

- ALTONA, C. & SUNDARALINGAM, M. (1970). *J. Am. Chem. Soc.* **92**, 1995–1999.
- BRUTCHER, F. V. JR & BAUER, W. JR (1962). *J. Am. Chem. Soc.* **84**, 2233–2236.
- DE CAMP, W. H. & PELLETIER, S. W. (1977). *Acta Cryst.* **B33**, 722–727.
- HANSON, H. P., HERMAN, F., LEA, J. D. & SKILLMAN, S. (1964). *Acta Cryst.* **17**, 1040–1044.
- IUPAC–IUB COMMISSION ON BIOCHEMICAL NOMENCLATURE (1970). *J. Mol. Biol.* **52**, 1–17.
- JOHNSON, C. K. (1965). *ORTEP*. Report ORNL-3794 revised. Oak Ridge National Laboratory, Tennessee.
- KARLE, I. L. & KARLE, J. (1963). *Acta Cryst.* **16**, 969–975.
- PELLETIER, S. W., DE CAMP, W. H. & MODY, N. V. (1978). *J. Am. Chem. Soc.* **100**, 7976–7987.
- PRZYBYLSKA, M. (1972). *Acta Cryst.* **B28**, 2814–2820.
- PRZYBYLSKA, M. & AHMED, F. R. (1974). *Acta Cryst.* **B30**, 2338–2342.
- STEWART, R. F., DAVIDSON, E. R. & SIMPSON, W. T. (1965). *J. Chem. Phys.* **42**, 3175–3187.
- WIESNER, K. (1978). IUPAC 11th Int. Symp. Chem. of Natural Products, Plenary Lecture, Golden Sands, Bulgaria.
- WIESNER, K., TSAI, T. Y. R. & NAMBIAR, K. P. (1978). *Can. J. Chem.* **56**, 1451–1454.

Acta Cryst. (1980). **B36**, 497–499

Refinement of the Structure of Nalidixic Acid*

BY CAROL P. HUBER

Division of Biological Sciences, National Research Council of Canada, Ottawa, Canada K1A 0R6

AND D. S. SAKE GOWDA AND K. RAVINDRA ACHARYA

Department of Physics, Central College, Bangalore University, Bangalore 560 001, India

(Received 8 August 1979; accepted 22 October 1979)

Abstract. $C_{12}H_{12}N_2O_3$, 1-ethyl-1,4-dihydro-7-methyl-4-oxo-1,8-naphthyridine-3-carboxylic acid, monoclinic, $P2_1/c$, $a = 8.921$ (1), $b = 13.156$ (2), $c = 9.369$ (1) Å, $\beta = 100.04$ (2)°, $V = 1082.7$ Å³, $D_m = 1.41$, $Z = 4$, $D_x = 1.42$, $Mg\ m^{-3}$. The structure was refined with 1284 observed independent reflections measured on a four-circle diffractometer to a final R value of 0.039. The present work generally confirms the earlier results of Achari & Neidle [*Acta Cryst.* (1976), **B32**, 600–602], but offers significantly improved precision.

Introduction. Nalidixic acid, which is used clinically to treat urinary-tract infections, exerts its antibacterial action on Gram-negative bacteria (*Escherichia coli*, *Staphylococcus*, most species of *Proteus*, etc.) by inhibiting DNA replication (Gale, Cundliffe, Reynolds, Richmond & Waring, 1972). Recent work (Gellert, Mizuuchi, O'Dea, Itoh & Tomizawa, 1977; Sugino, Peebles, Kreuzer & Cozzarelli, 1977) has established that it does this by inhibiting the P_{nal} component of DNA gyrase; gyrase introduces negative supercoils into DNA, using ATP as energy source, thereby preventing snarls during the unwinding of the DNA double helix and reducing the energy cost of strand separation. The P_{nal} component is involved in the

nicking-closing activity required in the supercoiling reaction.

With the improved understanding of the drug action of nalidixic acid, it seemed worthwhile to establish its crystal structure with greater precision than the earlier analysis (Achari & Neidle, 1976), based on 797 photographic data, provided.

Colourless prismatic crystals, elongated along a , were grown by slow evaporation of a methanol/water solution. A specimen $0.11 \times 0.20 \times 0.45$ mm was used for the diffractometer measurements, made with Ni-filtered Cu radiation. Cell parameters were obtained by a least-squares refinement based on the 2θ values of 22 reflections (with $63^\circ < 2\theta < 105^\circ$). Integrated intensities were measured for the 1829 independent reflections with $2\theta \leq 130^\circ$, using $\theta/2\theta$ scans of 2.0° (in 2θ) for $0^\circ < 2\theta \leq 90^\circ$ and 3.0° for $90^\circ < 2\theta \leq 130^\circ$. Background counts of 20 s each were recorded at the beginning and end of each scan. The threshold level, below which reflections were considered 'unobserved', was determined experimentally as a net count of 15 (decacounts) or a net count at least 10% of the total background count; 1284 reflections were considered 'observed'. Lorentz and polarization corrections were made, and an extinction correction ($g/\mu = 0.254 \times 10^{-3}$) was applied at a later stage.

The structure was refined by block-diagonal least squares, starting from a set of non-hydrogen-atom

* Issued as NRCC No. 17987.

Table 1. Fractional coordinates ($\times 10^4$, for H $\times 10^3$) and isotropic thermal parameters

E.s.d.'s (in parentheses) refer to the least significant digit.

	x	y	z	B_{eq}/B (\AA^2)
C(1)	1650 (3)	846 (2)	5800 (3)	4.20
C(2)	1512 (2)	108 (2)	6992 (2)	3.54
N(3)	1317 (2)	630 (1)	8361 (2)	2.88
C(4)	2518 (2)	755 (2)	9423 (2)	3.08
C(5)	2455 (2)	1205 (2)	10721 (2)	2.92
C(6)	1019 (2)	1552 (2)	11039 (2)	3.01
C(7)	-260 (2)	1442 (2)	9862 (2)	3.03
C(8)	-1725 (3)	1792 (2)	9983 (3)	3.89
C(9)	-2886 (3)	1691 (2)	8837 (3)	4.11
C(10)	-2612 (2)	1233 (2)	7567 (3)	3.34
N(11)	-1245 (2)	880 (1)	7421 (2)	3.01
C(12)	-105 (2)	1000 (2)	8548 (2)	2.77
C(13)	-3867 (3)	1102 (2)	6292 (3)	4.40
O(14)	875 (2)	1919 (1)	12242 (2)	3.86
C(15)	3873 (3)	1307 (2)	11796 (2)	3.63
O(16)	3718 (2)	1733 (2)	13041 (2)	4.58
O(17)	5107 (2)	1021 (2)	11580 (2)	4.93
H(1a)	176 (3)	45 (2)	494 (3)	2.4 (6)
H(1b)	251 (3)	130 (2)	604 (3)	2.2 (5)
H(1c)	69 (3)	128 (2)	553 (3)	2.6 (6)
H(2a)	241 (3)	-33 (2)	725 (3)	1.9 (5)
H(2b)	67 (3)	-34 (2)	671 (3)	1.9 (5)
H(4)	345 (3)	47 (2)	923 (2)	1.2 (4)
H(8)	-183 (3)	209 (2)	1084 (3)	2.3 (6)
H(9)	-390 (3)	195 (2)	889 (3)	2.6 (6)
H(13a)	-448 (4)	163 (3)	620 (3)	3.9 (7)
H(13b)	-442 (4)	55 (3)	636 (4)	4.8 (8)
H(13c)	-350 (4)	116 (3)	532 (4)	4.9 (8)
H(16)	268 (4)	196 (3)	1294 (3)	4.2 (7)

positions obtained routinely with *MULTAN* (Declercq, Germain, Main & Woolfson, 1973). H atoms were located on a difference map. Non-hydrogen atoms were refined with anisotropic, and H atoms with isotropic, thermal parameters. The weighting scheme used in the final least-squares cycles was: $w = 1.0/|F_o|$ if $|F_o| > 20$, otherwise $w = 1.0$, and $w = w \times 4.0 \sin^2 \theta$ if $\sin^2 \theta < 0.25$. Scattering-factor values were taken from *International Tables for X-ray Crystallography* (1974). Final atomic coordinates are listed in Table 1.*

As a check, the structure was also refined with a weighting scheme based on counting statistics. The resulting parameters were not significantly different from those in Table 1.

Discussion. Bond lengths and bond angles are shown in Fig. 1. E.s.d.'s for the bond lengths not involving H atoms are in the range 0.0027–0.0036 Å. The C–H bond lengths vary from 0.88 to 1.03 Å, with e.s.d.'s of about 0.03 Å. The bond angles not involving H atoms

* Lists of structure factors and anisotropic thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 34873 (10 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

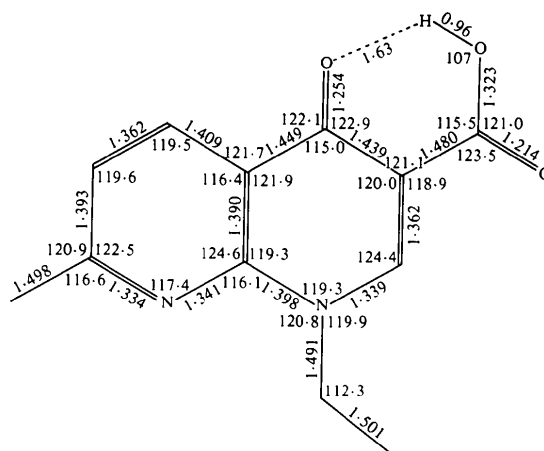


Fig. 1. Bond lengths (\AA) and bond angles ($^\circ$).

Table 2. Deviations (\AA , $\times 10^3$) of atoms from least-squares planes

X, Y and Z refer to an orthogonal axial system with X along a, Y along b and Z along c*. Daggers denote atoms used to define the planes. E.s.d.'s of the deviations are 0.002–0.003 Å.

	(I)	(II)	(III)
C(1)	1268		
C(2)	-79	-69	
N(3)	-27†	-19†	
C(4)	14†	0†	
C(5)	39†	20†	
C(6)	-21†	-21†	
C(7)	-20†	2†	0†
C(8)	-11†		-5†
C(9)	17†		3†
C(10)	21†		3†
N(11)	-5†		-8†
C(12)	-8†	17†	6†
C(13)	41		2
O(14)	-76	-80	
C(15)	101	58	
O(16)	98	51	
O(17)	147	87	

Equations of planes

$$\begin{aligned} \text{(I)} \quad & 0.2730X + 0.8928Y - 0.3582Z + 2.0482 = 0 \\ \text{(II)} \quad & 0.2576X + 0.8941Y - 0.3663Z + 2.1134 = 0 \\ \text{(III)} \quad & 0.2853X + 0.8924Y - 0.3497Z + 2.0154 = 0 \end{aligned}$$

have e.s.d.'s of about 0.2° . Because of the large e.s.d.'s in the previous determination (about 0.010 Å for bond lengths not involving H atoms, and about 0.7° for corresponding bond angles), the changes in values are, at most, marginally significant. However, the new bond lengths and angles agree very closely with corresponding values in aminooxolinic acid (Czugler, Argay, Frank, Meszaros, Kutschabsky & Reck, 1976). This is particularly interesting because oxolinic acid also inhibits the P_{nal} component of DNA gyrase (Gellert *et al.*, 1977; Suginio *et al.*, 1977).

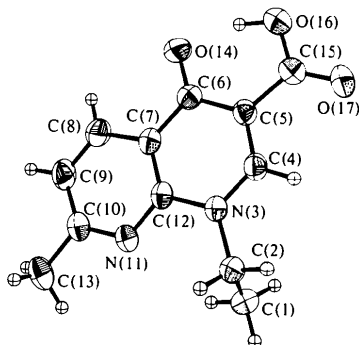


Fig. 2. Numbering scheme and thermal ellipsoids (enclosing 50% probability) of nalidixic acid.

With increased precision, both pyridine rings show significant deviations from planarity: the more-substituted ring toward a twist-boat shape, and the other ring toward a boat shape. Equations of mean planes and deviations from them are given in Table 2.

As shown in Fig. 2, the plane of the N-ethyl group is approximately perpendicular to the naphthyridine ring system; the C(1)–C(2)–N(3)–C(4) torsion angle is -99.0° .

Programs used in the analysis were from the NRC crystallographic program set (Ahmed, Hall, Pippy & Huber, 1973) and the IISc crystallographic programs (Shiono & Reddy, 1968).

We wish to thank Professor M. A. Viswamitra and Drs S. Ramakumar and V. Sudhakar, Indian Institute

Acta Cryst. (1980). B36, 499–502

Methyl Phenyl[*syn*- α -(tosylhydrazone)benzyl]phosphinate – A Short Intramolecular N–H...O Hydrogen Bond

BY G. MAAS*

Fachbereich Chemie der Universität, Postfach 3049, D-6750 Kaiserslautern, Federal Republic of Germany

AND R. HOGE

Fachrichtung 17.3 Kristallographie der Universität des Saarlandes, Im Stadtwald, D-6600 Saarbrücken, Federal Republic of Germany

(Received 28 August 1979; accepted 18 September 1979)

Abstract. $C_{21}H_{21}N_2O_4PS$, $M_r = 428.43$, triclinic, $P\bar{1}$, $a = 11.877(8)$, $b = 10.234(7)$, $c = 10.000(7)$ Å, $\alpha = 107.30(2)$, $\beta = 109.52(2)$, $\gamma = 70.54(2)^\circ$, $V = 1009$ Å³, $Z = 2$, $D_c = 1.410$ Mg m⁻³, $\mu(\text{Mo } K\alpha) = 0.271$ mm⁻¹. The *syn* configuration around the C=N double

of Science, Bangalore, for their helpful suggestions. We thank Professor K. N. Kuchela, Department of Physics, Bangalore University, for his interest in the work. DSSG is indebted to the Indian Council of Medical Research, New Delhi, for the financial support of that part of the research carried out in Bangalore.

References

- ACHARI, A. & NEIDLE, S. (1976). *Acta Cryst.* B32, 600–602.
- AHMED, F. R., HALL, S. R., PIPPY, M. E. & HUBER, C. P. (1973). NRC Crystallographic Programs for the IBM/360 System. Accession Nos. 133–147 in *J. Appl. Cryst.* 6, 309–346.
- CZUGLER, M., ARGAY, G., FRANK, J., MESZAROS, Z., KUTSCHABSKY, L. & RECK, G. (1976). *Acta Cryst.* B32, 3124–3126.
- DECLERCQ, J. P., GERMAIN, G., MAIN, P. & WOOLFSON, M. M. (1973). *Acta Cryst.* A29, 231–234.
- GALE, E. F., CUNLIFFE, E., REYNOLDS, P. E., RICHMOND, M. H. & WARING, M. J. (1972). *The Molecular Basis of Antibiotic Action*. London: John Wiley.
- GELLERT, M., MIZUUCHI, K., O'DEA, M. H., ITOH, T. & TOMIZAWA, J. (1977). *Proc. Natl Acad. Sci. USA*, 74, 4772–4776.
- International Tables for X-ray Crystallography* (1974). Vol. IV. Birmingham: Kynoch Press.
- SHIONO, R. & REDDY, S. (1968). IISc crystallographic programs.
- SUGINO, A., PEEBLES, C. L., KREUZER, K. N. & COZZARELLI, N. R. (1977). *Proc. Natl Acad. Sci. USA*, 74, 4767–4771.

bond supports the formation of an intramolecular N–H...O hydrogen bond which closes a part of the molecule to a six-membered ring: N–H...O 2.660(7), O...H 1.70(9) Å, $\angle \text{N–H...O}$ 143(9)°.

Introduction. The title compound (I) was obtained by benzophenone-sensitized irradiation of the known *anti*

* To whom correspondence should be addressed.