

FRENZ, B. A. (1978). *Computing in Crystallography*, edited by H. SCHENK, R. OLTJOF-HAZEKAMP, H. VAN KONINGSVELD & G. C. BASSI, pp. 44–71. Delft Univ. Press.

GOZLAN, H., MICHELOT, R., RICHE, C. & RIPS, R. (1977). *Tetrahedron* **33**, 2535–2542.

HAFELINGER, G. (1975). *The Chemistry of Amidines and Imidates*, edited by S. PATAI, p. 77. New York: Wiley-Interscience.

MCKECHNIE, J. S. & PAUL, L. C. (1968). *J. Chem. Soc. B*, pp. 984–988.

MAIN, P., FISKE, S. J., HULL, S. E., LESSINGER, L., GERMAIN, G., DECLERCQ, J.-P. & WOOLFSON, M. M. (1980). *MULTAN80. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data*. Univ. of York, England, and Louvain, Belgium.

MARSURA, A., LUU-DUC, C. & GELLON, G. (1985). *Synthesis*, pp. 537–541.

NARDIN, R., MARSURA, A. & LUU-DUC, C. (1985). *Org. Magn. Reson.* In the press.

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Structure of (\pm)-2-(2-Chloro-4,5-dimethoxyphenyl)-2-hydroxy-*N*-isopropylethylamine Hydrochloride, $C_{13}H_{21}ClNO_3^+ \cdot Cl^-$

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Abstract. $M_r = 310.2$, monoclinic, $P2_1/c$, $a = 24.19$ (1), $b = 8.782$ (4), $c = 7.430$ (4) Å, $\beta = 93.06$ (2)°, $V = 1576$ (1) Å³, $Z = 4$, $D_m = 1.32$ (1), $D_x = 1.307$ Mg m⁻³, $\lambda(\text{Mo } K\alpha) = 0.71069$ Å, $\mu = 0.365$ mm⁻¹, $F(000) = 656.0$, $T = 298$ K. Final $R = 0.054$ for 1804 observed reflections. The ethylamine side chain is orientated approximately perpendicular to the phenyl ring, and the isopropyl group is *gauche* to the chiral centre of the cation. The crystal structure is stabilized by a three-dimensional network of $N-H \cdots Cl^-$ and $O-H \cdots Cl^-$ hydrogen bonds.

Introduction. We report the crystal structure of the title compound, the second in a series of structurally related β -adrenoceptor blocking drugs (Koorts & Cairn, 1985) whose conformations we are studying by X-ray diffraction, ¹H NMR and quantum mechanical methods.

Experimental. Hexagonal plate-like crystals grown from 2-propanol solution by slow cooling. Density determined by flotation in PhBr–PhCl. Crystal system and space group from Weissenberg and precession photographs with Cu $K\alpha$ radiation ($\lambda = 1.5418$ Å). Crystal dimensions $0.48 \times 0.28 \times 0.08$ mm, Philips PW 1100 four-circle diffractometer, graphite-monochromated Mo $K\alpha$ radiation. Cell constants by least-squares refinement of angular data for 25 reflections. Three standard reflections monitored after every 56 reflections; no significant intensity variation. 2767 reflections measured by ω - 2θ technique, scan speed $0.030^\circ \theta$ s⁻¹, scan width $0.9^\circ \theta$, θ range 3 – 26° (hkl limits ± 29 , 10, 9); 2641 unique reflections ($R_{\text{int}} = 0.027$) of which 200 systematically absent; 637 reflections with $I_o < 2\sigma(I_o)$

omitted as unobserved [$\sigma(I_o)$ based on counting statistics]. Lorentz and polarization corrections applied, no absorption correction. Structure solved by Patterson and Fourier methods and refined by full-matrix least squares, program *SHELX76* (Sheldrick, 1976); $\sum w(|F_o| - |F_c|)^2$ minimized with $w = 1/\sigma^2(F_o)$ which yielded a constant distribution of $\langle w\Delta^2 \rangle$ with $(\sin\theta)/\lambda$ and $[F_o/F_o(\text{max})]^{1/2}$. All non-H atoms thermally anisotropic; all H atoms located in difference syntheses but [except for H(O) whose position was refined] included at idealized positions in a riding model (C–H, N–H = 1.08 Å) with common U_{iso} values for five groups of atoms [final values 0.055 (8)–0.11 (1) Å²]. $R = 0.054$, $wR = 0.046$ for 1804 observations and 191 parameters, average Δ/σ 0.005 in final cycle, max. 0.08 [for x coordinate of H(O)]. Max. and min. peak heights in final difference map 0.35 and -0.27 e Å⁻³. Scattering factors from *International Tables for X-ray Crystallography* (1974). Illustrations drawn with program *CRISTEP* (De Wet, 1980). Geometrical calculations performed with *XANADU* (Roberts & Sheldrick, 1975) and *PARST* (Nardelli, 1983).

Discussion. Table 1* lists final refined positional parameters and equivalent isotropic thermal parameters. Selected bond lengths and torsion angles, and hydrogen-bond data are listed in Table 2.

* Lists of structure factors, H-atom parameters, anisotropic thermal parameters, bond lengths, bond angles and least-squares planes have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 42261 (16 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Table 1. Fractional atomic coordinates ($\times 10^4$, $\times 10^5$ for Cl, $\times 10^3$ for H) and equivalent isotropic thermal parameters (U_{iso} for H) ($\text{\AA}^2 \times 10^3$) with e.s.d.'s in parentheses

$$U_{eq} = \frac{1}{3} \sum_i \sum_j U_{ij} a_i^* a_j^* \mathbf{a}_i \cdot \mathbf{a}_j$$

	<i>x</i>	<i>y</i>	<i>z</i>	U_{eq}
Cl(1)	75891 (4)	83038 (12)	75823 (14)	51 (1)
Cl(2)	62077 (5)	7296 (12)	76986 (13)	50 (1)
C(1)	7801 (2)	5286 (4)	7183 (4)	35 (2)
C(2)	8165 (2)	4047 (5)	7238 (5)	42 (3)
C(3)	8719 (2)	4236 (5)	7714 (5)	45 (3)
O(3)	9099 (1)	3084 (4)	7824 (4)	66 (2)
C(4)	8927 (2)	5694 (6)	8123 (5)	46 (3)
O(4)	9482 (1)	5774 (4)	8604 (4)	66 (2)
C(5)	8576 (2)	6930 (5)	8060 (5)	43 (3)
C(6)	8016 (2)	6704 (5)	7592 (5)	37 (2)
C(7)	7187 (1)	5001 (4)	6817 (5)	36 (2)
O(7)	7103 (1)	3668 (3)	5754 (4)	49 (2)
C(8)	6944 (1)	4754 (4)	8655 (5)	38 (2)
N(9)	6354 (1)	4233 (3)	8523 (4)	34 (2)
C(10)	5931 (2)	5250 (5)	7584 (5)	43 (3)
C(11)	5908 (2)	6772 (5)	8552 (6)	64 (3)
C(12)	5384 (2)	4418 (6)	7522 (7)	71 (3)
C(13)	8900 (2)	1559 (5)	7652 (6)	67 (3)
C(14)	9702 (2)	7180 (6)	9281 (6)	72 (3)
H(O)	689 (2)	391 (5)	484 (6)	72†

† Not refined.

Table 2. Selected bond lengths (\AA), torsion angles ($^\circ$) and hydrogen-bond data with e.s.d.'s in parentheses

C(6)—Cl(1)	1.744 (4)	C(8)—N(9)	1.495 (4)
C(3)—O(3)	1.367 (4)	N(9)—C(10)	1.502 (4)
C(4)—O(4)	1.373 (4)	C(13)—O(3)	1.427 (5)
C(1)—C(7)	1.516 (5)	C(14)—O(4)	1.425 (5)
C(7)—O(7)	1.421 (4)	O(7)—H(O)	0.86 (4)
C(7)—C(8)	1.531 (5)		
C(6)—C(1)—C(7)—C(8) (τ_1) [*]	-85.5 (4)	O(7)—C(7)—C(8)—N(9)	-52.8 (3)
C(1)—C(7)—C(8)—N(9) (τ_2) [*]	-171.6 (3)	C(8)—N(9)—C(10)—C(11)	-60.8 (4)
C(6)—C(1)—C(7)—O(7)	156.3 (4)	C(8)—N(9)—C(10)—C(12)	176.1 (4)
C(1)—C(7)—O(7)—H(O)	-127 (3)	C(2)—C(3)—O(3)—C(13)	-8.1 (4)
C(7)—C(8)—N(9)—C(10)	-60.3 (4)	C(3)—C(4)—O(4)—C(14)	-171.2 (4)
N(9)...Cl(2)	3.154 (3) \AA	N(9)—H(9A)...Cl(2)	152°
H(9A)...Cl(2)	2.16†		
H(9)...Cl(2)	3.142 (3)	N(9)—H(9B)...Cl(2)	160
H(9B)...Cl(2)	2.11†		
O(7)...Cl(2) ^b	3.098 (3)	O(7)—H(O)...Cl(2) ^b	170 (3)
H(O)...Cl(2) ^b	2.25 (4)		

Symmetry code: (i) $x, \frac{1}{2}-y, \frac{1}{2}+z$; (ii) $x, \frac{1}{2}-y, -\frac{1}{2}+z$.

* See Murray-Rust, Murray-Rust, Hartley, Hallett & Clifton (1984).

† H atoms in calculated positions.

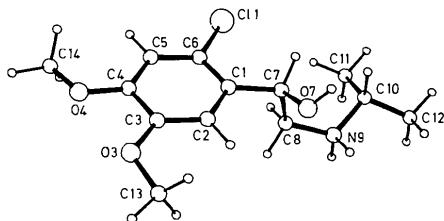


Fig. 1. Conformation of the (*R*)-enantiomeric cation showing atomic numbering.

Atomic coordinates refer to the (*R*)-enantiomeric cation illustrated in Fig. 1. Active dichloroisoproterenol analogues have the *R* configuration, while the configuration of active propranolol analogues is *S* (Howe & Rao, 1968; Dukes & Smith, 1971).

There are no unusual bond distances or angles. The phenyl ring is planar (r.m.s. deviation for the C atoms 0.004 \AA) and the methoxy groups are nearly coplanar with the ring. The *meta*-methoxy group C(13)—O(3) is *cis* with respect to the hydroxyl group at C(7). A perpendicular-*trans* conformation is adopted by the ethylamine side chain (τ_1 and τ_2 respectively, Table 2); this is the conformation which occurs most frequently in crystalline phenylethanolamine derivatives (Murray-Rust, Murray-Rust, Hartley, Hallett & Clifton, 1984). As a result, atom N(9) is *gauche* with respect to O(7) (Paxton & Hamor, 1977) and the non-bonded N(9)...O(7) distance of 2.856 (4) \AA lies within the range of analogous distances (2.65–3.04 \AA) reported for structurally related adrenergics (Ammon, Balsamo, Macchia, Macchia, Howe & Keefe, 1975). The conformation about the C(8)—N(9) bond is (–)-synclinal, in contrast to the (+)-anticyclinal conformation found for the *R* enantiomer in (\pm)-2-(2-chloro-3,4-dimethoxyphenyl)-*N*-isopropyl-2-methoxyethylamine hydrochloride (Koorts & Cairn, 1985) and the isopropyl group is folded away from the hydroxyl group at C(7).

The distance between N(9) and the calculated centre of the phenyl ring is 5.07 (3) \AA , in agreement with values observed in related molecules containing the 2-phenylethylamine nucleus (Pattanayek, Dattagupta & Saha, 1983); the displacement of N(9) from the plane of the ring is 1.915 (3) \AA . A feature which is common to this cation and that in (\pm)-2-(2-chloro-3,4-dimethoxyphenyl)-*N*-isopropyl-2-methoxyethylamine hydrochloride is the orientation of the C(7)—O(7) bond to the plane of the phenyl ring, 23.7 (4) and 23.4 (3)° respectively. Close contacts between ring *ortho*-substituents and atoms bonded to C(7) occur in both structures; in this case, they are Cl(1)...H(7) 2.73, O(7)...H(2) 2.40 \AA (H atoms in idealized positions).

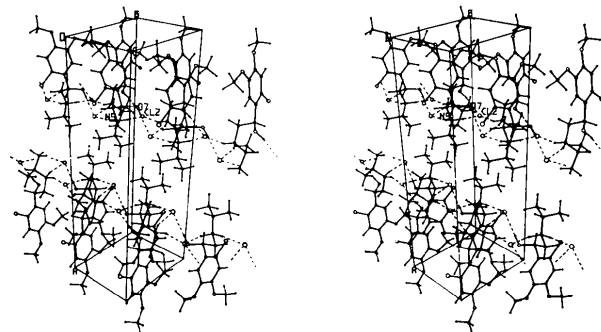


Fig. 2. Stereoview of the crystal packing. Hydrogen bonds are indicated by dashed lines.

Crystal packing and the hydrogen-bonding interactions are shown in Fig. 2. Each cation acts as donor in three distinct hydrogen bonds, namely one O—H...Cl⁻ and two N—H...Cl⁻ bonds (Table 2). The chloride ions involved are *c*-glide-related and their translation equivalents along *z*, resulting in a hydrogen-bonding network that links the hydrophilic residues in bands parallel to *c*. The hydrophobic portions of the cations intermesh in the region of the *yz* plane at $x = \frac{1}{2}$.

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References

- AMMON, H. L., BALSAMO, A., MACCHIA, B., MACCHIA, F., HOWE, D. B. & KEEFE, W. E. (1975). *Experientia*, **31**, 644–645.
 DE WET, J. F. (1980). *J. Appl. Cryst.* **13**, 625–629.
 DUKES, M. & SMITH, L. H. (1971). *J. Med. Chem.* **14**, 326–328.
 HOWE, R. & RAO, B. S. (1968). *J. Med. Chem.* **11**, 1118–1121.
International Tables for X-ray Crystallography (1974). Vol. IV, pp. 99, 149. Birmingham: Kynoch Press. (Present distributor D. Reidel, Dordrecht.)
 KOORTS, J. & CAIRA, M. (1985). *Acta Cryst.* **C41**, 552–554.
 MURRAY-RUST, P., MURRAY-RUST, J., HARTLEY, D., HALLETT, P. & CLIFTON, J. (1984). *Acta Cryst.* **C40**, 825–828.
 NARDELLI, M. (1983). *Comput. Chem.* **7**(3), 95–98.
 PATTANAYEK, R. R., DATTAGUPTA, J. K. & SAHA, N. N. (1983). *Acta Cryst.* **C39**, 91–92.
 PAXTON, K. & HAMOR, T. A. (1977). *Acta Cryst.* **B33**, 2143–2146.
 ROBERTS, P. & SHELDRIK, G. M. (1975). *XANADU*. Program for crystallographic calculations. Univ. of Cambridge, England.
 SHELDRIK, G. M. (1976). *SHELX76*. Program for crystal structure determination. Univ. of Cambridge, England.

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Bond Length and Reactivity. Structure of a Tetraalkyl Pyrophosphate, Bis(2-oxo-1,3,2λ⁵-dioxaphosphorinan-2-yl) Oxide,* C₆H₁₂O₇P₂

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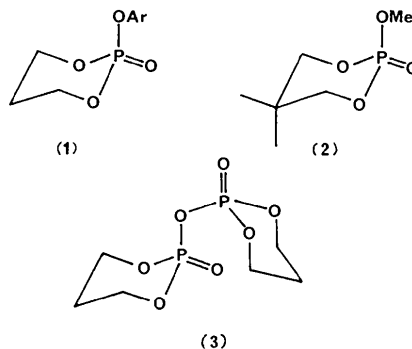
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Abstract. $M_r = 258.11$, orthorhombic, $P2_12_12_1$, $a = 8.619$ (2), $b = 10.612$ (2), $c = 11.401$ (2) Å, $V = 1042.8$ (5) Å³, $Z = 4$, $D_x = 1.644$ (2) g cm⁻³, $\lambda(\text{Mo } K\alpha) = 0.71069$ Å, $\mu = 4.0$ cm⁻¹, $F(000) = 536$, $T = 293$ K. $R = 0.039$ for 2168 observed reflections. The mean P—OP bond length is 1.602 Å, which appears to represent an upper limit for good leaving groups in the 1,3,2-dioxaphosphorinane 2-oxide system. The ring flattening at phosphorus is appreciably different in the two independent rings (torsion angles 40.6, 40.5 cf. 28.5, 27.3°).

Introduction. As part of an extensive investigation of the relationship between the length of a bond in the crystal and its reactivity towards heterocyclic cleavage in solution (Jones & Kirby, 1984), we have reported

crystal structures for a series of five dialkyl aryl phosphates [1, Ar = (a) phenyl, (b) 3-nitrophenyl, (c) 2-nitrophenyl, (d) 4-chloro-2-nitrophenyl, and (e) 2,4-dinitrophenyl; Jones, Sheldrick, Kirby & Briggs, 1984].



* *P,P'*-Oxybis(1,3,2λ⁵-dioxaphosphorinane 2-oxide).