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DIRECT NMR EVIDENCE OF THE AXIAL PREFERENCE OF THE SUBSTITUENT ON PHOSPHORUS IN 2-CHLORO- AND 2-METHOXY-1,2,3-DIOXAPHOSPHORINANES.

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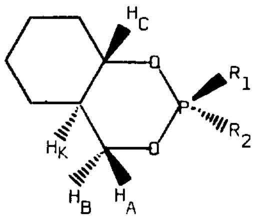
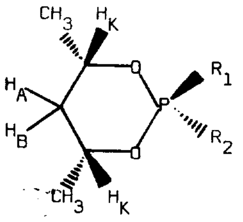
It was shown by NMR spectroscopy that the 1,3,2-dioxaphosphorinane cycle has a chair conformation (1,2,3). In tricoordinate phosphorus derivatives, the preferred orientation for the substituent on phosphorus (-OR or halogen) remains a subject of discussion. In fact, proofs of the preferred axiality have been given by different authors (2,4,5) but, until now, results obtained by NMR spectroscopy are insufficient to make a sure choice between axiality or equatoriality (1,3).

We have synthesized the phosphorochloridites I and I', the corresponding pairs of isomeric phosphites IIa, IIb and II'a, II'b and also the stable thiophosphates IIIa and IIIb, III'a and III'b.IIb and II'b are first obtained 95 % pure but, slowly, they give IIa and II'a. At equilibrium we have only IIa and II'a.



I	R_1 = Cl, R_2 = /	I'
IIa	R_1 = OCH_3, R_2 = /	II'a
IIb	R_1 = /, R_2 = OCH_3	II'b
IIIa	R_1 = OCH_3, R_2 = S	III'a
IIIb	R_1 = S, R_2 = OCH_3	III'b



/ ≡ lone pair

In this figure, as in the following, our configurational attribution is given, but obviously this attribution will only be justified by the end of the paper.

By the heteronuclear double irradiation technique, and using the iterative LAOCOON 3 program, we have made the complete analysis of the NMR signals corresponding to protons fixed on the dioxaphosphorinane ring. The results obtained are given in Table I and II. Details concerning synthesis and NMR analysis will be published later (see also 1c).

As indicated by the magnitude of coupling constants (Table I), for molecules I to III and for molecules I' and II', it is clear that only one chair conformation can exist for the 1,3,2-dioxaphosphorinane ring : in the case of I-III, the reason is trans ring junction, while in the case of I'-II' the reason is the presence of two equatorial 1,3 methyl groups (otherwise a strong 1,3-diaxial interaction would exist in the inverted chair conformation).

The only difference between a given pair of geometrical isomers is thus the orientation of the substituent(s) on the phosphorus atom (fig. 1).

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TABLE I.

Chemical shifts (in ppm) and proton-proton coupling constants (in Hz)

Derivative	δH_4^e	δH_4^a (1)	δH_5^e	δH_5^a (2)	$^2J_4$	$^2J_5$	$^3J_{aa}$	$^3J_{ae}$	$^3J_{ea}$	Solvent
I	3.79	4.19		-	-10.9		11.3		4.0	CCl_4
IIa	3.49	3.94		-	-10.6		11.4		4.2	CCl_4
IIb	3.91	3.59		-	-10.7		11.2		5.5	CCl_4
IIIa	4.10	4.05		-	-10.7		11.8		4.4	$CDCl_3$
IIIb	4.14	4.13		-	-10.7		11.2		4.5	$CDCl_3$
I'		4.74	1.80	1.74		-14.0	11.4	2.1		neat liq.
II'a		4.49	1.63	1.51		-13.9	11.6	2.2		neat liq.
II'b		4.18	1.66	1.84		-14.2	11.7	3.1		neat liq.

(1) For I, II and III, the H_6^a signal is a broad unresolved peak; for I' and II', $\delta H_4^a = \delta H_6^a$

(2) For I, II and III, the H_5^a signal is superimposed on the broad peak corresponding to cyclohexane protons.

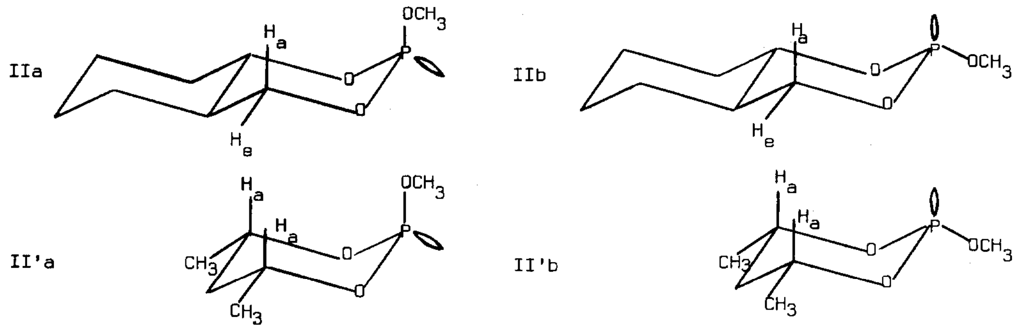
TABLE II.

$^{31}P-^{1}H$ coupling constants (Hz)

Derivative	$^3J_{H_4^aP}$	$^3J_{H_4^eP}$	$^4J_{H_5^aP}$	$^4J_{H_5^eP}$	$^3J_{P-OCH_3}$
I	5.4	10.8	-		-
IIa	2.5	10.8	-		11.8
IIb	4.6	8.3	-		10.6
IIIa	1.7	25.0	-		13.4
IIIb	4.2	24.3	-		13.6
I'	4.8		1.2	4.2	-
II'a	2.1		0.5	3.6	11.9
II'b	3.1		< 0.5	2.8	10.7

FIG. 1.

Conformations and configurations of the derivatives II and II'.



Previously, arguments based on the values of ^3J coupling constants between phosphorus and hydrogen were used to propose a preferred equatorial orientation for the substituent on phosphorus (1a, b). It is thus interesting to note that the $^3J_{P-O-C-H_e}$ in IIa <u>but also</u> in IIb are greater than the ^3J observed in 2,8,9-trioxa-1-phosphaadamantane where $^3J_{P-O-C-H_e} = 6$ Hz (6).

Considering these results, the preceding attribution based on coupling constants seems to be unsatisfactory.

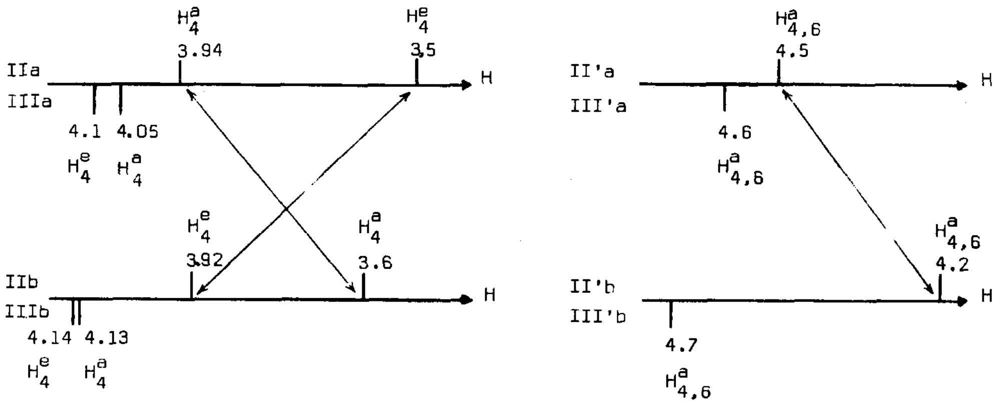
In our opinion, in this particular case, arguments based on chemical shift data are stronger and even unambiguous.

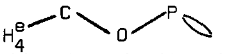
In I (which, as I', was obtained only in the more stable configuration) and in IIa, we have $\delta H_4^e < \delta H_4^a$ as in other similar compounds (1,2,3). The same situation exists in cyclic sulfites (1b,7) while in cyclohexane derivatives the normal trend is $\delta H_4^e > \delta H_4^a$.

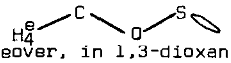
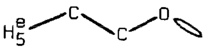
In IIb, on the contrary, we observe a "cyclohexane" sequence with $\delta H_4^e > \delta H_4^a$.

FIG. 2.

Relative signal positions (ppm) of cyclic protons β to phosphorus



In IIa and II'a, the axial protons on C_4 and C_6 are in syn diaxial interaction with the OCH_3 group (cfr. Fig. 1). Recently, it has been proved that such an interaction has a low field effect in the dioxane series (low field effect of the order of 0.3 - 0.4 ppm) (8). Comparing IIa and IIb or II'a and II'b we can see (Fig. 2) that in these compounds the low field effect is of the same order. In IIa, we have thus a low field displacement of the H_4^a signal but simultaneously we observe a high field shift of the H_4^e signal (compared with IIb) and this latter is also of the order of 0.4 ppm. We correlate this high field shift with the planar W arrangement  found in isomer IIa (Fig. 1).

It is very interesting to note that in cyclic sulfites, where the oxo group is known to be axial (9) the planar  system is accompanied by a similar high field effect on H_4^e signal. Moreover, in 1,3-dioxane (10), in trimethylene sulfite (7) and in 1,3,2-dioxaphosphorinane (11) the same effect is observed for the H_5^e proton which is also in a planar W arrangement (in this case ).

The generality of this high field shift originated by the relative position of the lone pair on heteroatom and the observed H is perhaps due to an interaction between the antilobes of C-H and lone pair orbitals (10).

We have thus based our configurational attribution, given in the preceding figures, on the low field shift of H_4^a signal in the isomer with axial $P\text{-}OCH_3$ group and also on the high field shift of the H_4^e signal in the same isomer. Consequently, the other isomer has an equatorial $P\text{-}OCH_3$ group, the latter configuration being the least stable as we have proved by equilibration experiments (more than 95 % of the axial configuration). In the case of chlorophosphite I, which exists only in one form, the relative position of H_4^a and H_4^e signals seems to be a sufficient argument for proposing also an axial orientation of the substituent on phosphorus. This preferred axiality must also be present in derivative I'.

The spectra of thiophosphates IIIa and IIIb are in perfect agreement with our attribution : no more lone pair on phosphorus, no high field shift of H_4^e in IIIa; an axial heteroatom on phosphorus in the two configurations, no clear difference between the chemical shifts of the H_4^a protons in the two isomers.

Our conclusions, based on direct NMR evidence, concerning the preferred axiality of OR or halogen substituents on tricoordinate phosphorus in 1,3,2-dioxaphosphorinane systems is thus in agreement with the point of view of other authors on this question (2,4,5,12).

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1. a) D. Gagnaire et J.B. Robert, *Bull. Soc. Chim. France*, 2240 (1967); b) D. Gagnaire, J.B. Robert et J. Verrier, idem, 2392 (1968); c) D. Gagnaire, J.B. Robert, J.P. Albrand et M. Haemers, idem, 3496 (1969).
2. C. Bodkin et P. Simpson, *Chem. Comm.*, 829 (1969).
3. J. Howard Hargis et W.G. Bentrude, *Tet. Letters*, 5365 (1968).
4. D.W. White, G.K. McEwen et J.G. Verkade, *Tet. Letters*, 5369 (1968).
5. W.G. Bentrude and K.C. Yee, *Tet. Letters*, 3999 (1970), ref. 1.
6. E.J. Boros, K.J. Coskran, R.W. King et J.G. Verkade, *J. Am. Chem. Soc.* 88, 1140 (1966).
7. D.G. Hellier, J.G. Tillett, H.F. Van Woerden et R.F. White, *Chem. and Ind.*, 1956 (1963).
8. E.L. Eliel et F.W. Nader, *J. Am. Chem. Soc.*, 92, 584 (1970).
9. H.F. Van Woerden et E. Havinga, *Rec. Trav. Chim. Pays Bas*, 86, 341 (1967).
10. M. Anteunis, D. Tavernier et F. Borremans, *Bull. Soc. Chim. Belges*, 75, 396 (1966) et ref.
11. Unpublished results.
12. M.U. Haque, C.N. Caughlan, J.H. Hargis et W.G. Bentrude, *J. Chem. Soc. (A)*, 1786 (1970).