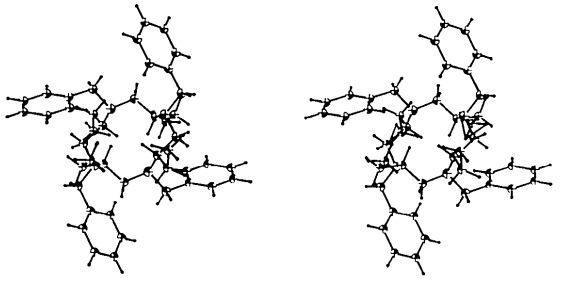

Fig. 5. A stereoscopic drawing of the molecular model at the subsidiary minimum *B*.

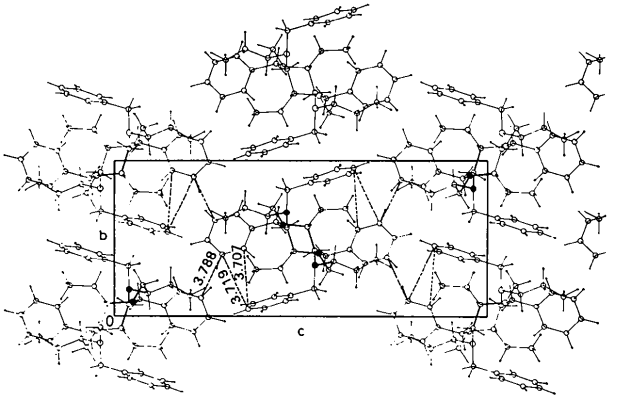

Fig. 6. Packing view of the crystal structure (*a*-axis projection).

The packing of the molecules in the crystal is shown in Fig. 6. None of the intermolecular C—C distances is shorter than 3·7 Å, and the main interactions are between the phenyl groups, as shown by the broken lines in Fig. 6.

Calculations were performed on a FACOM 230-75 computer of this Institute using the *UNICS* II program system (Sakurai, Iwasaki, Watanabe, Kobayashi, Bando & Nakamichi, 1974) for crystallography, *LSAM* (Main, Woolfson & Germain, 1972) for the direct phasing, and *MMB* (Sakurai & Kobayashi, 1972; Sakurai, 1978) for the conformational-energy calculation.

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Acta Cryst. (1979). B**35**, 1244–1248

17β-Hydroxy-5α-androst-1-en-3-one Hydrate*

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(*Received* 15 *August* 1978; *accepted* 18 *January* 1979)

Abstract. $C_{19}H_{28}O_2.H_2O$, $M_r = 306{\cdot}4$, $\rho_x = 1{\cdot}194$ Mg m^{-3}, monoclinic, $P2_1$, $Z = 2$, $a = 10{\cdot}5592$ (6), $b = 7{\cdot}8881$ (4), $c = 10{\cdot}2462$ (6) Å, $\beta = 92{\cdot}345$ (5)°, $V = 852{\cdot}71$ Å^3. Final $R = 0{\cdot}058$ for 1727 independent reflections. The 5α sofa conformation of the Δ^1-3-one *A* ring does not produce the type of convexity needed to explain the 1α stereoselectivity of methyl Grignard addition. The C(19) angular methyl hydrogens provide a steric cover for the β face of C(1), blocking approach from this direction by the reagent, while the C(1) α face is relatively open to attack.

Introduction. Attempts to explain the stereospecificity of conjugate addition reactions to Δ^1-3-one steroids have produced much speculation about the *A*-ring conformations of the precursor molecules and the resulting C(1) alkylated steroids. For example, Kirk &

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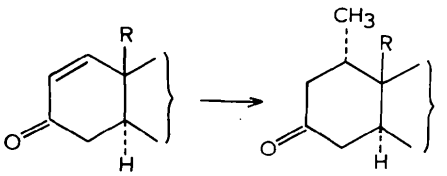
Hartshorn (1968) assumed such a convexity of the β face of the *A* ring in Δ^1-3-one-5α-steroids that the α face was shielded from incoming reagents. Bolt & Zeelen (1973), however, assumed a planar structure. In view of the well-established conformational flexibility of Δ^4-3-one steroids (Duax, Weeks & Rohrer, 1976), the Δ^1-3-one steroid series should also show a great deal of conformational flexibility.



(I) (II)

(*a*) $R = CH_3$ (*b*) $R = H$

Conjugate addition of methyl Grignard reagent to either Δ^1-5α-dihydrotestosterone (I*a*) or Δ^1-19-nor-5α-dihydrotestosterone (I*b*) proceeds, in either case, to 1α-methyl derivatives (II) (Mori, 1962; Bolt & Zeelen, 1973). With the 10β-methyl reactant (I*a*), the 1α-methyl product (II*a*) is to be expected because of steric hindrance of the approach of the incoming methyl group to the β face by the 10β-methyl group already present; but with the 19-nor reactant (I*b*), steric hindrance would seem less likely to be the cause of the α-orientation of the added methyl group. It has been proposed (Bolt & Zeelen, 1973) that (*a*) the 1α-methyl products are favored because in these products the *A*-ring conformation should be half-chair, whereas in the 1β-methyl products the conformation should be half-boat (*i.e.* sofa), and that (*b*) since the structure of the product appears to determine the course of the reaction, the structure of the reaction intermediate should be close to that of the product. The title molecule is an example of a 10β-methyl reactant (I, $R = CH_3$), and its structure has been analyzed in order to determine the conformation of its *A* ring. Crystallographic results are available for only one other example of a reactant (I) (see below), and no crystallographic results for an example of a product (II) – nor, indeed, for any 1-alkyl steroid – have been reported.

Crystallographic data were measured on a specimen crystal of dimensions 0·2 × 0·4 × 0·4 mm with an Enraf–Nonius CAD-4 automated diffractometer using Ni-filtered Cu $K\alpha$ radiation at room temperature. The crystals are monoclinic, and the condition $k = 2n$ limiting the possible $0k0$ reflections determines the space group of this optically active compound to be $P2_1$. Lattice dimensions were refined by a least-squares fit to a set of measured θ values [λ(Cu $K\alpha$) = 1·54051 Å] for 45 reflections in the interval $30° < \theta < 39°$. Integrated relative intensities for 1880 independent reflections accessible with $\theta < 75°$ were measured by ω–2θ scans; 1727 of these reflections were measured to be observed above background ($I > 2\sigma_I$).

Table 1. *Atomic coordinates of 17β-hydroxy-5α-androst-1-en-3-one hydrate*

The *y* coordinate of C(9) was held fixed.

	x	*y*	*z*
C(1)	0·7414 (2)	0·5294 (3)	0·6262 (2)
C(2)	0·8302 (2)	0·5260 (4)	0·5389 (3)
C(3)	0·8873 (2)	0·6811 (4)	0·4880 (2)
C(4)	0·8447 (2)	0·8466 (4)	0·5447 (2)
C(5)	0·7083 (2)	0·8371 (3)	0·5880 (2)
C(6)	0·6604 (2)	1·0060 (3)	0·6392 (2)
C(7)	0·5196 (2)	0·9948 (3)	0·6675 (2)
C(8)	0·4877 (2)	0·8445 (2)	0·7553 (2)
C(9)	0·5417 (2)	0·6763	0·7023 (2)
C(10)	0·6879 (2)	0·6901 (3)	0·6848 (2)
C(11)	0·5000 (2)	0·5233 (3)	0·7839 (2)
C(12)	0·3551 (2)	0·5142 (3)	0·7974 (2)
C(13)	0·3051 (2)	0·6784 (3)	0·8548 (2)
C(14)	0·3444 (2)	0·8271 (3)	0·7666 (2)
C(15)	0·2686 (2)	0·9778 (3)	0·8162 (2)
C(16)	0·1425 (2)	0·8975 (4)	0·8561 (3)
C(17)	0·1612 (2)	0·7028 (3)	0·8460 (2)
C(18)	0·3529 (2)	0·6988 (4)	0·9970 (2)
C(19)	0·7603 (2)	0·7155 (4)	0·8173 (2)
O(3)	0·9666 (2)	0·6751 (4)	0·4044 (2)
O(17β)	0·0926 (2)	0·6200 (3)	0·9453 (2)
O(*W*)	0·9899 (4)	0·8131 (4)	0·1456 (3)
H(1)	0·712 (3)	0·420 (6)	0·663 (3)
H(2)	0·853 (3)	0·423 (5)	0·505 (3)
H(4*A*)	0·845 (3)	0·939 (5)	0·483 (3)
H(4*B*)	0·896 (3)	0·884 (5)	0·611 (3)
H(5*A*)	0·650 (3)	0·807 (5)	0·504 (3)
H(6*A*)	0·680 (4)	1·094 (5)	0·576 (4)
H(6*B*)	0·718 (3)	1·051 (5)	0·726 (3)
H(7*A*)	0·467 (3)	0·985 (6)	0·585 (4)
H(7*B*)	0·485 (3)	1·109 (5)	0·723 (3)
H(8*B*)	0·526 (2)	0·876 (3)	0·843 (2)
H(9*A*)	0·503 (3)	0·663 (5)	0·599 (3)
H(11*A*)	0·530 (4)	0·419 (7)	0·738 (5)
H(11*B*)	0·545 (3)	0·543 (5)	0·887 (3)
H(12*A*)	0·321 (4)	0·496 (7)	0·698 (4)
H(12*B*)	0·330 (4)	0·416 (7)	0·859 (4)
H(14*A*)	0·317 (3)	0·798 (5)	0·680 (2)
H(15*A*)	0·261 (3)	1·060 (5)	0·754 (3)
H(15*B*)	0·315 (2)	1·026 (4)	0·896 (2)
H(16*A*)	0·064 (3)	0·930 (4)	0·787 (3)
H(16*B*)	0·114 (3)	0·936 (5)	0·938 (3)
H(17*A*)	0·131 (3)	0·666 (6)	0·747 (3)
H(18*A*)	0·427 (3)	0·717 (4)	1·012 (3)
H(18*B*)	0·335 (4)	0·606 (6)	1·045 (4)
H(18*C*)	0·324 (4)	0·792 (7)	1·043 (4)
H(19*A*)	0·831 (3)	0·732 (5)	0·821 (3)
H(19*B*)	0·755 (3)	0·612 (4)	0·883 (3)
H(19*C*)	0·740 (3)	0·819 (5)	0·878 (3)
H(17O)	0·077 (2)	0·533 (5)	0·929 (3)
H(*WA*)	0·976 (2)	0·760 (3)	0·223 (2)
H(*WB*)	0·980 (3)	0·749 (5)	0·092 (3)

The intensities were reduced to structure-factor amplitudes, and phase angles sufficient to locate the non-hydrogen atoms were obtained using the direct methods program *MULTAN* (Germain, Main & Woolfson, 1971). The H atoms were located on a

difference electron-density map prepared at an intermediate stage of least-squares refinement of structural parameters. In the final cycles of full-matrix, least-squares refinement, positional parameters for all atoms, anisotropic thermal vibration parameters for the non-hydrogen atoms, and isotropic thermal vibration parameters for the H atoms were varied. The quantities $(1/\sigma_F^2)$ were used to weight the least-squares differences for the observed data, where σ_F was as defined by Stout & Jensen (1968, p. 457, equation *H*14) but with an instability factor of 0·06 (instead of 0·01); unobserved data were given zero weight. The final values of the residual, $R = \sum||F_o| - |F_c||/\sum|F_o|$, were 0·058 for the observed data and 0·064 for all the measured data. The final weighted residual was 0·075. The scattering factors used throughout the refinement were generated from the coefficients given in Table 2.2*B* of *International Tables for X-ray Crystallography* (Cromer & Waber, 1974). Final positional parameters are listed in Table 1.*

Discussion. The crystallographically observed conformation of the steroid molecule is illustrated in Fig. 1. Fig. 2 shows the atom numbering and the intramolecular dimensions involving the non-hydrogen atoms; estimated standard deviations range from 0·002 to 0·004 Å for the bond distances, from 0·1 to 0·2° for the bond angles, and from 0·1 to 0·4° for the torsion angles. The shortness of the C(1)–C(2) and C(3)–O(3) bonds reflects their double-bond character, and, these two bonds being conjugate to one another, the intervening C(2)–C(3) bond is somewhat shorter than the other C–C single bonds in the molecule. These bond distances are similar to those observed in the conjugated system of the Δ^4-3-one steroids, in which the bond distances averaged over 37 different examples (Duax & Norton, 1975) are 1·228 (21) Å for the C(3)–O(3) and 1·342 (3) Å for the C(4)–C(5) double bonds, and 1·455 (3) Å for the intervening C(3)–C(4) bond. The 27 C–H bonds in the steroid molecule (not shown in Fig. 2) have bond distances ranging from 0·80 to 1·15 Å with estimated standard deviations ranging from 0·03 to 0·05 Å. The average of the C–H bond distances is 1·00 ± 0·10 Å. In the 17β-hydroxy

* Lists of structure factors and anisotropic thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34102 (11 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

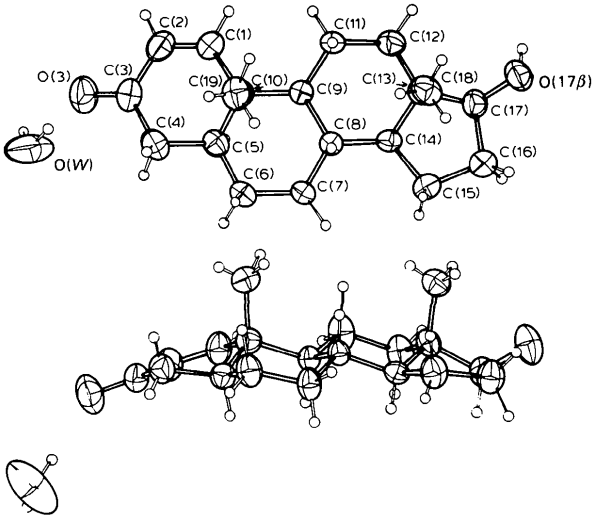


Fig. 1. *ORTEP* (Johnson, 1965) drawings of the structure. Thermal ellipsoids for the non-hydrogen atoms are scaled to 60% probability and hydrogen atoms are represented as spheres equivalent to $B = 1$ Å^2.

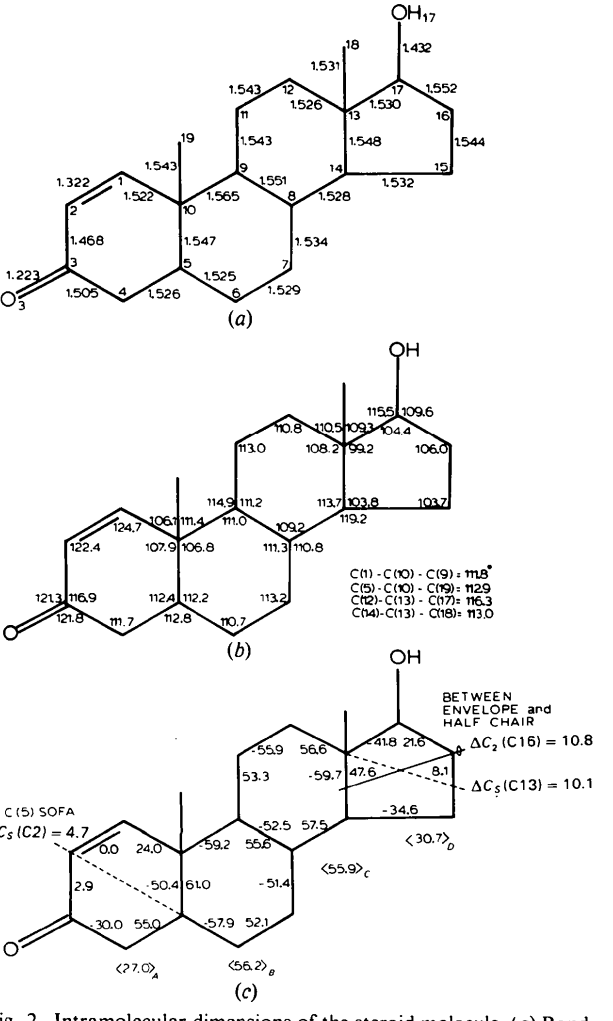


Fig. 2. Intramolecular dimensions of the steroid molecule. (*a*) Bond distances (Å), (*b*) bond angles (°), (*c*) endocyclic torsion angles (°). A torsion angle α–β–γ–δ is positive if, when viewed down the β–γ bond, the α–β bond will eclipse the γ–δ bond when rotated less than 180° in a clockwise direction. The numbers in brackets, $\langle\ \rangle$, are the average ring dihedral angles (°).

Table 2. *Intermolecular distances <3·5 Å between non-hydrogen atoms and hydrogen-bond dimensions*

(Estimated standard deviations in last digit given in parentheses.)

	Distance (Å)	Symmetry operator on second atom
C(4)···O(3)	3·297 (4)	$2-x, \frac{1}{2}+y, 1-z$
C(16)···O(*W*)	3·498 (5)	$-1+x, y, 1+z$
C(17)···O(*W*)	3·467 (5)	$1-x, -\frac{1}{2}+y, 1-z$

Donor *D*	Acceptor *A*	*D*···*A*	*D*–H	H···*A*	∠*D*–H···*A*
O(17β)···O(*W*^{i})		2·725 (4) Å	0·73 (4) Å	2·01 (4) Å	168 (2)°
O(*W*)···O(3^{ii})		2·886 (4)	0·91 (2)	1·99 (2)	170 (2)
O(*W*)···O(17β^{iii})		2·809 (4)	0·75 (3)	2·20 (3)	138 (2)

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

group, the O–H bond distance is 0·73 (4) Å and the C(17)–O–H bond angle is 113 (1)°. In the water molecule, the bond distances are 0·91 (2) and 0·75 (3) Å and the bond angle is 108 (1)°. Short intermolecular distances and hydrogen-bond dimensions in the crystal structure are listed in Table 2, where it is seen that the 3-keto oxygen accepts one hydrogen bond from a water molecule, and that the 17β-hydroxy group donates a hydrogen bond to one water molecule and accepts a bond from another (crystallographically equivalent) water molecule.

As can be seen in the view of Fig. 1 and from the asymmetry parameters ΔC_s and ΔC_2 (Duax, Weeks & Rohrer, 1976) given in Fig. 2(*c*), the conformation of the steroid *A* ring is close to an ideal 5α sofa, and that of the *D* ring is intermediate between a 13β envelope and a 13β,14α half-chair. In 17β-hydroxy-17α-methyl-5α-androst-1-en-3-one, the only other example of a Δ^1-3-one steroid for which crystallographic results have been reported (Rendle & Trotter, 1974), the *A*-ring conformation [ΔC_s(C2) = 12·9 and ΔC_2(C2–C3) = 13·0] is intermediate between a 5α sofa and a 5α,10β half-chair, but the *D*-ring conformation [ΔC_s(C13) = 11·7 and ΔC_2(C16) = 7·2] is quite close to that observed in the present study.

These differences in the *A*-ring conformations of two steroid molecules which differ only by a single methyl substituent on the *D* ring may be attributed either to long-range conformational transmission effects or to the potential for the *A* rings of both steroids to achieve either conformation. Recent studies of medroxyprogesterone acetate tend to support the former hypothesis (Duax, Cody, Griffin, Rohrer & Weeks, 1978).

It is clear from Fig. 1 that the *A* ring does not have a convex-shaped β face, but rather has a twisted shape making the overall molecule relatively planar. Thus, approach to C(1) is not limited solely by the conformation of the *A* ring. Consideration of the steric influence the hydrogens play in limiting approach to

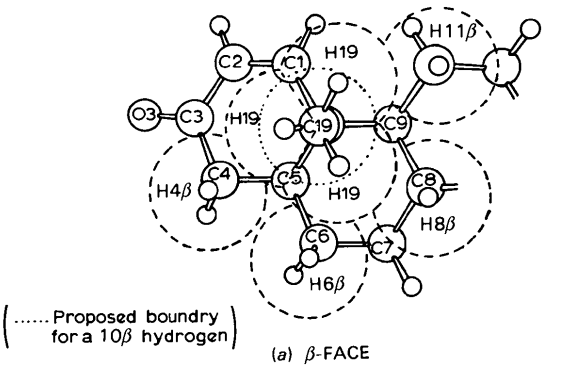


Fig. 3. Two views of the *A* and *B* ring region of the molecule showing the hydrogens adjacent to C(1) with a 1 Å steric boundary (– – –).

C(1), as shown in Fig. 3, clearly shows that the α face is much more open to attack. Fig. 3 also shows that the carbonyl is open on both the α and β sides, making it readily available for complexation to the magnesium in the Grignard addition. The 1α stereoselectivity of this molecule can easily be explained by the steric effects. However, the 1α selectivity of the 19-nor precursor is more difficult to explain as purely a result of steric hindrance to β-face approach. Although the 10β-hydrogen on the 19-nor molecule must partially block the β face of C(1), see Fig. 3(*a*), this explanation is not sufficient to explain the level of specificity observed. Perhaps, as has been proposed by Bolt & Zeelen (1973) the structure of the reaction product and the corresponding transition state also are involved. More structural work remains to be done in order to clarify this point.

This work was supported in part by Grant No. CA-10906 from the National Cancer Institute, DHEW. We would also like to thank Dr Zeelen of Organon Scientific Development Group, Oss, The Netherlands, for providing the sample, and for his help and encouragement in the preparation of this manuscript.

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Acta Cryst. (1979). B**35**, 1248–1250

3,4,6-Tri-*O*-acetyl-1,2-dideoxy-D-hex-1-enopyranose*

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(*Received* 4 *September* 1978; *accepted* 18 *January* 1979)

Abstract. $C_{12}H_{16}O_7$, $M_r = 272{\cdot}2$, $F(000) = 576$, orthorhombic, $P2_12_12_1$, $a = 5{\cdot}215$ (1), $b = 15{\cdot}485$ (2), $c = 16{\cdot}446$ (2) Å, $V = 1328{\cdot}1$ Å^3, $Z = 4$, $D_x = 1{\cdot}33$ Mg m^{-3}, μ(Cu $K\alpha$) = 0·98 mm^{-1}. The structure was solved by direct methods. The final R and R_w values were 0·059 and 0·043 respectively (weights from counting statistics). The six-membered hetero-ring of the molecule is characterized by the half-chair conformation $^4H_5$.

Introduction. The title compound (GLUCAL) is one of a series of unsaturated monosaccharides. GLUCAL is widely used in preparative carbohydrate chemistry. It represents a trisubstituted 3,4-dihydro-2*H*-pyran whose conformation is of interest in conformational analysis. Colorless crystals were obtained by recrystallization from diethyl ether–petroleum ether solution. The space group was determined from photographs. Cell dimensions and reflection intensities were measured on a Syntex $P2_1$ diffractometer (Institute of Organic Synthesis, Riga, USSR) with graphite-monochromated Cu $K\alpha$ radiation. Of the 1473 independent reflections ($2\theta < 150°$), 1121 had intensities greater than $2\sigma_{(I)}$. No correction for absorption was made. The structure was solved with the *MULTAN XTL* program (SuperNova Computer, Riga). At this stage, full-matrix least-squares refinement [program *CRYLSQ* in the XRAY 70 system (Stewart, Kundell & Baldwin, 1970), performed on a CDC Cyber-73 Computer, Warsaw] with individual isotropic temperature factors led to $R = 0{\cdot}158$ and $R_w = 0{\cdot}110$ [$w = 1/\sigma^2_{(F_o)}$]. The scattering factors used were those given in *International Tables for X-ray Crystallography* (1974). Several cycles of refinement with anisotropic thermal coefficients (and weights as above) were then performed. The final R and R_w values after inclusion of the geometrically calculated H coordinates were 0·059 and 0·043 respectively. The average shift/error value was 0·0015 (maximum = 0·0102). The final coordinates of the non-hydrogen atoms are listed in Table 1.†

Discussion. The six-membered hetero-ring of GLUCAL with a C(1)=C(2) double bond (Fig. 1) has

* For a preliminary account see Krajewski, Urbanczyk-Lipkowska, Gluzinski, Bleidelis & Kemme (1978).

† Lists of structure factors and anisotropic thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34103 (25 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

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