Discussion. The atomic coordinates are listed in Table 1, and bond distances and angles are given in Table 2.* A view of the molecule and the numbering scheme are shown in Fig. 1. The packing scheme is presented in Fig. 2.

Bond distances and angles are normal. Refinement of H atoms with isotropic thermal parameters and free coordinates was not successful. The H atoms had to be used as riding atoms with the C—H distance fixed until acceptable results were obtained. Earlier structural studies of chlorinated dibenzo-*p*-dioxins, *viz.* 2,3,7,8-tetrachloro- (TCDD) (Boer, van Remoortere, North & Neuman, 1972), 2,7-dichloro- (Boer & North, 1972), octachloro- (Neuman, North & Boer, 1972) and 2,8-dichlorodibenzo-*p*-dioxin (Boer, Neuman & Aniline, 1972), confirmed the assumed planarity of these molecules. The compound under study is less planar than the chlorinated dibenzo-*p*-dioxins just mentioned, but the deviations are so small that the molecule can be regarded as planar {largest deviation 0·081 (4) Å [Cl(2)] from least-squares plane}.

On the basis of the molecular dimensions of TCDD, Poland (Poland & Knutson, 1982) proposed that the TCDD molecule fits exactly into a particular receptor, disturbing its normal functioning and causing the toxic effects observed. The dimensions of this rectangular receptor would be 10 × 3 Å. Recently Gillner *et al.* (1985) improved Poland's theory by using instead molecular dimensions and van der Waals radii to evaluate the size of the dioxin receptor; namely, the

receptor size proposed by Poland cannot explain the similar toxic effects observed for polycyclic aromatic hydrocarbons (PAH). The receptor size as expanded by the van der Waals radii is 13·7 × 6·8 Å. The van der Waals expanded dimensions of the title compound are length 10·905 Å and height 7·928 Å. The height of 1,2,3,4-tetrachlorodibenzo-*p*-dioxin is thus too great for the molecule to fit exactly into the dioxin receptor. The compound does not, therefore, have similar toxic effects to TCDD and other molecules that fit into the dioxin receptor.

References

BOER, F. P., NEUMAN, M. A. & ANILINE, O. (1972). *Acta Cryst.* **B28**, 2878–2880.
BOER, F. P. & NORTH, P. P. (1972). *Acta Cryst.* **B28**, 1613–1618.
BOER, F. P., VAN REMOORTERE, F. P., NORTH, P. P. & NEUMAN, M. A. (1972). *Acta Cryst.* **B28**, 1023–1029.
FRENZ, B. A. (1978). *The Enraf–Nonius CAD4 SDP – A Real-Time System for Concurrent X-ray Data Collection and Crystal Structure Solution.* In *Computing in Crystallography,* edited by H. SCHENK, R. OLTHOF-HAZELKAMP, H. VAN KONIGSVELD & G. C. BASSI, pp. 64–71. Delft Univ. Press.
GILLNER, M., FERNSTRÖM, B., GUSTAFSSON, J. Å., CAMBILLEAU, C. & BERGMAN, J. (1985). DIOXIN 85 Symp., Bayreuth, Abstracts, p. 30.
International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor D. Reidel, Dordrecht.)
JOHNSON, C. K. (1976). *ORTEPII.* Report ORNL-5138. Oak Ridge National Laboratory, Tennessee.
MAIN, P., FISKE, S. J., HULL, S. E., LESSINGER, L., GERMAIN, G., DECLERCQ, J.-P. & WOOLFSON, M. M. (1982). *MULTAN11/82. A System of Computer Programs for the Automatic Solution of Crystal Structures from X-ray Diffraction Data.* Univs. of York, England, and Louvain, Belgium.
NEUMAN, M. A., NORTH, P. P. & BOER, F. P. (1972). *Acta Cryst.* **B28**, 2313–2317.
POLAND, A. & KNUTSON, J. C. (1982). *Ann. Rev. Pharmacol. Toxicol.* **22**, 517–554.
WALKER, N. & STUART, D. (1983). *Acta Cryst.* **A39**, 158–166.

* Lists of structure factors, anisotropic thermal parameters, least-squares planes and H-atom parameters have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 43434 (11 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

Structure of (3*R*,6*S*)-3-Neopentyl-1,4-diazabicyclo[4.3.0]nonane-2,5-dione

BY JINDŘICH SYMERSKÝ AND KAREL BLÁHA

Institute of Organic Chemistry and Biochemistry, Czechoslovak Academy of Sciences, 166 10 Praha 6, Czechoslovakia

AND VRATISLAV LANGER

Institute of Macromolecular Chemistry, Czechoslovak Academy of Sciences, 162 02 Praha 6, Czechoslovakia

Abstract. $C_{12}H_{20}N_2O_2$, $M_r = 224\cdot30$, orthorhombic, $P2_12_12_1$, $a = 10\cdot006$ (2), $b = 19\cdot696$ (6), $c = 6\cdot365$ (1) Å, $V = 1254\cdot4$ (5) Å^3, $Z = 4$, $D_x = 1\cdot19$ (1) g cm^{-3}, λ(Cu $K\alpha$) $= 1\cdot5418$ Å, $\mu = 6\cdot19$ cm^{-1}, $F(000) = 488$, $T = 295$ K, final $R = 0\cdot067$ for 1178 unique observed reflections. The 2,5-piperazinedione

ring is in a twist-boat conformation containing slightly non-planar amide groups related by C_2 symmetry. The *tert*-butyl group is oriented out of the ring plane. The 3*R*,6*S* diastereoisomer was confirmed. The molecules are connected by N—H···O hydrogen bonds into antiparallel helices along the *c* axis.

Introduction. The estimation of the geometry of the 2,5-piperazinedione ring is part of the amide-group investigation project (Ealick & van der Helm, 1977; Bláha *et al.*, 1978; Bláha & Maloň, 1980; Kálal, Bláha & Langer, 1984; Symerský, Kálal, Bláha & Langer, 1986; Tichý, Farag, Maloň & Bláha, 1984; Bláha *et al.*, 1984). The cyclodipeptide under study contains a non-coded amino acid neopentylglycine.
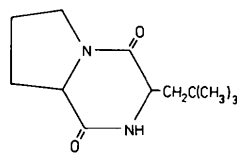
(I)

Experimental. Colorless long prismatic crystals grown by slow evaporation from ethanol solution kindly prepared by Dr J. Pospíšek, Institute of Organic Chemistry and Biochemistry, Praha. Density measurement was not performed because there was insufficient material. Preliminary cell dimensions and space group determined from oscillation and Weissenberg photographs recorded with Cu *Kα* radiation. Syntex *P*2$_1$ automated diffractometer with graphite monochromator, Cu *Kα* radiation, $[(\sin\theta)/\lambda]_{max} =$ 0·6095 Å⁻¹, crystal 0·20 × 0·40 × 0·15 mm, final cell dimensions refined on 25 diffractometer reflections with $8 \cdot 9 < 2\theta < 26 \cdot 5°$. θ–2θ scan technique, no background measurement, intensities and their respective e.s.d.'s were calculated using combined methods of profile analysis (Lehmann & Larsen, 1974) and mask procedure (Sjölin & Wlodawer, 1981). $0 \le h \le 12$, $0 \le k \le 23$, $0 \le l \le 7$; in range up to $2\theta = 140°$; 1385 unique reflections measured, 1178 observed with $I > 1 \cdot 96\sigma_I$. Check reflections 400, 0,12,0 and 002 monitored after every 47 reflections showed decreasing intensity throughout data collection (to 63, 66, 67%, respectively, of initial intensity). The measurements were reduced to the same scale with *INTER* (Langer, 1973). Corrections made for Lorentz and polarization factors, not for absorption. The phase problem was solved using direct methods (*MULTAN*80; Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980). The enantiomorph assigned by the program agreed with the declared (*S*)-proline chirality known from chemical synthesis. Refinement on |*F*| by full-matrix LS method with *SHELX*76 (Sheldrick, 1976). Some H atoms were located on the $\Delta\rho$ map, others were calculated in

theoretical positions. Most of the H atoms were unstable during refinement, therefore they were put in theoretical positions and refined using a riding model with fixed $U_{iso} = 0 \cdot 1$ Å^2 for methyl H atoms and U_{iso} $= 0 \cdot 08$ Å^2 for other H atoms not found on the $\Delta\rho$ map. Empirical correction for secondary extinction as F_c^{corr} $= F_c(1 - gF_c^2/\sin\theta)$, where $g = 1 \cdot 2$ (3) $\times$ 10⁻⁶. Number of parameters refined 184, refinement stopped when $(\Delta/\sigma)_{max} = 0 \cdot 07$. Final $R = 0 \cdot 0667$, $wR = 0 \cdot 0814$ for observed reflections, 0·0795 and 0·0882 respectively for all reflections, with $w = 1 \cdot 080/[\sigma_F^2 + (0 \cdot 03F)^2]$, where σ_F is taken from counting statistics. The max. in final $\Delta\rho$ map on all reflections was 0·22 and min. $-0 \cdot 30$ e Å^{-3}. Atomic scattering factors from *International Tables for X-ray Crystallography* (1974). Final geometrical features of the molecule calculated with *PARST*83 (Nardelli, 1983).

Discussion. The compound investigated is a model for cyclodipeptides (diketopiperazines). A view of the molecule with the numbering scheme is shown in Fig. 1. The fractional atomic coordinates and B_{eq} values are given in Table 1, selected bond lengths and angles in Table 2.* The crystal packing and hydrogen bonds are shown in Fig. 2. The hydrogen-bond parameters are: N(16)—H(161) = 0·87 (6), H(161)···O(8) = 2·09 (6), N(16)···O(8) = 2·930 (6) Å and N(16)—H(161)··· O(8) = 163 (5)°. The molecules are connected by these hydrogen bonds into antiparallel helices along the *c* axis. The six-membered 2,5-piperazinedione ring has a twist-boat conformation, the χ^2 value for its weighted mean plane is 6360; the C(12) atom of the proline ring is an equatorial substituent and C(5) of the neopentyl is an axial one. From the (*S*)-proline chirality, known from the chemical synthesis, the 3*R*,6*S* configuration was found. The bulky *tert*-butyl group is oriented out of the plane of the ring, with torsional angle |N(16)—

---

* Lists of structure factors, anisotropic thermal parameters, H-atom coordinates and thermal parameters along with weak hydrogen contacts have been deposited with the British Library Document Supply Centre as Supplementary Publication No. SUP 43429 (12 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.
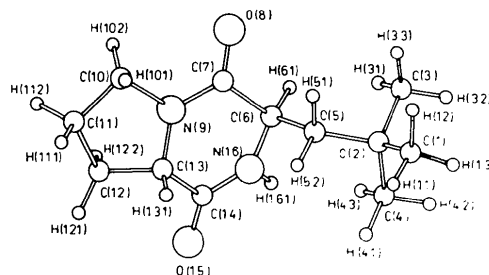

Fig. 1. Projection of the structure with numbering scheme.

C(6)—C(5)—C(2)] 80 (1)°. Comparison with the structure of *cyclo*(-L-Pro-D-*tert*-Leu-) (Sklenář & Ječný, 1979) (*tert*-Leu = 2-amino-3,3-dimethylbutyryl) shows no strong influence by the same bulky aliphatic substituent on the geometry of the 2,5-piperazinedione ring with respect to the distance from the ring. Deviations of the two amide groups from planarity are described by the torsion parameter τ', following Winkler & Dunitz (1971) and by the pyramidal parameters χ_C and χ_N following Warshel, Levitt & Lifson (1970) and these are listed in Table 3.

The slightly non-planar arrangement of the amide groups is due to a torsion around the C—N amide bond (τ). Comparison of the corresponding atomic coordinates for the amide groups did not show significant differences in any projection. The two amide groups are approximately related by C_2 symmetry. The proline ring has approximate C_2 symmetry, with the C_2 axis

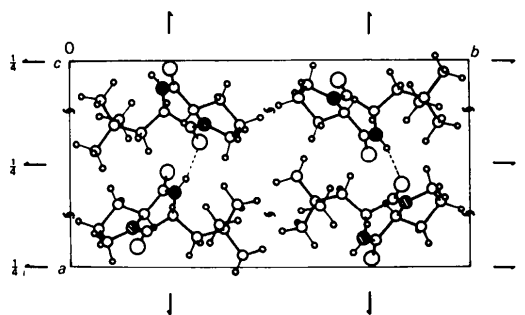

Fig. 2. Crystal packing in the projection along the *c* axis. N atoms are shaded. The hydrogen bonds are shown.

Table 1. *Fractional atomic coordinates* ($\times 10^4$) *and* B_{eq} (Å^2) *values with e.s.d.'s in parentheses*

	x	y	z	B_{eq}*
C(13)	2430 (5)	3131 (2)	9633 (8)	4·0 (1)
C(3)	2909 (8)	1261 (3)	2465 (10)	6·5 (2)
O(8)	3973 (4)	3279 (2)	4531 (6)	5·1 (1)
N(16)	1385 (4)	2347 (2)	7217 (7)	4·2 (1)
C(14)	1320 (4)	2644 (2)	9098 (8)	4·0 (1)
N(9)	3117 (4)	3391 (2)	7801 (6)	3·8 (1)
C(7)	3265 (5)	3063 (2)	6005 (8)	3·9 (1)
C(6)	2503 (4)	2395 (2)	5761 (8)	3·8 (1)
O(15)	417 (4)	2538 (2)	10360 (7)	5·9 (1)
C(5)	3515 (5)	1809 (2)	5892 (9)	4·3 (1)
C(2)	3154 (5)	1135 (2)	4785 (9)	4·4 (1)
C(12)	1969 (5)	3785 (3)	10722 (10)	5·1 (1)
C(11)	3136 (7)	4271 (3)	10276 (12)	6·4 (2)
C(10)	3733 (6)	4049 (3)	8235 (10)	5·1 (1)
C(4)	1936 (7)	801 (3)	5772 (13)	6·3 (2)
C(1)	4365 (7)	664 (3)	5060 (13)	6·9 (2)

$* B_{eq} = \frac{8}{3}\pi^2 \sum_i \sum_j U_{ij} a_i^* a_j^* \mathbf{a}_i.\mathbf{a}_j.$

Table 2. *Bond lengths* (Å) *and angles* (°) *for the molecule*

C(13)—C(14)	1·506 (6)	N(9)—C(10)	1·461 (7)
C(13)—N(9)	1·447 (6)	C(7)—C(6)	1·529 (6)
C(13)—C(12)	1·534 (7)	C(6)—C(5)	1·538 (6)
C(3)—C(2)	1·517 (9)	C(5)—C(2)	1·546 (6)
O(8)—C(7)	1·250 (6)	C(2)—C(1)	1·536 (8)
N(16)—C(14)	1·334 (7)	C(2)—C(4)	1·521 (9)
N(16)—C(6)	1·456 (6)	C(12)—C(11)	1·536 (9)
C(14)—O(15)	1·227 (6)	C(11)—C(10)	1·495 (10)
N(9)—C(7)	1·321 (6)		

N(9)—C(13)—C(12)	102·1 (4)	N(16)—C(6)—C(7)	112·0 (4)
C(14)—C(13)—C(12)	114·5 (4)	C(7)—C(6)—C(5)	108·2 (4)
C(14)—C(13)—N(9)	113·2 (4)	N(16)—C(6)—C(5)	115·0 (4)
C(14)—N(16)—C(6)	125·5 (4)	C(6)—C(5)—C(2)	117·8 (4)
C(13)—C(14)—N(16)	116·5 (4)	C(3)—C(2)—C(5)	109·9 (4)
N(16)—C(14)—O(15)	123·3 (4)	C(5)—C(2)—C(4)	111·8 (4)
C(13)—C(14)—O(15)	120·2 (4)	C(5)—C(2)—C(1)	106·4 (4)
C(13)—N(9)—C(10)	111·2 (4)	C(3)—C(2)—C(4)	110·1 (5)
C(13)—N(9)—C(7)	125·3 (4)	C(3)—C(2)—C(1)	109·7 (5)
C(7)—N(9)—C(10)	123·4 (4)	C(1)—C(2)—C(4)	108·9 (4)
O(8)—C(7)—N(9)	123·1 (4)	C(13)—C(12)—C(11)	102·2 (5)
N(9)—C(7)—C(6)	116·9 (4)	C(12)—C(11)—C(10)	106·4 (5)
O(8)—C(7)—C(6)	120·0 (4)	N(9)—C(10)—C(11)	104·8 (5)

Table 3. *Parameters and angles* (°) *describing the geometry of the amide group*

(1) Amide group at N(16)

ω_1	$\omega[C(13)-C(14)-N(16)-C(6)]$	7·4 (7)
ω_2	$\omega[O(15)-C(14)-N(16)-H(161)]$	5 (4)
ω_3	$\omega[O(15)-C(14)-N(16)-C(6)]$	-172·7 (4)
ω_4	$\omega[C(13)-C(14)-N(16)-H(161)]$	-175 (4)
$\tau' = \omega_1 + \omega_2$		12 (4)
$\chi_C = \omega_1 - \omega_3 + 180$ mod 360°		0·1 (7)
$\chi_N = \omega_2 - \omega_3 + 180$		-2 (4)

(2) Amide group at N(9)

ω_1	$\omega[C(6)-C(7)-N(9)-C(13)]$	8·0 (7)
ω_2	$\omega[O(8)-C(7)-N(9)-C(10)]$	1·8 (8)
ω_3	$\omega[O(8)-C(7)-N(9)-C(13)]$	-173·0 (4)
ω_4	$\omega[C(6)-C(7)-N(9)-C(10)]$	-177·3 (4)
$\tau' = \omega_1 + \omega_2$		9·8 (8)
$\chi_C = \omega_1 - \omega_3 + 180$ mod 360°		1·0 (7)
$\chi_N = \omega_2 - \omega_3 + 180$		-5·2 (8)

running through C(10) and the centre of the C(13)—C(12) bond. Note that the H(161) atom of the amide group was found on the $\Delta\rho$ map after five cycles of isotropic refinement of the non-H atoms and was successfully refined without constraints.

References

BLÁHA, K., FARAG, A. M., VAN DER HELM, D., HOSSAIN, M. B., BUDĚŠÍNSKÝ, M., MALOŇ, P., SMOLÍKOVÁ, J. & TICHÝ, M. (1984). *Collect. Czech. Chem. Commun.* **49**, 712–742.

BLÁHA, K. & MALOŇ, P. (1980). *Acta Univ. Palacki. Olomuc. Fac. Med.* **93**, 81–96.

BLÁHA, K., MALOŇ, P., TICHÝ, M., FRIČ, I., USHA, R., RAMAKUMAR, S. & VENKATESAN, K. (1978). *Collect. Czech. Chem. Commun.* **43**, 3241–3246.

EALICK, S. E. & VAN DER HELM, D. (1977). *Acta Cryst.* **B33**, 76–80.

International Tables for X-ray Crystallography (1974). Vol. IV. Birmingham: Kynoch Press. (Present distributor D. Reidel, Dordrecht.)

KÁLAL, P., BLÁHA, K. & LANGER, V. (1984). Acta Cryst. C40, 1242–1245.

LANGER, V. (1973). INTER. UMCH-111. Institute of Macromolecular Chemistry, Praha.

LEHMANN, M. S. & LARSEN, F. K. (1974). Acta Cryst. A30, 580–584.

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. Univs. of York, England, and Louvain, Belgium.

NARDELLI, M. (1983). PARST83. A System of Computer Routines for Calculating Molecular Parameters from the Results of Crystal Structure Analysis. Univ. of Parma, Italy.

SHELDRICK, G. M. (1976). SHELX76. Program for crystal structure determination. Univ. of Cambridge, England.

SJÖLIN, L. & WLODAWER, A. (1981). Acta Cryst. A37, 594–604.

SKLENÁŘ, I. & JEČNÝ, J. (1979). Acta Cryst. B35, 513–515.

SYMERSKÝ, J., KÁLAL, P., BLÁHA, K. & LANGER, V. (1986). Acta Cryst. C42, 76–78.

TICHÝ, M., FARAG, A. M., MALOŇ, P. & BLÁHA, K. (1984). Collect. Czech. Chem. Commun. 49, 834–839.

WARSHEL, A., LEVITT, M. & LIFSON, S. (1970). J. Mol. Spectrosc. 33, 84–99.

WINKLER, F. K. & DUNITZ, J. D. (1971). J. Mol. Biol. 59, 169–182.

N-(4-Acetylphenyl)acetohydroxamic Acid

BY DOUGLAS R. POWELL AND DICK VAN DER HELM

Department of Chemistry, University of Oklahoma, Norman, OK 73019, USA

Abstract. $C_{10}H_{11}NO_3$, $M_r = 193 \cdot 20$, monoclinic, $P2_1/n$, $a = 23 \cdot 539\,(5)$, $b = 8 \cdot 473\,(2)$, $c = 9 \cdot 540\,\text{Å}$, $\beta = 99 \cdot 44\,(2)°$, $V = 1876 \cdot 9\,(7)\,\text{Å}^3$, $Z = 8$, $D_x = 1 \cdot 367\,\text{g cm}^{-3}$, Ni-filtered $Cu\,K\alpha$, $\lambda = 1 \cdot 5418\,\text{Å}$, $\mu = 7 \cdot 55\,\text{cm}^{-1}$, $F(000) = 816$, $T = 138\,(2)\,\text{K}$, $R = 0 \cdot 057$ for 3018 data. The hydroxamate groups of the two crystallographically unique molecules have a trans conformation. Both molecules are roughly planar and have similar molecular conformations and identical dimensions, which are compared with those of other N-substituted acetohydroxamic acids. The molecules are linked by two intermolecular hydrogen bonds with lengths $2 \cdot 631\,(2)$ and $2 \cdot 636\,(2)\,\text{Å}$.

Introduction. Under iron-limiting conditions, micro-organisms produce a variety of small chelating agents which solubilize ferric iron in the environment and transport the iron to the cell. Many of these metabolites chelate the iron through hydroxamic acid groups. Both naturally occurring and synthetic hydroxamic acids have been used as therapeutic agents for treatment of iron overload (Anderson & Hiller, 1977). Crystal structures of synthetic hydroxamic acids with a trans conformation include N,N'-dihydroxy-N,N'-diisopropylhexanediamide (hipa) (Smith & Raymond, 1980), N-(4-cyanophenyl)acetohydroxamic acid (p-cnpa) (Mocherla, Powell, Barnes & van der Helm, 1983) and N-(3-cyanophenyl)acetohydroxamic acid (m-cnpa) (Mocharla, Powell & van der Helm, 1984). This article describes the crystal and molecular structure of N-(4-acetylphenyl)acetohydroxamic acid (apa).

Experimental. A sample of the title compound was kindly supplied by Dr A. L. Crumbliss, P. M. Gross Chemical Laboratory, Department of Chemistry, Duke University, Durham, North Carolina. Colorless plate-shaped crystals were grown by diffusing benzene into a solution of the compound in ethyl acetate. Crystal: $0 \cdot 08 \times 0 \cdot 25 \times 0 \cdot 50\,\text{mm}$, Enraf–Nonius CAD-4, 48 reflections used for lattice constants, systematic absences: $h0l$, $h + l = 2n + 1$, $0k0$, $k = 2n + 1$, no absorption correction applied, all data $2\theta < 150°$ in $-29 \le h \le 29$, $0 \le k \le 10$, $0 \le l \le 11$ collected, three intensity monitors had a maximum difference of $0 \cdot 074$ and an e.s.d. of $0 \cdot 019$, 3826 unique data measured, 808 unobserved data $[F < 3 \cdot 8\sigma(F)]$, solved by MULTAN (Main, Fiske, Hull, Lessinger, Germain, Declercq & Woolfson, 1980), refined by block full-matrix least squares minimizing $\sum w(|F_o| - |F_c|)^2$, hydrogens located on a difference electron density map, all heavy atoms refined anisotropically, hydrogens refined isotropically, $R = 0 \cdot 057$, $wR = 0 \cdot 078$, $S = 2 \cdot 79$, $w = 1/\sigma^2(F)$, maximum and average shift-to-e.s.d. ratios $= 0 \cdot 48$, $0 \cdot 10$, maximum and minimum on final difference map $= 0 \cdot 35$ and $0 \cdot 34\,\text{e Å}^{-3}$, C, N and O scattering factors from Cromer & Mann (1968), H scattering factors from Stewart, Davidson & Simpson (1965), programs used include SHELX (Sheldrick, 1976) and ORTEP (Johnson, 1965).

Discussion. The final coordinates of the nonhydrogen atoms are given in Table 1. The atom-numbering scheme is shown in Fig. 1 (Johnson, 1965). Bond