	4.4	2.8
(VII) *	CCl_4	16, 21 (21)	4.21	4.32	4.4	2.8
		(16)	4.24	4.34	7.9	1.0
(VIII)	CCl_4	20	4.26	4.36	7.1	0.7

*Mixture of stereoisomers.

As regards the high stability of forms with axially orientated P-Phenyl in I-VIII the stereoisomers I-V and VII are the only products of the reactions (which was carried out under conditions of thermodynamic control). VI and VII are themselves conformers. The effects of the oxygen atom on the orientation of the P substituent in 1,3,5-dioxaphosphorinanes and derivatives have been discussed in [14] and find new confirmation here.

As a result of the axial P-Phenyl in I-VIII the 2-substituted and 2,2-disubstituted compounds lead to clarification of the NMR spectral characteristics of 1,3,5-dioxaphosphorinances with and without an axial substituent on carbon 2. Comparison of the PMR parameters for the methylene protons shows that a characteristic axial substituent effect on the $^2J_{PH}$ value is absent. The changes in relative chemical shifts of the methylene signals after additional verification may probably be used as a diagnostic test for establishing the substituent orientation, tending to show an anomeric effect. An axial substituent shifts the ^{31}P NMR signal by 8-14 ppm to low field depending on the steric demand of that substituent. This marked effect can undoubtedly be used both to find the orientation of the substituent in position 2 of the stereoisomers and as a typical interaction for the axial substituent. The stereoisomer with the equatorial substituent has the signal shifted to higher field and that with the axial substituent to lower field to an extent dependent upon the magnitude of the substituent steric demand.



$\delta^{31}P$ 8 ppm $\delta^{31}P$ 16-22 ppm

In [12] the sulfides and selenides of 5-phenyl-5-ethoxy-1,3,5-dioxaphosphorinane was obtained in the form of two isomers differing in the ethoxy group orientation. On the basis of comparing the $^2J_{PH}$ values together with constants for the corresponding stereoisomers of 2,4,6-trisubstituted 5-phenyl-5-thio-1,3,5-dioxaphosphorinanes, 4,6-disubstituted 5-phenyl-5-thio-1,3,2,5-dioxaboraphosphorinanes, and their pyridine complexes (where the flattened acetal fragment led to a lower constant) the stereoisomer with the lower $^2J_{PH}$ value was assigned to have an axial ethoxy group. The ^{31}P NMR signals for these stereoisomers were at weaker fields and this was in agreement with the criteria given above thus confirming the assignments given in [12].

EXPERIMENTAL

^{31}P NMR Spectra were recorded at 10.2 MHz on a KGU-4 spectrometer with proton noise decoupling at 25.2 MHz. Chemical shifts are given relative to 85% H_3PO_4 (negative values to higher field). PMR Spectra were measured on a Varian T60 machine at 34.5°C.

2-(2-Furyl)-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (I). A mixture of PHPS (5.41 g, 0.026 mole) and furfural diethylacetal (4.42 g, 0.026 mole) were heated at 140°C until distillation of alcohol ceased. The residue (60%) was a liquid with a $\delta^{31}P$ chemical shift of 8

ppm. A pure sample (mp 106°C) was obtained by chromatography on silica gel (eluant ether: pet. ether 1:4) and also had δ^{31} of 8 ppm (benzene). Found: C 56.10; H 4.76; P 10.67; S 11.40%. $C_{13}H_{13}PO_3S$. Calculated: C 55.71; H 4.64; P 11.07; S 11.42%.

2-Styryl-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (II). A mixture of PHPS (6.25 g, 0.03 mole) and cinnamaldehyde diethylacetal (6.37 g, 0.03 mole) were heated at 140°C until distillation ceased. The residue was recrystallized from MeCN to give 7.8 g (80%) with mp 141°C and δ^{31}P 8 ppm (benzene). Found: C 64.70; H 5.4; P 9.40; S 10.10%. $C_{17}H_{17}PO_2P$. Calculated: C 64.55; H 5.37; P 9.81; S 10.12%.

2-(p-Methoxyphenyl)-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (III). A mixture of PHPS (6.65 g, 0.035 mole) and p-methoxybenzaldehyde diethylacetal (7.54 g, 0.035 mole) were heated at 180°C until alcohol distillation ceased leaving a liquid (80%) with δ^{31}P 8 ppm (benzene). Chromatography on silica gel (eluant ether:pet. ether 1:3) yielded pure product with mp 121°C and δ^{31}P 8 ppm (benzene). Found: C 59.78; H 5.38; P 9.79; S 10.19%. $C_{16}H_{17}PO_3S$. Calculated: C 60.00; H 5.31; P 9.68; S 10.00%.

2-(p-Ethoxyphenyl)-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (IV). A mixture of PHPS (4.03 g, 0.02 mole) and p-ethoxybenzaldehyde diethylacetal (4.48 g, 0.02 mole) were heated at 180°C until alcohol distillation ceased leaving a liquid (80%) with δ^{31}P 8 ppm. Chromatography on silica gel (eluant ether: pet. ether 1:4) yielded pure product with mp 100°C and δ^{31}P 8 ppm (benzene). Found: C 60.62; H 5.67; P 9.30; S 9.92 %. $C_{17}H_{19}PO_3S$. Calculated: C 61.07; H 5.68; P 9.28; S 9.58%.

2-Propenyl-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (V). A mixture of PHPS (4.03 g, 0.02 mole) and 3-ethoxybutyraldehyde diethylacetal (4.6 g, 0.02 mole) were heated at 180°C until alcohol distillation ceased leaving a liquid (80%) with δ^{31}P 8 ppm. Chromatography on silica gel (eluant ether: pet. ether 1:4) yielded pure product with mp 95°C and δ^{31}P 8 ppm (benzene). Found: C 56.52; H 5.97; P 11.80; S 12.82%. $C_{12}H_{15}PO_2S$. Calculated: C 56.89; H 5.90; P 12.20; S 12.59%.

2,2-Dimethyl-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (VI). A mixture of PHPS (5 g, 0.025 mole) and acetone diethylketal (3.3 g, 0.025 mole) were heated at 140°C until alcohol distillation ceased leaving a liquid with δ^{31}P 22 ppm (100% yield). Chromatography on silica gel (eluant ether: pet. ether 1:4) yielded pure product with mp 73°C and δ^{31}P 22 ppm (benzene). Found: C 54.64; H 6.24; P 12.29; S 13.35%. $C_{11}H_{15}PO_2S$. Calculated: C 54.54; H 6.19; P 12.80; S 13.22%.

2-Methyl-2-ethyl-5-phenyl-5-thio-1,3,5-dioxaphosphorinane (VII). A mixture of PHPS (5.68 g, 0.028 mole) and methylethyl ketone diethylketal (4.1 g, 0.028 mole) were heated at 140°C until alcohol distillation ceased leaving a liquid (78%) with δ^{31}P 16 and 21 ppm. Chromatography on silica gel (eluant ether: pet. ether 1:4) yielded pure product with mp 48-50°C and δ^{31}P 16, 21 ppm. Found: C 56.33; H 6.52; P 12.36; S 12.68%. $C_{12}H_{17}PO_2S$. Calculated: C 56.25; H 6.64; P 12.10; S 12.50%.

5-Phenyl-5-thio-1,3,5-dioxaphosphaspiro [5,5] undecane (VIII). A mixture of PHPS (4.96 g, 0.025 mole) and cyclohexane diethylketal (4.22 g, 0.025 mole) were heated at 140°C until alcohol distillation ceased leaving a liquid (60%) with δ^{31}P 20 ppm. Chromatography on silica gel (eluant ether: pet. ether 1:4) yielded pure product with mp 63°C and δ^{31}P 20 ppm (benzene). Found: C 59.89; H 6.60; P 11.05; S 11.39%. $C_{14}H_{19}PO_2S$. Calculated: C 59.57; H 6.73; P 10.99; S 11.34%.

CONCLUSIONS

Treatment of phenylbis(hydroxymethyl)phosphine sulfide with acetals and ketals gives the corresponding 2-substituted and 2,2-disubstituted 5-phenyl-5-thio-1,3,5-dioxaphosphorinanes in which the P-Phenyl substituent occupies an axial position.

LITERATURE CITED

1. O. A. Erastov and G. N. Nikonov, Usp. Khim., 53, 625 (1984).
2. B. A. Arbuzov, O. A. Erastov, S. Sh. Khetagurova, and T.A. Zyablikova, Izv. Akad. SSSR, Ser. Khim., 2136 (1979).
3. A. B. Pepperman, G. J. Boaduaux, and T. H. Siddall, J. Org. Chem., 40, 2056 (1975).
4. R. K. Valetdinov, A. N. Zuikova, T. A. Zyablikova, and A. V. Il'yasov, Zh. Obshch. Khim., 48, 97 (1978).

5. B. A. Arbuzov, O. A. Erastov, G. N. Nikonov, I. P. Romanova, R. P. Arshinova, and R. A. Kadyrov, Izv. Akad. Nauk SSSR, Ser. Khim., 1374 (1983).
6. B. A. Arbuzov, G. N. Nikonov, and O. A. Erastov, Izv. Akad. Nauk SSSR, Ser. Khim., 2362 (1985).
7. B. A. Arbuzov, G. N. Nikonov, and O. A. Erastov, Izv. Akad. Nauk SSSR, Ser. Khim., 2369 (1985).
8. B. A. Arbuzov, G. N. Nikonov, and O. A. Erastov, Izv. Akad. Nauk SSSR, Ser. Khim., 171 (1986).
9. B. A. Arbuzov, O. A. Erastov, S. Sh. Khetagurova, T. A. Zyablikova, R. P. Arshinova, and R. A. Kadyrov, Izv. Akad. Nauk SSSR, Ser. Khim., 1626 (1980).
10. B. A. Arbuzov, O. A. Erastov, and A. S. Ionkin, Izv. Akad. Nauk SSSR, Ser. Khim., 418 (1986).
11. B. A. Arbusov, O. A. Erastov, and A. S. Ionkin, Izv. Akad. Nauk SSSR, Ser. Khim., 2506 (1986).
12. B. A. Arbuzov, O. A. Erastov, A. S. Ionkin, and S. N. Ignat'eva, Izv. Akad. Nauk SSSR, Ser. Khim., 640 (1986).
13. B. A. Arbuzov, O. A. Erastov, G. N. Nikonov, and A. S. Ionkin, Izv. Akad. Nauk SSSR, Ser. Khim., 2501 (1984).
14. O. A. Erastov and G. N. Nikonov, in: Conformational Analysis of Organoelemental Compounds [in Russian], Nauka, Moscow, pp. 124-154.

SYNTHESIS AND VIBRATIONAL SPECTRA OF SOME 2-ALKOXY-5,6-BENZO-1,3,2-DIOXASTIBEPINES

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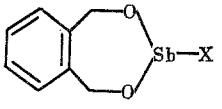
Spectral studies of 2-chloro and 2-alkoxy derivatives of 1,3,2-dioxastibinane indicate their tendency to self-association. In the crystalline state the degree of association is determined by steric factors [1]. In melt and in solution there is a polymer ⇌ dimer ⇌ monomer equilibrium for a number of compounds [2]. According to the ^1HNMR data the predominant molecular conformation of the 2-alkoxy derivatives of 1,3,2-dioxastibinane – 2-methoxy- and 2-tert-butoxy-5,6-benzo-1,3,2-dioxastibepine – in solution is the monomeric chair form with axial disposition of the exocyclic Sb–O bond (K-2a) [3].

The present article considers the vibrational spectra and molecular structure and presents more complete data on the synthesis of the seven-member ring compounds I-III:



where X = OMe (I), OEt (II), OBu-t (III). Transesterification of the respective Sb trialkoxides with phthalyl alcohol according to [4] gave the white crystalline materials I-III. Compound I forms as crystals that are insoluble in organic solvents and do not melt when heated above 250°C. Compounds II and III are unstable at room temperature in the crystalline state and in solution, and also when heated (see Experimental Part). Under conditions of cryoscopic determination of molecular weight, III exists as monomer in $CHBr_3$ and as dimer in camphor, according to results of the Rast method.

In order to study structure and association, the IR and Raman spectra of II and III in various aggregate states were obtained. Substantial spectral changes were established in the

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