# Crystal and Molecular Structure of Organophosphorus Insecticides. II. Coroxon

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The detailed molecular structure of Coroxon (O,O-diethyl O-(3-chloro-4-methyl-2-oxo-($2H$)-1-benzo-pyran-7-yl) phosphate) has been determined by single-crystal x-ray diffraction techniques. The space group is $P2_1/c$ with a = 9.305 (3), b = 23.114 (10), and c = 7.815 (2) Å, β = 108.52 (3)°, and four molecules in the unit cell. Direct methods yielded an initial structural model and subsequent least-squares refinement based on the 1202 observed ($I > 3\sigma_I$) structure factors gave a final agreement factor of 4.0%. The geometry around the phosphorus atom is distorted from tetrahedral with angles ranging from 100.6 (2) to 116.0 (2)°. A comparison of the three single P–O bonds indicates that the bond to the oxygen of the aryl group is somewhat elongated relative to the others (1.593 (3) vs. 1.551 (4) and 1.554 (4) Å). Distances from the phosphorus to the centers of the two fused rings are 3.93 and 5.80 Å.

It is generally accepted that a very large class of phosphate esters owe their apparently complex biological activity to the inhibition of acetylcholinesterase (AChE). This inhibition is the result of phosphorylation of an active enzyme site which is then no longer available to bind the natural substrate, i.e.

$$(RO)_2POX + EH \rightarrow (RO)_2POE + HX$$
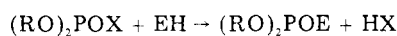
where X is the "leaving group" on the ester and EH is the uninhibited AChE (O'Brien, 1960).

The natural substrate is acetylcholine and the phosphorylation is due, in part, to the structural and chemical similarities between this molecule and the many OP insecticides. Thus, the phosphate ester plays the role of the acetyl group and some portion of the leaving group corresponds to the quaternary nitrogen of the acetylcholine molecule (Fukuto, 1971). The phosphorylated enzyme is very stable and its generation lowers the concentration of AChE available for binding acetylcholine. Since nerve action depends on the continual generation and subsequent hydrolysis by AChE of acetylcholine, the result is disruption of the nervous system. In mammals the eventual result can be respiratory failure and asphyxiation.

The degree of AChE inhibition attained by a variety of substituted phenyl diethyl phosphates is dependent on both the nature of the substituent (i.e. the Hammett σ constant) and overall steric effects (O'Brien, 1960; Fukuto and Metcalf, 1956; Fukuto, 1971; Hansch and Deutsch, 1966; Canepa et al., 1966).

Diffraction studies can provide information on not only the overall molecular configuration but also those subtle changes in molecular geometry brought about by the replacement of one substituent atom by another. Modern techniques can readily provide such detailed information and we have embarked upon such a program in this laboratory. In particular we have completed a crystal and molecular structure investigation for O,O-diethyl O-(3-chloro-4-methyl-2-oxo-($2H$)-1-benzopyran-7-yl) phosphate, usually referred to as Coroxon.

Coroxon has been shown to be the active AChE inhibitor derived metabolically from Coumaphos, the corresponding phosphorothioate. Coumaphos finds use commercially in the control of animal parasites.

EXPERIMENTAL SECTION

Crystal Data. O,O-Diethyl O-(3-chloro-4-methyl-2-oxo-($2H$)-1-benzopyran-7-yl) phosphate (Coroxon), formula

weight = 346.7 g/mol, monoclinic, $P2_1/c$, a = 9.305 (3), b = 23.114 (10), and c = 7.815 (2) Å, β = 108.52 (3)°, V = 1593.77 Å^3, ρ(calcd) = 1.44 g/ml for Z = 4 formula units per unit cell, μ = 3.67 cm^{-1}, Mo Kα (λ = 0.70954 Å selected by monochromator).

A sample of the title compound was kindly supplied by P. A. Dahm. A single needlelike light yellow crystal of approximate dimensions 0.2 mm × 0.2 mm × 0.5 mm was selected and mounted on a glass fiber. The crystal was then placed on a four-circle diffractometer and initial ω-oscillation photographs were taken. The photographs verified that the crystal selected was indeed single. From these photographs 11 reflections were accurately located on the diffractometer and their coordinates were input to our automatic indexing program (Jacobson, 1974). The reduced cell and the reduced cell scalars that resulted from this program indicated monoclinic symmetry and this was subsequently confirmed by taking ω-oscillation photographs about each of the three axes in turn. Only the b axis showed a mirror plane and layer line spacings predicted by the computer agreed with those observed to within the experimental error.

Data were collected near room temperature (ca. 32°C) utilizing an automated four-circle diffractometer designed and built in the Ames Laboratory, and equipped with a graphite reflected-beam monochromator and scintillation counter. Using Mo Kα radiation, all data within a sphere defined by $2\theta \leq 42.5°$ were collected in the hkl and $\bar{h}kl$ octants using a modified peak height data collection mode. Each peak was maximized in ω. Two measurements were made bracketing the peak center and differing by 0.01° in ω, followed by background measurements on each side of the peak. All counting times were 2.5 sec. If the measurement at the peak center did not exceed the background by 7 counts or more, which corresponds to approximately 1–2 standard deviations in the background for larger values of θ, no further measurement was made on the reflection.

As a general check on stability of the instrument and crystal, the peak heights of three reflections were remeasured every 50 reflections. These three standards showed no significant change over the entire period of data collection. A total of 1961 reflections were recorded in the hkl and $\bar{h}kl$ octants.

The unit cell parameters and their standard deviations were determined by a least-squares fit (Williams, 1964) to the angular settings of 11 independent reflections whose centers were accurately determined by half-height counting techniques on the previously aligned four-circle diffractometer.

Table I. Final Parameters for Coroxon

(i) Positional Parameters			
Atom	x	y	z
Cl	−0.0169 (2)[a]	0.1314 (1)	0.5912 (2)
P	0.5012 (2)	−0.1491 (1)	0.2657 (2)
O-1	0.0349 (5)	0.1099 (2)	0.2472 (5)
O-2	0.1827 (4)	0.0336 (1)	0.3229 (4)
O-3	0.5126 (4)	−0.1084 (1)	0.1293 (4)
O-4	0.3450 (4)	−0.1788 (2)	0.2296 (4)
O-5	0.6254 (4)	−0.1966 (1)	0.3042 (4)
O-6	0.5315 (4)	−0.1234 (1)	0.4633 (4)
C-1	0.0962 (5)	0.0773 (2)	0.5506 (7)
C-2	0.1001 (6)	0.0769 (2)	0.3655 (7)
C-3	0.2666 (5)	−0.0055 (2)	0.4502 (6)
C-4	0.2652 (5)	−0.0033 (2)	0.6273 (6)
C-5	0.1734 (6)	0.0399 (2)	0.6799 (6)
C-6	0.1693 (6)	0.0413 (2)	0.8697 (7)
C-7	0.3505 (6)	−0.0444 (2)	0.3874 (6)
C-8	0.4376 (5)	−0.0838 (2)	0.5101 (6)
C-9	0.4417 (6)	−0.0838 (2)	0.6888 (7)
C-10	0.3572 (6)	−0.0439 (2)	0.7463 (7)
C-11	0.2195 (8)	−0.1714 (3)	0.0636 (10)
C-12	0.1991 (10)	−0.2194 (3)	−0.0517 (10)
C-13	0.6383 (10)	−0.2425 (3)	0.4308 (10)
C-14	0.7714 (8)	−0.2773 (3)	0.4585 (9)
H-1	0.0896	0.0738	0.8853
H-2	0.2819	0.0507	0.9648
H-3	0.1334	−0.0013	0.9062
H-4	0.3686 (66)	−0.0447 (24)	0.8677 (79)
H-5	0.5105 (68)	−0.1115 (24)	0.7742 (76)
H-6	0.3530 (63)	−0.0412 (24)	0.2632 (78)
H-7	0.1302 (70)	−0.1885 (26)	0.0918 (78)
H-8	0.2452 (73)	−0.1401 (27)	0.0137 (82)
H-9	0.2815	−0.2184	−0.1252
H-10	0.2233	−0.2598	0.0332
H-11	0.0858	−0.2232	−0.1454
H-12	0.6052 (66)	−0.2277 (24)	0.5320 (78)
H-13	0.5679 (72)	−0.2740 (28)	0.3838 (82)
H-14	0.8740	−0.2510	0.5338
H-15	0.7732	−0.3161	0.5386
H-16	0.7857	−0.2894	0.3302

(ii) Thermal Parameters[b]						
Atom	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
Cl	186 (3)	25 (1)	374 (4)	10 (1)	92 (3)	−12 (1)
P	150 (2)	18 (1)	145 (3)	1 (1)	34 (2)	1 (1)
O-1	274 (9)	32 (1)	269 (9)	47 (3)	49 (7)	29 (3)
O-2	159 (6)	21 (1)	177 (7)	16 (2)	33 (5)	9 (2)
O-3	207 (7)	26 (1)	191 (7)	2 (2)	67 (6)	20 (2)
O-4	183 (6)	27 (1)	219 (8)	−18 (2)	5 (6)	7 (2)
O-5	215 (7)	22 (1)	189 (7)	17 (2)	81 (6)	9 (2)
O-6	163 (6)	23 (1)	149 (7)	15 (2)	19 (5)	0 (2)
C-1	122 (8)	17 (1)	249 (13)	−4 (2)	53 (8)	−10 (3)
C-2	155 (9)	24 (1)	214 (14)	7 (3)	26 (9)	0 (4)
C-3	130 (8)	16 (1)	155 (11)	3 (3)	29 (8)	7 (3)
C-4	133 (8)	17 (1)	16 (11)	−7 (3)	41 (8)	1 (3)
C-5	134 (9)	18 (1)	198 (12)	−7 (3)	57 (8)	−4 (3)
C-6	182 (10)	27 (1)	205 (12)	0 (3)	82 (9)	−9 (3)
C-7	143 (8)	18 (1)	136 (10)	1 (3)	24 (8)	1 (3)
C-8	134 (8)	16 (1)	160 (11)	1 (3)	23 (8)	−2 (3)
C-9	173 (9)	18 (1)	148 (11)	4 (3)	40 (8)	6 (3)
C-10	170 (10)	23 (1)	150 (10)	−7 (3)	57 (9)	2 (3)
C-11	182 (11)	32 (2)	320 (18)	−16 (4)	−8 (12)	−8 (5)
C-12	334 (17)	50 (2)	342 (19)	27 (5)	−31 (15)	−62 (6)
C-13	418 (22)	31 (2)	339 (19)	46 (5)	227 (18)	48 (5)
C-14	294 (15)	40 (2)	389 (20)	51 (5)	158 (15)	52 (5)

[a] In this and succeeding tables estimated standard deviations are given in parentheses for the least significant figures.
[b] The β_{ij} are defined by: $T = \exp\{-(h^2\beta_{11} + k^2\beta_{22} + l^2\beta_{33} + 2hk\beta_{12} + 2hl\beta_{13} + 2kl\beta_{23})\}$. All hydrogen isotropic B's have been set equal to 5.0. Nonhydrogen anisotropic thermal parameters are ($\times 10^4$).

Intensity data were corrected for Lorentz and polarization effects. The variance of an intensity was estimated by:

$$\sigma_I^2 = C_T + C_B + (0.03 C_T)^2 + (0.03 C_B)^2$$

where C_T and C_B are the total and background counts, respectively. Since the maximum and minimum trans-

mission coefficients were 0.93 and 0.83, no absorption correction was deemed necessary. The estimated standard deviations in the structure factors were calculated by a finite difference method (Lawton and Jacobson, 1968). Of the 1961 measured reflections, 1202 had $I > 3\sigma_I$ and were therefore considered observed. Examination of the data set revealed the following systematic extinctions: $h0l$ when

Table II. Selected Interatomic Distances (Å) for Coroxon

Cl-C-1	1.729 (5)	C-9-C-10	1.376 (7)
O-1-C-2	1.204 (6)	C-10-C-4	1.405 (6)
C-6-C-5	1.496 (7)	C-8-O-6	1.394 (5)
C-1-C-2	1.459 (7)	O-6-P	1.593 (3)
C-2-O-2	1.364 (6)	P-O-3	1.451 (3)
O-2-C-3	1.386 (5)	P-O-4	1.551 (4)
C-3-C-4	1.389 (6)	P-O-5	1.554 (4)
C-4-C-5	1.456 (6)	O-4-C-11	1.455 (7)
C-5-C-1	1.350 (6)	C-11-C-12	1.408 (9)
C-3-C-7	1.381 (7)	O-5-C-13	1.427 (7)
C-7-C-8	1.382 (6)	C-13-C-14	1.436 (9)
C-8-C-9	1.385 (6)		

Table III. Bond Angles (Degrees) for Coroxon

Cl-C-1-C-2	113.5 (4)	P-O-4-C-11	123.5 (4)
Cl-C-1-C-5	122.3 (5)	P-O-5-C-13	123.5 (4)
C-1-C-2-C-1	126.2 (5)	O-4-C-11-C-12	112.5 (6)
O-1-C-2-O-2	117.6 (5)	O-5-C-13-C-14	113.6 (6)
C-6-C-5-C-1	123.6 (5)	C-10-C-4-C-3	116.0 (5)
C-6-C-5-C-4	119.7 (4)	C-5-C-4-C-10	124.1 (4)
C-1-C-2-O-2	116.2 (4)	C-2-C-3-C-7	115.0 (4)
C-2-O-2-C-3	122.3 (4)	C-9-C-8-O-6	116.5 (4)
O-3-C-3-C-4	120.7 (4)	C-7-C-8-O-6	122.0 (4)
C-3-C-4-C-5	119.9 (4)	C-8-O-6-P	124.5 (3)
C-4-C-5-C-1	116.7 (4)	O-6-P-O-3	116.0 (2)
C-5-C-1-C-2	124.2 (5)	O-6-P-O-5	100.6 (2)
C-4-C-3-C-7	124.3 (4)	O-6-P-O-4	102.1 (2)
C-3-C-7-C-8	117.1 (4)	O-3-P-O-4	115.9 (2)
C-7-C-8-C-9	121.5 (5)	O-3-P-O-5	112.2 (2)
C-8-C-9-C-10	119.6 (5)	O-4-P-O-4	108.6 (2)
C-9-C-10-C-4	121.5 (5)		

$l = 2n + 1$, $0k0$ when $k = 2n + 1$. These absences uniquely determine the space group to be $P2_1/c$.

Solution and Refinement. Direct methods and the automated map analysis of the program package built around MULTAN (Main et al., 1971) were employed to obtain a refinable model; first E values were calculated and then the 499 E values greater than 1.5 were phased using the third-order tangent formula. All nonhydrogen atoms of the molecule could be seen in the resultant E map with the best figures of merit.

These atoms were then refined using a full-matrix least-squares procedure and minimizing the function $\Sigma\omega(|F_o| - |F_c|)^2$ with $\omega = 1/\sigma_F^2$ (Busing et al., 1962). With all atoms anisotropic, refinement converged to a crystallographic discrepancy factor, $R = \{\Sigma_i||F_i^{obsd}| - |F_i^{calcd}||\}/\Sigma_i|F_i^{obsd}| = 0.06$. The scattering factors of Hanson et al. (1960) were used, with those for the chlorine and phosphorus atoms modified for the real and imaginary part of anomalous dispersion (Templeton, 1962).

A difference map (Hubbard et al., 1971) was then examined for peaks due to hydrogen atoms. By careful analysis of this map approximate locations for nearly all 16 hydrogen atoms were found. Methyl hydrogens were fitted by a least-squares fit to the peaks in this map and were not refined further. The nonmethyl hydrogen atoms were assigned an isotropic temperature factor of 5.0 Å^2 and their positional parameters were allowed to refine. Final convergence was obtained at $R = 4.0\%$ and $R_\omega = 4.8\%$; $R_\omega = \{[\Sigma\omega_i(F_i^{obsd} - F_i^{calcd})^2]/\Sigma_i\omega_i|F_i^{obsd}|^2\}^{1/2}$, where $\omega_i = 1/\sigma(F_i)^2$. At this stage all residual peaks on the difference map were less than 0.6 electron per Å^3.

The final positional and thermal parameters are listed in Table I. The standard deviations were calculated from the inverse matrix of the final least-squares refinement cycle. Bond distances and angles along with their standard deviations are given in Figure 1 and Tables II and III (Busing et al., 1964). A computer generated perspective drawing of the molecule is shown in Figure 2 (Johnson, 1971).
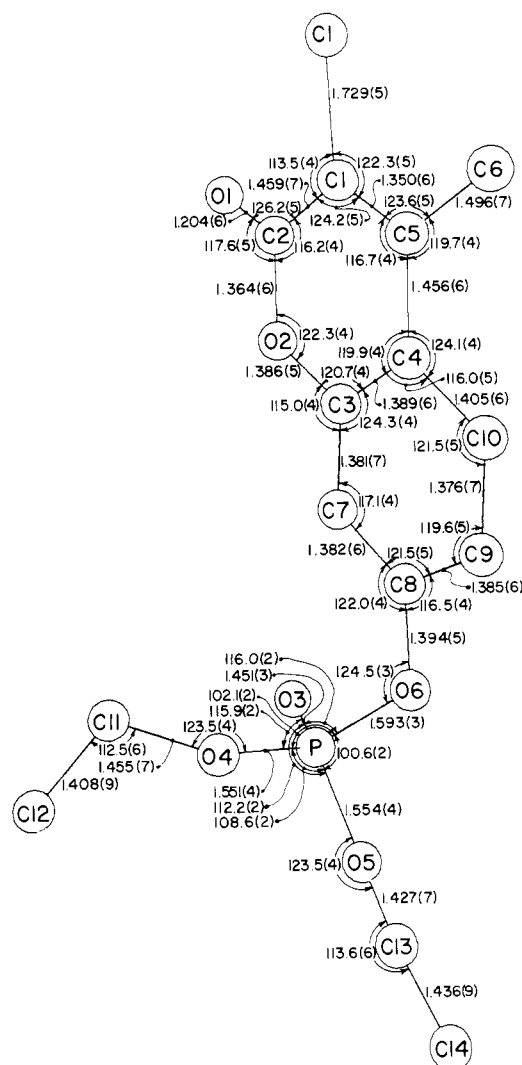

Figure 1. The molecule of Coroxon displaying interatomic bond distances and angles.
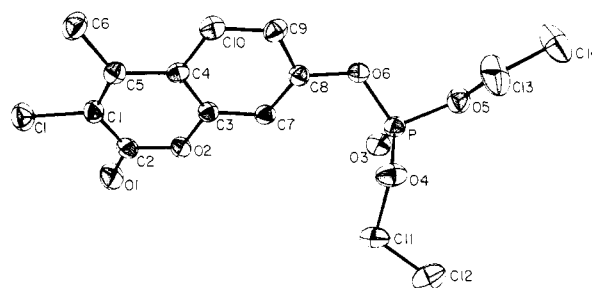

Figure 2. A perspective view of the molecule with 50% probability thermal motion ellipsoids.

DISCUSSION

The intramolecular bond distances and angles (Figure 1 and Tables II and III) are generally in good agreement with those reported in the literature. The P-O distances are 1.451 for the doubly bonded oxygen, O-3, and 1.551 to 1.593 Å for the singly bonded type; the O-P-O angles involving O-3 are all somewhat greater than tetrahedral (112.2 to 116.0°) while the remaining angles are all somewhat less than tetrahedral. Similar trends have been observed in H$_3$PO$_4$ (Furberg, 1955) and H$_3$PO$_4$·0.5H$_2$O (Dickens et al., 1974) and more pronouncedly in the insecticides ronnel, (H$_3$CO)$_2$-P-(S)-OC$_6$H$_2$Cl$_3$ (Baughman and Jacobson, 1975), methylparathion, (H$_3$CO)$_2$-P(S)-OPhNO$_2$ (Bally, 1970), and trichlorfon, (H$_3$CO)$_2$-

Table IV. Comparison of Geometry around Phosphorus for Six Related Molecules; Distances, P to Atom Number in Angstroms; Angles, Atom i to Atom j through P in Degrees

Compound	1	2	3	4	$i\ j$ 1 2	$i\ j$ 1 3	$i\ j$ 1 4	$i\ j$ 2 3	$i\ j$ 2 4	$i\ j$ 3 4
H_3PO_4	1.517 (=O)	1.577 (—O)	1.570 (—O)	1.568 (—O)	112.8	112.2	110.9	105.3	106.8	105.3
$H_3PO_4 \cdot 0.5H_2O$	1.497 (=O)	1.553 (—O)	1.542 (—O)	1.551 (—O)	114.2	111.8	112.2	106.2	103.8	108.0
Coroxon	1.451 (=O)	1.593 (—O)	1.551 (—O)	1.554 (—O)	116.0	115.9	112.2	102.1	100.6	108.6
Methylparathion	1.89 (=S)	1.60 (—O)	1.58 (—O)	1.56 (—O)	116.0	117.8	111.9	99.8	106.1	103.6
Trichlorfon	1.44 (=O)	1.85 (—C)	1.53 (—O)	1.58 (—O)	113	119	115	102	110	97
Ronnel	1.903 (=S)	1.592 (—O)	1.535 (—O)	1.545 (—O)	117.0	117.4	118.0	100.2	98.0	103.0

P(O)–CH(OH)CCl₃ (Hohme and Lohs, 1969). The latter two were studied without the benefit of modern instrumentation. The geometry around phosphorus in each of these molecules and for Coroxon is summarized in Table IV. The overall geometry around the phosphorus is also consistent with the Hückel–molecular orbital treatment of Collin (1966).

The differences found among Coroxon's singly bonded P–O distances, although small, do appear to be significant. The ethoxy P–O distances are 1.551 and 1.554 Å, while the oxygen O-6, bonded to the aryl group, forms a slightly longer P–O bond, 1.593 Å. This oxygen appears to participate in a slightly stronger C–O bond to the aryl group as evidenced by the distance of 1.394 Å compared to those of 1.455 and 1.427 Å for the C–O bonds in the ethoxy groups. Such a lengthening of the P–O-6 and shortening of the O-6–C-8 bond is in agreement with the proposal of Clark et al. (1964) relating effectiveness in phosphorylation to weakness of such a P–O bond.

The results of least-squares plane calculations for various parts of the aryl moiety are given in Table V. It is evident that the six-membered ring described by C-3, C-4, C-7–C-10 exhibits appreciably less deviation from planarity than does the second ring (O-2, C-1–C-5). Some deviation from planarity for the second ring would be expected due to the presence of O-2 as one of its members. A recent structural study of Avicennin (Lai and Marsh, 1974) reports a similar ring fused with a coumarin system. Analogous bond lengths are identical to within experimental error and a similar distortion is found. A larger angle, C-2–C-1–C-5, and smaller angle, C-1–C-5–C-4 (both by 4°), in Coroxon over the analogous angles in Avicennin probably reflect repulsive effects between the Cl and C-6 substituents which are absent in the latter molecule.

In particular, our results indicate that the second ring is twisted about the C-3–C-4 bond relative to the first ring as if it were the flap on an envelope. This causes C-1, O-1, and C-2 to have the greatest deviations (0.073, 0.158, and 0.096 Å) from the plane of the first ring. Distances in the first ring are all normal and essentially identical while somewhat greater variation is found among the C–C distances in the second ring.

The importance of substituent chlorine on the benzopyranyl system is obvious from the startling difference in activity between Coumaphos (the thionate analogue of Coroxon) and Potasan (differing from Coumaphos only by lack of this chlorine). The following LC₁₀₀ values for the two compounds have been reported (both against A. aegypti larvae): Potasan, 100 ppm; Coumaphos, 0.01 ppm. The phosphorus–chlorine distance in Coroxon is 8.92 Å. This is somewhat lower than the value of 9.4 Å reported from model building studies (O'Brien, 1963). Other distances worthy of note include: P–C-7, 3.09; P–C-9, 3.83;

Table V. Least-Squares Planes for Coroxon[a]

| Atoms	Plane 1	Plane 2	Plane 3
Cl	0.0732	-0.0208	0.0179
O-1	0.1582	0.0590	0.0976
O-2	0.0248	-0.0104*	-0.0093*
O-6	0.0571	0.1586	0.0791
C-1	0.0487	-0.0052*	0.0091*
C-2	0.0960	0.0304*	0.0500*
C-3	-0.0006*	0.0040*	-0.0177*
C-4	-0.0030*	0.0122*	-0.0141*
C-5	0.0034	-0.0123*	-0.0197*
C-6	-0.0325	-0.0367	-0.0493*
C-7	0.0041*	0.0357	-0.0027*
C-8	0.0030*	0.0687	0.0074*
C-9	-0.0008*	0.0834	0.0163*
C-10	0.0048*	0.0611	0.0112*
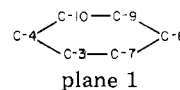
plane 1

$$0.73332x + 0.64123y + 0.22599z - 1.62792 = 0$$
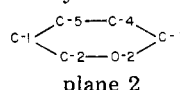
plane 2

$$0.74777x + 0.61910y + 0.23991z - 1.73723 = 0$$
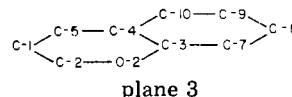
plane 3

$$0.73899x + 0.63223y + 0.23277z - 1.72143 = 0$$

[a] Entries in a column give distance of atom (angstroms) from the corresponding least-squares plane. The atoms to which a given plane is fitted are indicated by an asterisk. Cartesian coordinates X, Y, Z are related to crystal axes x, y, z by:

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \begin{pmatrix} a & 0 & c \cos \beta \\ 0 & b & 0 \\ 0 & 0 & c \sin \beta \end{pmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}$$

P–C-6, 7.77; P–O-1, 7.37; P–(center of ring: C-3, C-4, C-7, C-8, C-9, C-10), 3.93; and P–(center of ring: O-2, C-1, C-2, C-3, C-4, C-5), 5.80 Å. By comparison, the distance between nitrogen and the carbonyl carbon of acetylcholine is 4.1 Å (Canepa et al., 1966).

The special relationships around the phosphorus are perhaps best characterized by selected torsion angles (following the convention of Klyne and Prelog, 1960): C-9–C-8–O-6–P, 154.2 (4)°; C-7–C-8–O-6–P, 29.0 (6)°; and C-8–O-6–P–O, 67.4 (4)°.

Closest nonbonding interactions occur between a given molecule and those on either side of it by a simple translation along the c direction. The shortest distances are: C-6–O-1, 3.89 Å; C-6–O-2, 3.50 Å [between molecules at (x,y,z) and $(x,y,z + 1)$]; O-3–C-9, 3.34 Å; O-3–C-10, 3.24

Å [between molecules at (x,y,z) and $(x,y,z-1)$]. None of these are appreciably smaller than the sum of corresponding van der Waals radii (Pauling, 1960), and hence do not represent significant interactions which would modify the geometry about the phosphorus; the distortions found should represent a molecular property and not the consequence of packing forces within the crystal structure.

That is, owing to the lack of intermolecular interactions, the molecular geometry should be very close to the absolute ground-state geometry. The rotational degree of freedom about the C-8–O-6 bond is minimized. Consequently, the phosphorus position, and therefore the intramolecular distances involving phosphorus, are within a small range of possible values. Barring unusual solvent interactions, the solid state geometry should also be very close to that in vivo.

Supplementary Material Available: A listing of the observed and calculated structure factor amplitudes (six pages). Ordering information is given on any current masthead page.

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Analysis of Phosphorus-Containing Hydrolytic Products of Organophosphorus Insecticides in Water

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A new approach to the analysis of ionic dialkyl phosphates and thiophosphates in large volumes of aqueous media by using Amberlite XAD-4 resin is presented. Recoveries for diethylphosphoric acid and diethylthiophosphoric acid at 0.01–0.1 ppm in 500 to 4000 ml of aqueous media were 100 and 85%, respectively; recoveries for dimethylphosphoric acid and dimethylthiophosphoric acid at 0.1 ppm in 500 ml of aqueous media were 50 and 97%, respectively. Several easy methods are described for the elimination of possible interference due to inorganic phosphate and the potential application for urine analysis is discussed. All four ionic dialkyl phosphates were shown to be nearly as inhibitory as parathion to human plasma cholinesterase.

The fate of organophosphorus insecticides in the environment has been the subject of numerous investigations and is currently an important issue in worker-reentry studies in California (Spear et al., 1975). Chemical and enzymatic hydrolysis of these insecticides generally results in formation of a dialkylphosphoric acid or dialkylphosphorothioic acid. Efficient methods for the isolation and analysis of these highly polar and acidic hydrolytic products in field samples are at present not available.

Diesters of phosphoric acid occur naturally in biological systems (dinucleotides and phosphoglycerides). Phosphorus and sulfur from organophosphorus insecticides are

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