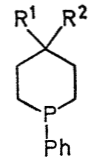
Crystal Structure and Conformation of 1-Phenyl-4,4-dimethoxyphosphorinan

By A. T. McPHAIL,* J. J. BREEN, J. H. SOMERS, J. C. H. STEELE, JUN., and L. D. QUIN
(*Paul M. Gross Chemical Laboratory, Duke University, Durham, North Carolina* 27706)

Summary The title compound is shown by *X*-ray analysis to have a chair conformation with an axial phenyl substituent; the ^{1}H n.m.r. spectrum is consistent with one preferred conformation in solution, and ^{31}P and ^{13}C chemical shifts are also reported.

IT has been shown recently[1] that in the solid state 1-phenylphosphorinan-4-one (I) exists in a chair conformation with an axially orientated phenyl substituent. In order to verify that the preference for this conformer was not simply the result of crystal packing forces, and unique to this compound, we studied the closely related 1-phenyl-4,4-dimethoxyphosphorinan (II). We here report preliminary *X*-ray and n.m.r. results.

Compound (II) was prepared by refluxing a methanolic solution of (I)[2] and $HC(OMe)_3$ saturated with dry HCl. Methyl formate was distilled off, and the reaction was repeated twice with additional $HC(OMe)_3$ and HCl to obtain appreciable conversion into (II). The product was



(I) $R^1, R^2 = O$
(II) $R^1 = R^2 = OMe$

distilled off (b.p. 113—118° at 0·20 mmHg) and purified by g.l.c.; samples were collected in benzene which was then removed by vacuum sublimation.

Sublimation of (II) provided single crystals (m.p. 55·0—56·0°) suitable for an *X*-ray study. One of these was

sealed in a thin-walled capillary for data collection. The crystals are monoclinic, space group $P2_1/c$; $a = 7{\cdot}12$, $b = 7{\cdot}05$, $c = 26{\cdot}22$ Å, $\beta = 90{\cdot}58$; $Z = 4$. Intensity data were obtained from equi-inclination multiple-film Weissenberg photographs. The structure was solved by the heavy-atom method, and the positional and anisotropic thermal parameters of the non-hydrogen atoms were refined by full-matrix least-squares calculations. Hydrogen atoms, except those of the methyl groups, were included at their calculated positions, and the present R for 1685 reflexions is 0·086.

The molecular conformation in the crystal is shown in the Figure. No abnormally short intermolecular separations occur; the shortest (3·50 Å) involves an oxygen atom and a phenyl carbon atom. In accord with the studies of (I), the phosphorinan ring torsion angles (Table) are indicative of a chair conformation flattened at phosphorus, and the phenyl substituent is axially orientated. The phosphorus atom is displaced by 0·11 Å from the least-squares plane through the phenyl carbon atoms (r.m.s.d. 0·012 Å), the displacement being similar to that for (I) (0·29 Å). This decreased value for (II) reflects the smaller phenyl ring–diaxial hydrogen interactions resulting from the replacement of an sp^2 by an sp^3 carbon atom at position 4. Thus we note that although (I) and (II) exist in different crystalline environments, the axial conformer is preferred in both. We conclude, therefore, that crystal packing forces are not alone responsible for the observed solid-state conformations.

TABLE

Torsion angles (°) *of the phosphorinan ring of* (II)

C(6)–P(1)–C(2)–C(3)	45·5	C(3)–C(4)–C(5)–C(6)	−60·5
P(1)–C(2)–C(3)–C(4)	58·0	C(4)–C(5)–C(6)–C(1)	56·1
C(2)–C(3)–C(4)–C(5)	62·4	C(5)–C(6)–P(1)–C(2)	−44·7

The ^{1}H n.m.r. spectrum† of acetal (II) (cyclohexane; 60 MHz) showed two sharp OMe signals (1 : 1) at δ 3·08 and 3·13 p.p.m. This suggests that one conformation, presumably that for the solid, is predominant in solution.‡ The fact that the i.r. spectrum of (II) as a melt was virtually identical to that of a KBr disc supports this contention. The ^{31}P n.m.r. absorption† of (II) occurred at +37·9 p.p.m. in benzene (relative to 85% H_3PO_4) while the ^{31}P signal of ketone (I) appeared at nearly the same position (+37·0 p.p.m.). These results indicate that conformational preferences of (I) and (II) in solution are similar, for substantial differences (8—10 p.p.m.) occur in the ^{31}P spectra of phosphorinan isomers containing axial or equatorial P-substituents.[3]

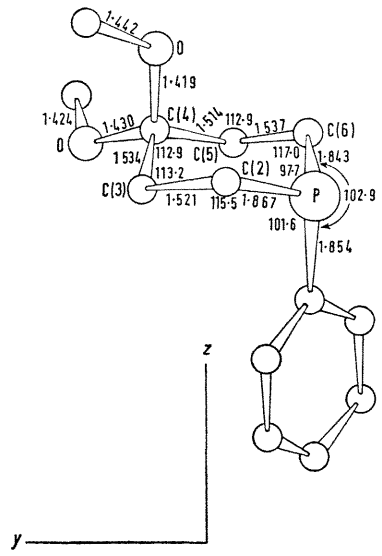


FIGURE. *Molecular conformation and some important lengths* (Å) *and angles* (°). *E.s.d.s. are* ± 0·005 Å *for* P—C *bonds* ± 0·007 *for* C–C *and* C–O *bonds*, ±0·2° *for* C–P–C *angles, and* ±0·3° *for other angles.*

We are also conducting ^{13}C n.m.r. studies† on these compounds and report here values for acetal (II). These data, the first for a phosphorinan, are: +171·5 [d, $^1J_{PC}$ 16 ± 2·5 Hz, C(2), C(6)], +161·2 [d, $^2J_{PC}$ *ca.* 3·0 Hz, C(3), C(5)], and +91·2 p.p.m. [d, $^3J_{PC}$ *ca.* 3·0 Hz, C(4)]. The nonequivalence of the OMe substituents resulted in two signals at +144·2 and +144·8 p.p.m.

This work was supported in part by a Public Health Service Research grant from the National Cancer Institute and by a Biomedical Sciences Support Grant to Duke University. The U.S. National Science Foundation generously provided funds towards the purchase of the Bruker spectrometer.

(*Received, June 17th,* 1971; *Com.* 988.)

† ^{1}H N.m.r. spectra were run on a Varian A-60 spectrometer; ^{31}P n.m.r. data were obtained on a Varian V-4300 B spectrometer at 19·3 MHz; the ^{13}C n.m.r. spectrum was obtained with a Bruker HFX-90 spectrometer on a $CHCl_3$ solution containing Me_4Si as internal reference and C_6F_6 in a 3 mm coaxial capillary as external heteronuclear lock. The Fourier transform of an ensemble average of 4096 scans (100 μs per point, with 4096 points per scan) was calculated. The resolution was about 2·5 Hz. Chemical shifts are upfield with respect to CS_2.

‡ 4-Substituents which bias the conformational equilibrium of 1,1-dimethoxycyclohexanes cause the methoxy-groups to be non-equivalent (D. Tavernier and M. Anteunis, *Bull. Soc. Chim. Belg.*, 1967, **76**, 475; E. L. Eliel and R. J. L. Martin, *J. Amer. Chem. Soc.*, 1968, **90**, 682). In the phosphorinan series, a *P*-methyl substituent does not appear to exert a substantial conformational preference, and in nonaromatic solvents 1-methyl-4,4-dimethoxyphosphorinan exhibits a single OMe signal (ref. 3).

[1] A. T. McPhail, J. J. Breen, and L. D. Quin, *J. Amer. Chem. Soc.*, 1971, **93**, 2574.
[2] R. P. Welcher, G. A. Johnson, and V. P. Wystrach, *J. Amer. Chem. Soc.*, 1960, **82**, 4437.
[3] L. D. Quin and J. H. Somers, unpublished results.