the three planar segments in the molecule result in a rather loosely packed structure consistent with the ease of sublimation of the solid material.

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References

BRENNAN, T. F., GARAFALO, A. R. & WILLIAMS, D. A. (1979). *Cryst. Struct. Commun.* **8**, 953–957.

BROWN, J. N. & TREFONAS, L. M. (1972). *J. Am. Chem. Soc.* **94**, 4311–4314.

BRUDERER, H., METZGER, J., BROSSI, A. & DALY, J. J. (1976). *Helv. Chim. Acta*, **59**, 2793–2807.

CAVA, M. P., STERN, P. & WAKISAKA, K. (1973). *Tetrahedron*, **29**, 2245–2249.

CROMER, D. T. & LIBERMAN, D. (1970). *J. Chem. Phys.* **53**, 1891–1898.

CROMER, D. T. & WABER, J. T. (1965). *Acta Cryst.* **18**, 104–109.

GERMAIN, G., MAIN, P. & WOOLFSON, M. M. (1971). *Acta Cryst.* A**27**, 368–376.

JOHNSON, C. K. (1965). *ORTEP*. Report ORNL-3794, revised. Oak Ridge National Laboratory, Tennessee.

SHAKKED, Z. & KENNARD, O. (1977). *Acta Cryst.* B**33**, 516–522.

STEWART, R. F., DAVIDSON, E. R. & SIMPSON, W. T. (1965). *J. Chem. Phys.* **42**, 3175–3187.

WONG-NG, W. & NYBURG, S. C. (1979). *Can. J. Chem.* **57**, 157–159.

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Structure of (*S*)-*N*-(α-Methylbenzyl)nicotinamide; a Chiral NADH Analog

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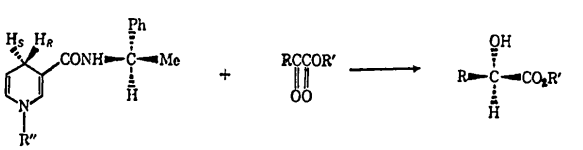
Abstract. $C_{14}H_{14}N_2O$, monoclinic, $C2$, $a = 20{\cdot}651$ (3), $b = 5{\cdot}2276$ (8), $c = 18{\cdot}650$ (3) Å, $\beta = 142{\cdot}70$ (1)°, $Z = 4$, $D_o = 1{\cdot}23$ (1), $D_c = 1{\cdot}23$ Mg m^{-3}. Least-squares refinement (nonhydrogen atoms anisotropic, H atoms isotropic) led to a final unweighted R value (on F; 1392 observed reflections) of 0·038. The carboxamide group is rotated by 34° from the plane of the pyridine ring and oriented such that the carbonyl O atom is directed toward the 4 position of the pyridine ring. The hybridization of the amide N is close to sp^2; the chiral C atom, C(7), is 0·20 Å out of the plane of the carboxamide group. The phenyl group extends toward the *B* side of the molecule and the methyl group towards the *A* side. The conformation of the molecule is discussed in relation to studies of stereospecific reduction by models for the reduced pyridine nucleotide, NADH. It is found that the structure leads to predictions of asymmetric induction which are opposite to those experimentally observed.

Introduction. Ohnishi, Kagami & Ohno (1975)* reported the first example of the stereoselective, non-enzymatic reduction of pyruvate esters by a 1,4-dihydronicotinamide; a reaction which mimics that catalyzed by lactate dehydrogenase (Everse & Kaplan, 1973). The reduction was achieved by the use of the chiral dihydronicotinamides (1). It was argued that the stereoselectivity of the reaction was the result of non-bonded, steric interactions between the substrate and the chiral nicotinamide. These interactions favored the approach of the pyruvate ester toward the *A* side* of the dihydropyridine ring leading to L-lactate as the predominant product.



(1)

(1*a*) R'' = *n*-propyl
(1*b*) R'' = benzyl
(1*c*) R'' = 2,6-dichlorobenzyl

* For more recent work with chiral nicotinamides see DeVrie & Kellog (1979) and Ohno, Ikeguchi, Kimura & Oka (1979).

* The *A* side of the nicotinamide ring is the side which faces the viewer when the ring is viewed from a direction perpendicular to the plane of the ring and one travels around the ring in a counterclockwise direction when taking the shortest path from the ring N atom to the carboxamide group.

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Since these arguments are based on a number of assumptions about the conformation of the chiral nicotinamide we decided to determine the structure of compound (1) or a related compound. Compounds 1(*a*)–(*c*) and their oxidized forms, the pyridinium salts, were found to be intractable oils. Therefore, the determination of the structure of the parent nicotinamide was undertaken. It is important to note that the compound whose structure is reported here is the *S* enantiomer. The compound drawn above and discussed by Ohnishi, Kagami & Ohno (1975) is the *R* enantiomer.

Intensity data were collected on a crystal of dimensions 0·39 × 0·23 × 0·17 mm mounted on a glass fiber on a Syntex $P2_1$ computer-controlled diffractometer. Photographic and diffractometric examination of the reciprocal lattice revealed systematic absences consistent with space group *C*2. Using a θ–2θ scan and Mo $K\alpha$ filtered radiation (λ = 0·71069 Å), data were collected out to 55° in 2θ and 1556 unique reflections were measured; 1392 of these reflections with $F > 3\sigma(F)$ were used in the subsequent refinement. During data collection the intensities of seven reflections from diverse regions of reciprocal space were monitored regularly. They showed no systematic changes in intensity.

The structure was solved by direct methods and refined by full-matrix least-squares techniques. Refinement was on F and the function minimized was $R_w = [\sum w(|F_{obs}| - |F_{calc}|)^2/\sum wF_{obs}^2]^{1/2}$ where $w^{-1} = \sigma(F)^2 + (0{\cdot}2F_{obs})^2$. At the end of the final cycle R_w = 0·046 and the figure of merit, *g*, was 1·599. The largest shift in a parameter in the final cycle was 0·02σ in the *z* coordinate of H(N1). The final atomic parameters are listed in Table 1.*

Table 1. *Positional parameters* (×10⁴, *for* H ×10³) *and isotropic thermal parameters*

Standard deviations are in parentheses.

	x	*y*	*z*	B_{eq}†/*B* (Å²)
C(1)	−3476 (2)	−125 (6)	−4456 (2)	3·90 (8)
C(2)	−4264 (2)	−1895 (7)	−5314 (2)	4·81 (11)
C(3)	−4818 (2)	−1747 (8)	−6449 (2)	6·24 (16)
C(4)	−4596 (3)	161 (8)	−6730 (3)	6·60 (16)
C(5)	−3793 (3)	1903 (8)	−5878 (3)	6·70 (15)
C(6)	−3245 (2)	1759 (7)	−4750 (2)	5·46 (12)
C(7)	−2903 (2)	−213 (5)	−3234 (2)	3·71 (9)
C(8)	−3296 (2)	1888 (7)	−3078 (2)	4·41 (10)
N(1)	−1745 (2)	0000 (0)	−2309 (2)	3·77 (8)
C(9)	−1119 (2)	−2024 (5)	−1875 (2)	3·34 (8)
O(1)	−1431 (1)	−4246 (5)	−2098 (2)	4·56 (8)
C(10)	12 (1)	−1474 (5)	−1089 (2)	3·27 (8)
C(11)	822 (2)	−3172 (6)	−188 (2)	4·15 (9)
C(12)	1839 (2)	−2702 (7)	458 (2)	4·91 (12)
C(13)	2013 (2)	−625 (7)	177 (2)	5·06 (12)
N(2)	1245 (2)	1026 (6)	−691 (2)	5·50 (10)
C(14)	271 (2)	568 (6)	−1292 (2)	4·51 (10)
H(2)	−435 (2)	−332 (6)	−506 (2)	5·0 (6)
H(3)	−526 (3)	−305 (10)	−692 (3)	8·7 (10)
H(4)	−511 (3)	31 (8)	−761 (3)	9·0 (9)
H(5)	−364 (3)	329 (11)	−610 (3)	10·3 (11)
H(6)	−281 (2)	313 (8)	−426 (2)	6·8 (7)
H(7)	−305 (2)	−188 (5)	−315 (2)	3·3 (4)
H(81)	−300 (2)	194 (6)	−236 (2)	4·6 (5)
H(82)	−317 (2)	354 (6)	−315 (2)	4·7 (6)
H(83)	−406 (3)	163 (8)	−366 (3)	7·7 (8)
H(N1)	−150 (2)	141 (6)	−211 (2)	4·3 (6)
H(11)	57 (2)	−460 (6)	−14 (2)	4·7 (5)
H(12)	246 (2)	−374 (7)	114 (2)	6·1 (6)
H(13)	269 (3)	−3 (8)	59 (3)	8·2 (9)
H(14)	−34 (2)	178 (6)	−200 (2)	5·3 (6)

† For nonhydrogen atoms $B_{eq} = \frac{1}{24}\pi^2 \sum_i \sum_j B_{ij} a_i^* a_j^* \mathbf{a}_i.\mathbf{a}_j$ and the standard deviation in B_{eq} is estimated by $\sigma_{eq} = B_{eq}(\sigma_{11}/B_{11} + \sigma_{22}/B_{22} + \sigma_{33}/B_{33})/3{\cdot}0$.

Discussion. The crystal structure consists of molecules of $C_{14}H_{14}N_2O$ connected by hydrogen bonds of length 2·28 Å between the amide N atom of each molecule and the amide O atom of the adjacent molecule at *x*, *y* + 1, *z*. The numbering scheme used in this paper and a general view of the molecule are shown in Fig. 1. Fig. 2 shows another view, with selected bond lengths and bond angles in the molecule.

The bond lengths and bond angles in the pyridine ring agree well with those found in analogous 3-substituted pyridines (Wright & King, 1954; Herriott, Camerman & Deranleau, 1974). The pyridine ring is, within experimental error, strictly planar. Table 2 describes least-squares planes through the molecule and deviations of atoms from those planes. The entries in the table show that the carboxamide group is not coplanar with the heterocycle. It is rotated 34° with respect to the plane of the pyridine ring. The carboxamide C atom, C(9), is 0·12 Å out of the heterocyclic plane toward the *A* side of the pyridine ring. The rotation of the carboxamide group is similar to that found in nicotinamide, 24° (Wright & King, 1954), and benzamide, 26° (Penfold & White, 1959). Rotations between 58–71° have been found in metal complexes

* Lists of structure factors and thermal parameters have been deposited with the British Library Lending Division as Supplementary Publication No. SUP 36054 (7 pp.). Copies may be obtained through The Executive Secretary, International Union of Crystallography, 5 Abbey Square, Chester CH1 2HU, England.

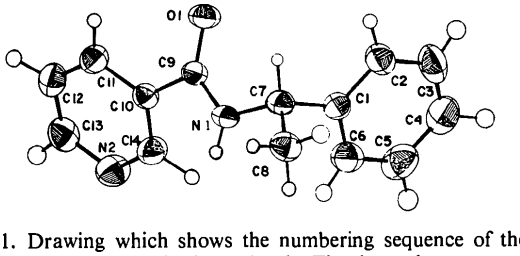

Fig. 1. Drawing which shows the numbering sequence of the 17 nonhydrogen atoms in the molecule. The thermal parameters for the H atoms have been made artificially small for clarity.

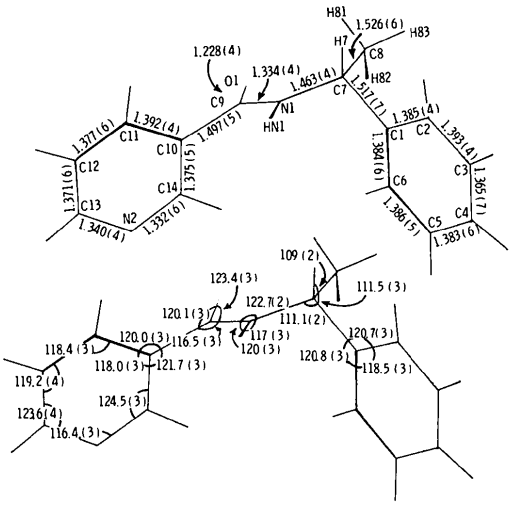

Fig. 2. Drawings which show selected bond lengths (Å) and bond angles (°) in the molecule.

of *N*,*N*-diethylnicotinamide (Bigoli, Braibanti, Pellinghelli & Tiripicchio, 1973, and references therein).

While these structures suggest that the twist of the carboxamide group in the present compound is normal, a variety of other orientations have been observed (Herriott, Camerman & Deranleau, 1974; Frank, Thayer & Paul, 1973, and references therein; Karle, 1961). However, in many of these latter structures the carboxamide groups are involved in extensive hydrogen bonding which may be affecting the conformation of the molecule in the solid state.

The amide group itself is not strictly planar. The substituent atoms on the amide nitrogen, H(N1) and C(7), are out of the plane of the carboxamide group by 0·04 and 0·20 Å respectively. The normals to the plane of the carboxamide group and the plane formed by H(N1), N(1) and C(7) make an angle of 8·1°. The C(7), N(1), C(9), O(1) dihedral angle is 9·6°.

The α-methylbenzyl group is oriented in such a way that the bulk of this group is distributed on both sides of the plane of the pyridine ring. The three substituents at C(7) are oriented such that the smallest of them, H(7), is closest to the carbonyl O atom. The bulky phenyl group extends toward the *B* side of the pyridine ring and the methyl group toward the *A* side.

The structural results outlined above allow a discussion of the experiments of Ohnishi, Kagami & Ohno (1975). Since those workers used a nicotinamide with an *R* configuration the following discussion is in terms of that enantiomer. Ohnishi, Kagami & Ohno (1975) reasoned that the most favorable orientation of the substrate and the dihydropyridine (1) could be predicted if stereochemical factors are considered. A ketone oriented parallel to the dihydropyridine ring would be expected to approach the least hindered side of the molecule. Our structural results show that the *B* side of the molecule is the least hindered because both the phenyl group and the amide O atom are on the *A* side of the molecule. When the substrate is an α-keto ester the assumption can be made that the alkoxycarbonyl group is the bulkiest substituent at the keto carbon. This leads one to predict that the ketone would be oriented as shown in Fig. 3 and that the (*S*)-alcohol would be the major product. Ohnishi, Kagami & Ohno (1975) reached the opposite conclusion by assuming that the carboxamide group is rotated 180° from the position shown in Fig. 3. In that conformation the phenyl group would be on the *B* side of the molecule. Steric considerations and experiment (Karle, 1961) argue against such an orientation of the carboxamide group. There would be unfavorable interactions between the N–H hydrogen atom and the H atoms at the 4-position of the dihydropyridine ring.

We conclude that the most probable molecular conformation is that shown in Fig. 3. The experimental fact that the major product of the reaction is the (*R*)-alcohol suggests that some of the basic assumptions made by Ohnishi, Kagami & Ohno (1975) about the interactions between the substrate and the dihydropyridine should be reconsidered.

Table 2. *Deviations of atoms from planes, and angles between normals to planes*

	Deviations of atoms not in plane from plane (Å)
Plane 1: N(2), C(10), C(11)–C(14)	C(9), 0·12 (1); O(1), 0·77 (1); N(1) –0·48 (1)
Plane 2: N(1), C(9), O(1)	C(7), 0·20 (1); H(N1), –0·04 (3)
Plane 3: N(1), H(N1), C(7)	C(9), 0·12 (2); O(1), 0·07 (2)
Plane 4: C(1), C(2), C(3)–C(6)	C(7), 0·06 (1)

Plane 1/Plane 2	34·1 (9)°	Plane 2/Plane 3	8·1 (10)°
Plane 1/Plane 4	–57·3 (8)	Plane 2/Plane 4	–77·3 (9)

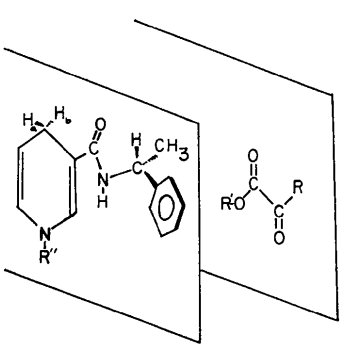

Fig. 3. Schematic representation of the orientation of the *R* enantiomer of the dihydropyridine and an α-keto ester in a collision complex. Note that the *R* enantiomer has been drawn here in order to facilitate the discussion of the work of Ohnishi, Kagami & Ohno (1975).

References

BIGOLI, F., BRAIBANTI, A., PELLINGHELLI, M. A. & TIRIPICCHIO, A. (1973). *Acta Cryst.* B**29**, 2344–2348.

DEVRIE, J. G. & KELLOG, R. M. (1979). *J. Am. Chem. Soc.* **101**, 2759–2761.

EVERSE, J. & KAPLAN, N. O. (1973). *Adv. Enzymol. Relat. Areas Mol. Biol.* **37**, 61–67.

FRANK, J. K., THAYER, N. N. & PAUL, I. C. (1973). *J. Am. Chem. Soc.* **95**, 5386–5390.

HERRIOTT, J. R., CAMERMAN, A. & DERANLEAU, D. A. (1974). *J. Am. Chem. Soc.* **96**, 1585–1589.

KARLE, I. L. (1961). *Acta Cryst.* **14**, 497–502.

OHNISHI, Y., KAGAMI, M. & OHNO, A. (1975). *J. Am. Chem. Soc.* **97**, 4766–4768.

OHNO, A., IKEGUCHI, M., KIMURI, T. & OKA, S. (1979). *J. Am. Chem. Soc.* **101**, 7036–7040.

PENFOLD, B. R. & WHITE, J. C. B. (1959). *Acta Cryst.* **12**, 130–135.

WRIGHT, W. B. & KING, G. S. D. (1954). *Acta Cryst.* **7**, 283–288.

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Oxalate de {[Chloro-3 (phénylthio)-6 phénylamino]-3 propyl}diéthylammonium*

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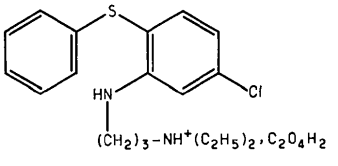
(*Reçu le* 23 *octobre* 1980, *accepté le* 9 *mars* 1981)

Abstract. $C_{19}H_{26}ClN_2S^+.C_2HO_4^-$, monoclinic, $P2_1/c$, $a = 8{\cdot}851$ (3), $b = 23{\cdot}335$ (8), $c = 11{\cdot}247$ (4) Å, $\beta = 111{\cdot}9$ (1)°, $Z = 4$. $R = 0{\cdot}057$ for 2905 observed reflexions. The angle between the two ring planes is 99·1 (5)°. In spite of a very different crystal packing and chain flexibility, the molecular configuration is very close to that of some related molecules, previously reported.

Introduction. La formule développée du composé étudié est:



Comme tous les homologues étudiés précédemment il a été synthétisé au laboratoire de Pharmacie Chimique, UER de Pharmacie, Lille, France (Professeur M. Debaert). Dans la nomenclature de ces composés il porte la référence CB8. C'est en quelque sorte une phénothiazine dont l'hétérocycle central est ouvert. Alors que le CB7 étudié précédemment (Marsau & Cotrait, 1976*a*) était l'homologue direct de la chlorpromazine, celui-ci possède une chaîne diéthylammonio qui, dans la série des phénothiazines, conduit à une molécule aux propriétés neuroleptiques très atténuées.

Le cristal de CB8 est une aiguille de 0,3 × 0,3 × 0,8 mm obtenue par évaporation lente d'une solution dans un mélange eau–méthanol. Les paramètres cristallins ont été obtenus par affinement par moindres carrés à partir de 25 réflexions mesurées sur diffractomètre Nonius CAD-4.

La structure a été résolue par la méthode de Patterson, qui a permis en effet, de positionner les atomes de chlore et de soufre. Des cartes de Fourier successives ont permis d'obtenir de proche en proche les positions de tous les atomes de la molécule, à l'exception des atomes d'hydrogène. Un affinement a été réalisé avec des facteurs d'agitation thermique isotropes. A partir des positions atomiques ainsi obtenues les atomes d'hydrogène ont été, soit placés en position théorique, soit obtenus à partir de cartes de Fourier différence (méthyles). Il leur a été attribué le coefficient d'agitation isotrope de l'atome auquel ils étaient liés. L'affinement a été poursuivi avec une agitation thermique isotrope pour les hydrogènes, anisotrope pour les autres atomes. Le facteur résiduel R

* Dérivés de l'Amino-2 Diphénylsulfure. VI.

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