*Acta Cryst.* (1999). C**55**, 654–656

# 1-Chloro-2,4-dimorpholino-5-nitrobenzene

César Zucco, Ademir Neves, Ivo Vencato, Bruno Szpoganicz and Fabiano C. Bertoldi

*Departamento Química, UFSC, 88040-900 Florianópolis, SC, Brazil. E-mail: vencato@qmc.ufsc.br*

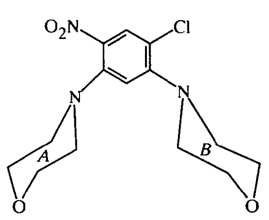
*(Received 12 May 1998; accepted 6 November 1998)*

## Abstract

The title compound, $C_{14}H_{18}ClN_3O_4$, is a product of the reaction between 1,2-dichloro-4,5-dinitrobenzene and morpholine. Its structure is described as part of our work involving the study of the kinetics of this unusual substitution reaction on the aromatic ring.

## Comment

Nucleophilic substitutions at aromatic carbon are known to proceed so slowly that they are not considered feasible for aromatic substrates. However, there are some successful reactions, and these exceptions stem from the special features of the substrates, *i.e.* they are activated by electron-withdrawing groups such as $NO_2$. The recent reinvestigation of nucleophilic additions and substitutions on aromatic activated substrates shows that the simple classical mechanism is inadequate, and there is evidence that single-electron transfer (SET) is a common mechanism in organic chemistry (Bacaloglu *et al.*, 1987, 1991, 1992; Pross, 1985, 1987). As part of our involvement in the search for systems that can be used as models for SET, we decided to study the kinetics of the reaction between 1,2-dichloro-4,5-dinitrobenzene and morpholine. Since the unusual substitution occurs on the aromatic ring, studies have been carried out on the structure of the resulting product, 1-chloro-2,4-dimorpholino-5-nitrobenzene, (I), and are reported here.



(I)

A *ZORTEP* (Zsolnai *et al.*, 1996) illustration of (I) is shown in Fig. 1, and selected bond lengths and angles are given in Table 1. The values of the bond lengths and angles in the morpholine groups are in general agreement with those of other derivatives containing this ring. As observed in the structure of 1,8-dimorpholinonaphthalene (Wong-Ng *et al.*, 1982), the C—N bonds between the $C_{phenyl}$ and the N atoms are significantly shorter [average 1.404 (3) Å] than the remaining four C—N bonds [average 1.470 (3) Å]. The sum of the bond angles at nitrogen is 342.2 (2)° for N1 and 344.0 (1)° for N2, and N1 and N2 are at distances of 0.359 (2) and 0.339 (2) Å from the C1/C4/C5 and C9/C11/C14 planes, respectively. These parameters indicate, at least to some extent, considerable double-bond character for the N—$C_{phenyl}$ bonds.

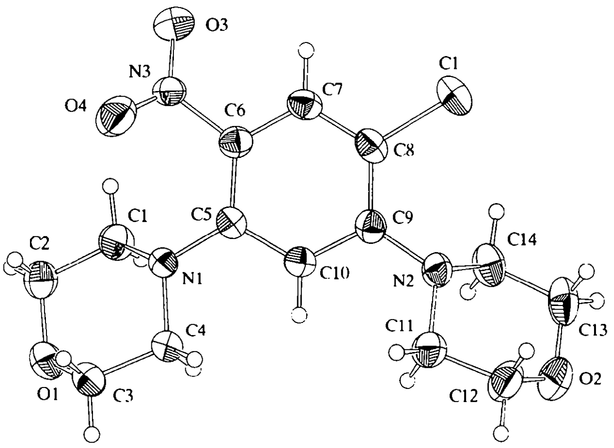


Fig. 1. A *ZORTEP* (Zsolnai *et al.*, 1996) drawing of the molecular structure of (I). Displacement ellipsoids are shown at the 50% probability level and H atoms are drawn as spheres of arbitrary radii.

The morpholine rings *A* (O1, C1–C4, N1) and *B* (O2, C11–C14, N2) adopt the usual chair conformation and the four C atoms deviate only slightly from coplanarity, in agreement with structural data available from the Cambridge Structural Database (1997). The calculated deviations of the N and O atoms from the mean four-C-atom plane are, respectively, 0.645 (3) and −0.670 (3) Å for ring *A*, and −0.663 (3) and 0.645 (3) Å for ring *B*, and these values compare very well with those found in 1,8-dimorpholinonaphthalene (0.663 and −0.651, and −0.680 and 0.665 Å, respectively). In addition, the phenyl ring forms angles of 37.2 (2) and 49.2 (1)° with the four coplanar atoms of the morpholine rings *A* and *B*, respectively. According to the Cremer & Pople (1975) puckering parameters, ring *B* is more distorted than ring *A*, as can be seen from the $\varphi$ values of 28 (6)° for *A* and 253 (8)° for *B*.

The intermolecular packing is stabilized by a C—H···O hydrogen bond [C11···O4$^{i}$ 3.132 (4), H11*B*···O4$^{i}$ 2.451 (3) Å and C11—H11*B*···O4$^{i}$ 127.1 (2)°; symmetry code: (i) $-x$, $-y$, $1-z$] (Desiraju, 1996). The phenyl ring forms an angle of 32.9 (2)° with the coplanar nitro group, which is in close contact with the N1 atom of the morpholine ring *A* through two intramolecular hydrogen bonds bifurcated to O4 and N3 [C1···O4 3.092 (4), H1*B*···O4 2.547 (3) Å and C1—H1*B*···O4 115.6 (2)°; C1···N3 3.209 (4), H1*B*···N3 2.558 (2) Å and C1—H1*B*···N3 124.5 (2)°]. There is an additional intramolecular hydrogen bond between C14 of the morpholine ring *B* and the *ortho*-Cl atom bonded to the phenyl ring [C14···Cl 3.297 (3), H14*A*···Cl 2.681 (9) Å and C14—H14*A*···Cl 121.7 (2)°].

Finally, we have determined the p$K_a$ for the first protonation of (I) as being 3.05 (1). Interestingly, this value demonstrates that the present compound is about four orders of magnitude less basic than 1,8-dimorpholinonaphthalene, which has been described as a proton sponge [p$K_a$ = 7.5 (1)] on the basis of the relatively short distance between the morpholine N atoms. The low basic character of the title compound might come from resonance interactions in aqueous solution, between the nitro substituent and the morpholine N atom through the aromatic ring. This is supported in part by the structural parameters, which indicate the double-bond character between the morpholine N and the aromatic C atoms.

## Experimental

Morpholine (2.6 ml, 2.96 mmol) was added to a solution of 1,2-dichloro-4,5-dinitrobenzene (0.7 g, 2.96 mmol) in dimethyl sulfoxide (2 ml). The solution was stirred for 30 min at room temperature and then left for 5 d. After this time, a precipitate was formed, which was removed by filtration. The solid, (I), was washed with ethanol and recrystallized from solution in a 1:1 mixture of ethanol/chloroform (yield 0.67 g, 70%; m.p. 446–448 K). Single crystals suitable for X-ray analysis were obtained by slow evaporation of a chloroform solution of (I). $^1$H NMR ($\delta$, p.p.m.): 3.09 (*m*, 12H), 3.88 (*m*, 8H), 6.53 (*s*, 1H), 8.03 (*s*, 1H); $^{13}$C NMR ($\delta$, p.p.m.): 51.00 (4C), 66.68 (4C), 110.33, 119.63, 129.56, 136.04, 146.91, 153.95.

The potentiometric studies were performed in ethanol/water solutions (70/30% *v*/*v*) due to the low solubility of the ligand in water. The p$K_w$ of water in this ethanol/water solution is 14.71 (Schwingel *et al.*, 1996). The experimental solution of the ligand ($1.00 \times 10^{-3}$ *M*) was placed in a 100 ml insulated thermostatically controlled reaction vessel with an airtight cap, fitted with gas inlet and outlet tubes, glass and reference electrodes and a calomel system. A 20 ml automatic piston burette and a magnetic stirrer were used. The Micronal pH meter employed (model BB75) was calibrated with a standard strong acid (HCl) in an ethanol/water solution. The titrations were carried out at 298.0 (1) K, under an argon atmosphere with a CO$_2$-free KOH standard titrant, and at an ionic strength of 0.100 *M* (KCl), so as to read the hydrogen-ion concentration (pH) directly. The data obtained were analysed on a PC with the aid of the *BEST7* program (Martel & Motekaitis, 1992), and the procedure has been described in detail elsewhere.

*Crystal data*

$C_{14}H_{18}ClN_3O_4$
$M_r$ = 327.76
Monoclinic
$C2/c$
$a$ = 22.997 (5) Å
$b$ = 8.069 (2) Å
$c$ = 20.001 (4) Å
$\beta$ = 125.00 (3)°
$V$ = 3040.2 (12) Å$^3$
$Z$ = 8
$D_x$ = 1.432 Mg m$^{-3}$
$D_m$ not measured

Mo $K\alpha$ radiation
$\lambda$ = 0.71073 Å
Cell parameters from 25 reflections
$\theta$ = 9.99–18.50°
$\mu$ = 0.273 mm$^{-1}$
$T$ = 293 (2) K
Prismatic
0.52 × 0.46 × 0.26 mm
Yellow

*Data collection*

Nonius CAD-4 diffractometer
$\omega/2\theta$ scans
Absorption correction: $\psi$ scan (*MolEN*; Fair, 1990)
$T_{\min}$ = 0.90, $T_{\max}$ = 0.93
2771 measured reflections
2683 independent reflections
2064 reflections with $I > 2\sigma(I)$

$R_{\rm int}$ = 0.019
$\theta_{\max}$ = 25°
$h = -22 \rightarrow 27$
$k = 0 \rightarrow 9$
$l = -23 \rightarrow 0$
3 standard reflections
frequency: 60 min
intensity decay: −1.1%

*Refinement*

Refinement on $F^2$
$R[F^2 > 2\sigma(F^2)]$ = 0.042
$wR(F^2)$ = 0.124
$S$ = 1.11
2683 reflections
199 parameters
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.050P)^2 + 4.07P]$ where $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{\max}$ = 0.02
$\Delta\rho_{\max}$ = 0.34 e Å$^{-3}$
$\Delta\rho_{\min}$ = −0.31 e Å$^{-3}$
Extinction correction: none
Scattering factors from *International Tables for Crystallography* (Vol. C)

Table 1. *Selected geometric parameters (Å, °)*

| | | | |
|---|---|---|---|
| Cl—C8 | 1.736 (2) | N1—C1 | 1.478 (3) |
| O3—N3 | 1.219 (3) | N2—C9 | 1.403 (3) |
| O4—N3 | 1.198 (3) | N2—C11 | 1.462 (3) |
| N1—C5 | 1.405 (3) | N2—C14 | 1.475 (3) |
| N1—C4 | 1.465 (3) | N3—C6 | 1.480 (3) |
| C2—O1—C3 | 109.3 (2) | C4—N1—C1 | 110.4 (2) |
| C12—O2—C13 | 110.1 (2) | C9—N2—C11 | 116.5 (2) |
| C5—N1—C4 | 116.3 (2) | C9—N2—C14 | 117.1 (2) |
| C5—N1—C1 | 115.5 (2) | C11—N2—C14 | 110.4 (2) |

All H atoms were placed in calculated positions using a riding model [C—H = 0.93 Å and $U$(H) = 1.2$U_{\rm eq}$(C) for C$sp^2$; C—H = 0.97 Å and $U$(H) = 1.5$U_{\rm eq}$(C) for C$sp^3$].

Data collection: *CAD*-4 *EXPRESS* (Enraf–Nonius, 1994). Cell refinement: *SET*4 in *CAD*-4 *EXPRESS*. Data reduction: *MolEN* (Fair, 1990). Program(s) used to solve structure: *SHELXS*97 (Sheldrick, 1990). Program(s) used to refine structure: *SHELXL*97 (Sheldrick, 1997). Molecular graphics: *ZORTEP* (Zsolnai *et al.*, 1996). Software used to prepare material for publication: *SHELXL*97.

This work was supported by grants from PADCT, CNPq and PRONEX.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: BK1415). Services for accessing these data are described at the back of the journal.

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*Acta Cryst.* (1999). C**55**, 656–659

# Two novel optically active penam derivatives

ALEKSANDAR DANILOVSKI, MLADEN VINKOVIĆ AND JURE J. HERAK

*PLIVA Inc. – Research Institute, Prilaz baruna Filipovića 25, HR-10000 Zagreb, Croatia. E-mail: sasa@zagreb.zoak.pmf.hr*

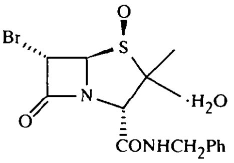
(*Received 6 May 1998; accepted 17 November 1998*)

## Abstract

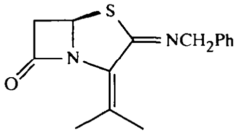
The X-ray structure analyses of the two optically active penam derivatives, (2*S*,4*S*,5*R*,6*S*)-2-benzylcarbamoyl-6-bromo-3,3-dimethyl-4-thia-1-azabicyclo[3.2.0]heptan-7-one 4-oxide hydrate, $C_{15}H_{17}BrN_2O_3S{\cdot}H_2O$, (I), and (5*R*)-3-benzylimino-2-isopropylidene-4-thia-1-azabicyclo[3.2.0]heptan-7-one, $C_{15}H_{16}N_2OS$, (II), have been determined in order to ascertain their absolute configurations. Both compounds adopt the open-book conformation for the fused β-lactam and thiazolidine rings. The β-lactam ring is in a distorted planar conformation, while the thiazolidine ring is in an envelope conformation. The pyramidalization effect of the N1 atom in both compounds has been characterized by a displacement of the N atom from the plane of its substituents: the N atom is displaced 0.344 (5) and 0.350 (5) Å in molecules *A* and *B* of compound (I) and 0.410 (5) Å in compound (II).

## Comment

As a continuation of our previous studies (Herak *et al.*, 1994, 1995; Herak, 1996) of penicillanic acid amide (penam), two novel optically active penam derivatives, (2*S*,4*S*,5*R*,6*S*)-2-benzylcarbamoyl-6-bromo-3,3-dimethyl-4-thia-1-azabicyclo[3.2.0]heptan-7-one 4-oxide hydrate, (I), and (5*R*)-3-benzylimino-2-isopropylidene-4-thia-1-azabicyclo-[3.2.0]heptan-7-one, (II), have been synthesized (Herak & Vinković, 1996) and structurally characterized. Their main importance arises from their subsequent transformation into chiral 4-substituted-2-azetidinone or into other non-classical bicyclic β-lactams.



(I)



(II)

The present study has been undertaken in order to confirm the absolute configurations of both penam compounds, as well as to elucidate their conformational properties. The atomic numbering scheme and the displacement ellipsoids for both compounds are depicted in Figs. 1 and 2. The crystal structure determination of compound (I), which crystallizes in the form of the monohydrate, revealed the presence of two independent molecules per asymmetric unit. These two molecules differ primarily in the conformation of the benzyl group [the N23—C24—C25—C30 torsion angles are −50.4 (12) and 72.3 (10)° in molecules *A* and *B*, respectively].

According to the spectroscopic data, the configuration at atom S4 in compound (I) is indecisive. The absolute configurations of all four chiral centres in (I) (Fig. 1) have been verified by the estimated Flack parameter (Flack, 1983) of −0.014 (12). From this, it follows that S4 has the *S* configuration, with H2 in the *syn*-axial position. It was assumed that the right D-enantiomer of