Acta Cryst E CRYSTALLOGRAPHIC COMMUNICATIONS

ISSN 2056-9890

Crystal structure and Hirshfeld surface analysis of 4′-(2-chlorophenyl)-1′-methyl-3″-phenyl-7″,8″-dihydro-5″*H*-dispiro[indoline-3,2′-pyrrolidine-3′,6″-isoquinoline]-2,5″-dione

R. Vishnupriya,[a] C. Selva Meenatchi,[a] J. Suresh,[a] R. V. Sumesh,[b] R. Ranjith Kumar[b] and P. L. Nilantha Lakshman[c]*

[a]Department of Physics, The Madura College, Madurai 625 011, India, [b]Department of Organic Chemistry, School of Chemistry, Madurai Kamaraj University, Madurai 625 021, India, and [c]Department of Food Science and Technology, University of Ruhuna, Mapalana, Kamburupitiya 81100, Sri Lanka. *Correspondence e-mail: plakshmannilantha@ymail.com

Received 26 March 2018
Accepted 9 April 2018

Edited by H. Stoeckli-Evans, University of Neuchâtel, Switzerland

Keywords: crystal structure; dispiro; indoline; pyrrolidine; isoquinoline; hydrogen bonding; Hirshfeld surface analysis.

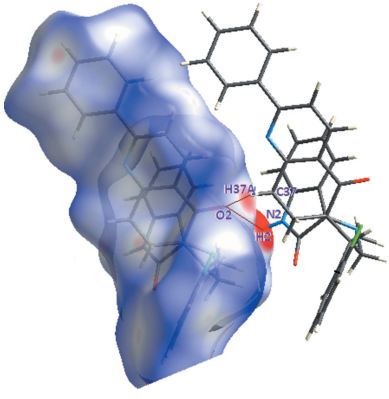
CCDC reference: 1835595

Supporting information: this article has supporting information at journals.iucr.org/e

In the title dispiro compound, $C_{32}H_{26}ClN_3O_2$, the cyclohexanone ring of the isoquinoline unit has a distorted envelope conformation, with the methylene C atom adjacent to the spiro C atom as the flap. The central 1-methylpyrrolidine ring has an envelope conformation with the N atom as the flap. The mean planes of the indolin-2-one ring system, the chlorobenzene ring and the isoquinoline ring system are inclined to the mean plane of the central 1-methylpyrrolidine ring by 87.95 (11), 71.01 (12) and 88.81 (10)°, respectively. There are two short C—H···O intramolecular contacts present. In the crystal, molecules are linked *via* C—H··· O hydrogen bonds, forming chains along the *a*-axis direction. The NH H atom is involved in a weak N—H···O hydrogen bond with the same carbonyl O atom. There are no further significant intermolecular contacts present. The largest contribution to the overall Hirshfeld surface of 52.3% is due to H—H contacts.

1. Chemical context

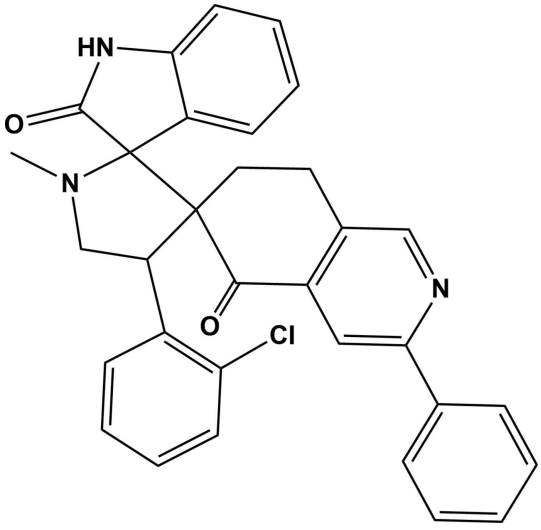
Spiro scaffolds are being used more and more in drug discovery because of their built-in three-dimensionality and structural variations, resulting in new synthetic routes to introduce spiro building blocks into more pharmaceutically active molecules (Kobayashi *et al.*, 1991; James *et al.*, 1991). The spiro-pyrrolidine ring system is a structural motif present in many biologically important and pharmacologically relevant alkaloids. Spiro-pyrrolidine-indolin-2-one ring systems are also found in a number of alkaloids of biological importance (Hilton *et al.*, 2000). Some derivatives are used as antimicrobial and antitumour agents (Sundar *et al.*, 2011), or possess analgesic (Crooks & Sommerville, 1982) and anti-influenza virus (Stylianakis *et al.*, 2003) activities. In view of this importance, the primary goal for the X-ray analyses of the title compound is to obtain detailed information on the structural conformation that may be useful in understanding the chemical reactivity of such compounds.



2. Structural commentary

The molecular structure of the title molecule is shown in Fig. 1. There are two short C—H···O intramolecular contacts present (Table 1). In the isoquinoline ring system (N3/C3/C31–

C38) the cyclohexanone ring (C3/C31–C38) adopts a distorted envelope conformation [puckering parameters: Q = 0.500 (2) Å, θ = 63.7 (2)°, φ = 308.9 (3)°], with atom C38 as the flap. The pyridine ring (N3/C32–C36) has a shallow twist-boat conformation [puckering parameters: Q = 0.094 (2) Å, θ = 92.3 (13)°, φ = 84.5 (13)°]. Their mean planes are inclined to each other by 14.06 (10)°, and the phenyl ring (C51–C56) is inclined to the pyridine ring mean plane by 22.35 (12)°.



In the indolin-2-one ring system (N2/C2/C21–C27), the benzene (C21–C26) and pyrrolidine (N2/C2/C21/C26/C27) rings make a dihedral angle of 2.45 (12)°, while the keto atom O1 deviates from the attached pyrrolidine ring by 0.043 (1) Å. The 1-methylpyrrole ring (N1/C2–C5) has an envelope conformation with atom N1 as the flap [puckering parameters: Q = 0.094 (2) Å, θ = 92.3 (13)°, φ = 84.5 (13)°]. The mean planes of the indolin-2-one ring system, the chlorobenzene (C41–C46) ring and the isoquinoline (N3/C3/C31–C38) ring system are inclined to the mean plane of the central 1-methylpyrrolidine (N1/C2–C5) ring by 87.95 (11), 71.01 (12) and 88.81 (10)°, respectively. The sum of the bond angles around atoms N1 and N2 are 333.6 and 358.6°, respectively, indicating a pyramidal geometry and sp^3 hybridization.

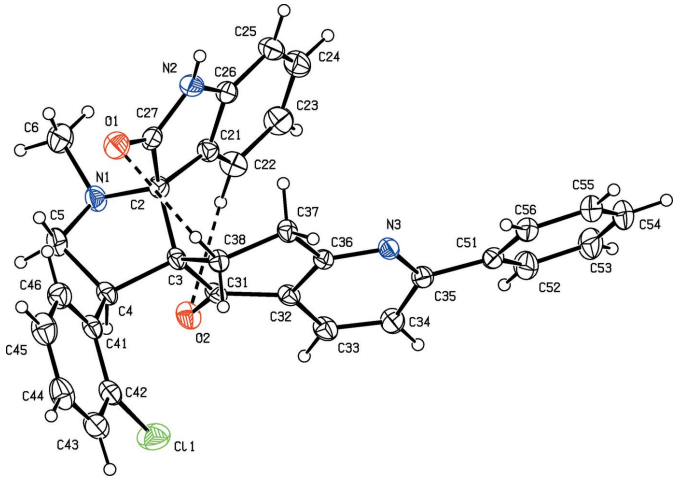


Figure 1
The molecular structure of the title compound, showing 30% probability displacement ellipsoids and atom labelling. The intramolecular C—H···O contacts (see Table 1) are shown as dashed lines.

Table 1
Hydrogen-bond geometry (Å, °).

D—H···A	D—H	H···A	D···A	D—H···A
C22—H22···O2	0.93	2.57	3.227 (3)	128
C38—H38A···O1	0.97	2.46	3.135 (3)	127
C37—H37A···O2^{i}	0.97	2.38	3.159 (3)	137
N2—H2···O2^{i}	0.88 (3)	2.50 (2)	2.911 (3)	109.0 (19)

Symmetry code: (i) $x-1, y, z$.

3. Supramolecular features

In the crystal, molecules are linked by C—H···O hydrogen bonds and a weak N—H···O hydrogen bond, forming chains propagating along the a-axis direction (Fig. 2 and Table 1). There are no further significant intermolecular interactions present.

4. Database survey

A search of the Cambridge Structural Database (Version 5.39, last update February 2018; Groom *et al.*, 2016) for the central dispiro fragment, 1′-methyldispiro[cyclohexane-1,3′-pyrrolidine-2′,3″-indoline]-2,2″-dione (see Fig. 3), gave eight hits of which coordinates were available for six structures. Two compounds closely resemble the title compound, *viz*. 4′-(4-chlorophenyl)-1′-methyl-3,4-dihydro-1*H*-dispiro[acridine-2,3′-pyrrolidine-2′,3″-indole]-1,2″(1″*H*)-dione methanol solvate

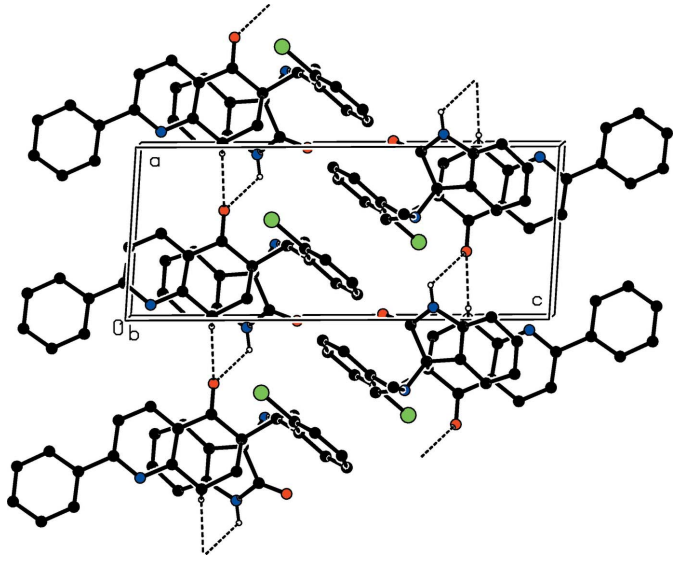


Figure 2
A view along the b axis of the crystal packing of the title compound, illustrating the formation of the hydrogen-bonded (dashed lines; Table 1) chains running along the a-axis direction. H atoms not involved in these interactions have been omitted for clarity.

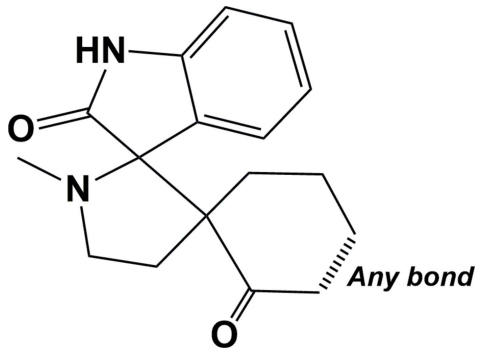


Figure 3
Structural fragment for the CSD search.

(CSD refcode NAQCAL: Maheswari *et al.*, 2012), and 4′-(2,4-dichlorophenyl)-1′,3″-dimethyl-1″-phenyl-7″,8″-dihydrodispiro[indole-3,2′-pyrrolidine-3′,6″-pyrazolo[3,4-*b*]quinoline]-2,5″(1*H*,1″*H*)-dione chloroform solvate (UQIROD; Sumesh *et al.*, 2016). In both compounds, the mean plane of the 1-methylpyrrolidine ring was found to be almost perpendicular to the mean plane of the indoline ring system and the mean plane of the cyclohexanone ring, similar to the situation in the title compound, see Section 2 *Structural commentary*.

5. Hirshfeld Analysis

The program *CrystalExplorer* (Wolff *et al.*, 2012) was used to generate the Hirshfeld surfaces mapped over d_{norm}, and the electrostatic potential for the title compound. The contact distances, d_i and d_e, from the Hirshfeld surface to the nearest atom, inside and outside, respectively, enable the analysis of the intermolecular interactions through the mapping of d_{norm}. Two-dimensional fingerprint plots (Rohl *et al.*, 2008) provide an indication of the intermolecular contacts in the crystal.

The hydrogen-bonding network generated in the crystal can be visualized using Hirshfeld surface analysis. The bright-red spots on the Hirshfeld surface mapped over d_{norm} (Fig. 4), with labels H2 and H37*A*, on the surface represent donors for potential hydrogen bonds (see Table 1); the corresponding acceptor on the surface appears as a bright-red spot at atom O2.

The overall two-dimensional fingerprint plot is illustrated in Fig. 5*a*, and those delineated into C···H/H···C, Cl···H/H···Cl, H···H, N···H/H···N and O···H/H···O in Fig. 5*b–f*, respectively. The greatest contribution to the overall Hirshfeld surface, *i.e.* 52.3%, is due to H···H contacts (Fig. 5*d*; widely scattered points with a high concentration in the middle region, shown in green). The relative contributions of the other different intermolecular interactions to the Hirshfeld surface in descending order are: C···H/H···C (23.3%), O···H/H···O (8.5%), Cl···H/H···Cl (8.4%), N···H/H···N (4.1%) and there is only a very small contribution from other

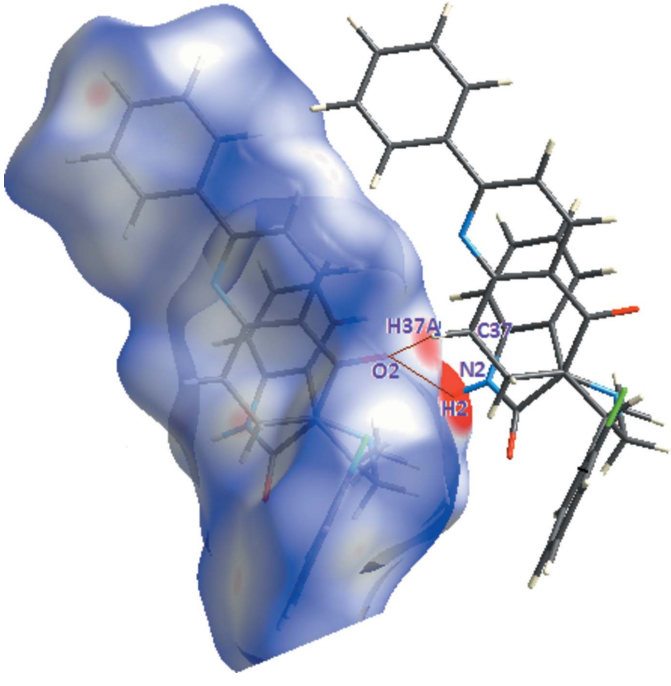


Figure 4
d_{norm} mapped on the Hirshfeld surface for visualizing the contacts of the title compound. Dotted lines indicate hydrogen bonds.

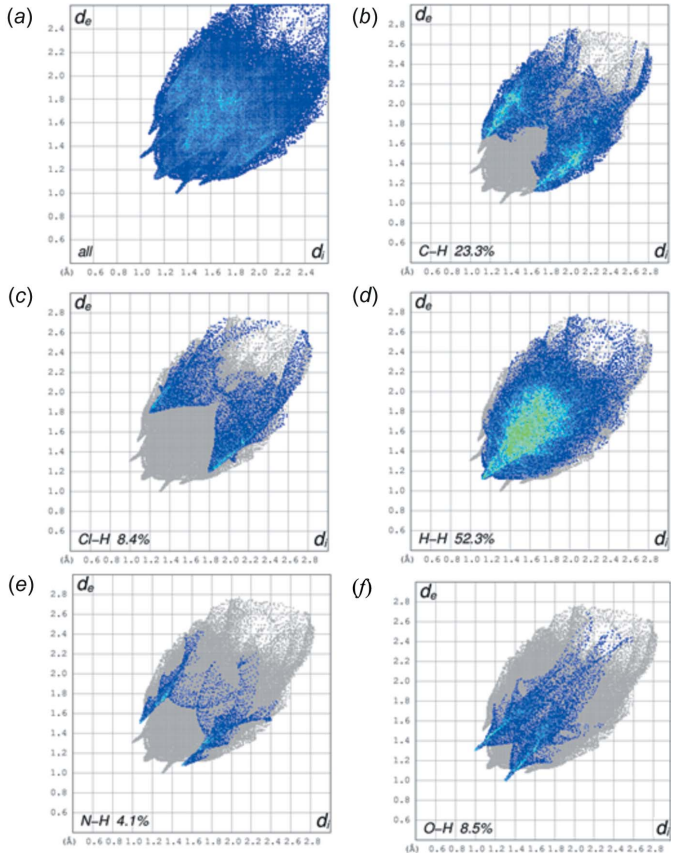


Figure 5
Fingerprint plot of the title compound, (*a*) all, (*b*) H···H, (*c*) C···H/H···C, (*d*) O···H/H···O, (*e*) Cl···H/H···Cl and (*f*) N···H/H···N contacts. The outline of the full fingerprint plots is shown in grey. d_i is the closet internal distance from a given point on the Hirshfeld surface and d_e is the closest external contact.

contacts, *i.e.* 3.1%, in the structure. This illustrates that the N—H···O and C—H···O interactions contribute significantly to the crystal packing of the title compound.

6. Synthesis and crystallization

An equimolar mixture of 2-phenyl-5,6,7,8-tetrahydro-5-quinolinone and 2-chlorobenzaldehyde was dissolved in 10 ml of ethanol followed by the addition of 0.5 equiv. of potassium hydroxide. The mixture was stirred for 1 h at ambient temperature and the precipitate formed was filtered and dried to obtain pure (*E*)-6-(2-chlorobenzylidene)-2-phenyl-7,8-dihydroquinolin-5(6*H*)-one (*L*) in 94% yield (m.p. 323–324 K). A mixture of isatin (1.1 mmol) and sarcosine (1.1 mmol) was taken in 10 ml of acetonitrile in a 50 ml round-bottom flask and heated to reflux for 2 h. Then 1 mmol of *L* was added to the above reaction mixture and reflux was continued for a further 14 h. After completion of the reaction, as evident from TLC, the solvent was removed under reduced pressure and the residue washed with ice-cold water (50 ml). The crude product was purified by column chromatography using a 90:10 (*v*/*v*) petroleum ether–ethyl acetate mixture to obtain the pure product (yield 82%, m.p. 356 K). Colourless block-like crystals were obtained by slow evaporation of a solution in ethyl acetate.

7. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. The NH H atom was located in a difference-Fourier map and freely refined. The C-bound H atoms were placed in calculated positions and allowed to ride on their carrier atoms: C—H = 0.93–0.98 Å with U_{iso} = 1.5U_{eq}(C-methyl) and 1.2U_{eq}(C) for other H atoms.

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{32}H_{26}ClN_3O_2$
M_r	520.01
Crystal system, space group	Triclinic, $P\overline{1}$
Temperature (K)	293
a, b, c (Å)	6.7722 (4), 11.5017 (8), 16.6305 (11)
α, β, γ (°)	80.224 (3), 84.618 (3), 81.077 (3)
V (Å^3)	1258.09 (14)
Z	2
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.19
Crystal size (mm)	0.23 × 0.21 × 0.19
Data collection	
Diffractometer	Bruker Kappa APEXII
Absorption correction	Multi-scan (*SADABS*; Bruker, 2004)
T_{min}, T_{max}	0.967, 0.974
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	25368, 4659, 3577
R_{int}	0.035
(sin $\theta/\lambda)_{max}$ (Å^{-1})	0.606
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.047, 0.133, 1.05
No. of reflections	4659
No. of parameters	347
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.37, −0.46

Computer programs: *APEX2* and *SAINT* (Bruker, 2004), *SHELXS97* (Sheldrick, 2008), *SHELXL97* (Sheldrick, 2008) and *PLATON* (Spek, 2009).

Acknowledgements

JS and RV thank the management of Madurai College for their encouragement and support.

Funding information

JS thanks the UGC for funds under project No. F MRP-7018/16(SERO/UGC).

References

Bruker (2004). *APEX2*, *SAINT* and *SADABS*. Bruker AXS Inc., Madison, Wisconsin, USA.

crooks, P. A. & Sommerville, R. (1982). *J. Pharm. Sci.* **71**, 291–294.

Groom, C. R., Bruno, I. J., Lightfoot, M. P. & Ward, S. C. (2016). *Acta Cryst.* B**72**, 171–179.

Hilton, S. T., Ho, T. C. T., Pljevaljcic, G. & Jones, K. (2000). *Org. Lett.* **2**, 2639–2641.

James, D. M., Kunze, H. B. & Faulkner, D. J. (1991). *J. Nat. Prod.* **54**, 1137–1140.

Kobayashi, J., Tsuda, M., Agemi, K., Shigemori, H., Ishibashi, M., Sasaki, T. & Mikami, Y. (1991). *Tetrahedron*, **47**, 6617–6622.

Maheswari, S. U., Perumal, S. & Almansour, A. I. (2012). *Tetrahedron Lett.* **53**, 349–353.

Rohl, A. L., Moret, M., Kaminsky, W., Claborn, K., McKinnon, J. J. & Kahr, B. (2008). *Cryst. Growth Des.* **8**, 4517–4525.

Sheldrick, G. M. (2008). *Acta Cryst.* A**64**, 112–122.

Spek, A. L. (2009). *Acta Cryst.* D**65**, 148–155.

Stylianakis, I., Kolocouris, A., Kolocouris, N., Fytas, G., Foscolos, G. B., Padalko, E., Neyts, J. & De Clercq, E. (2003). *Bioorg. Med. Chem. Lett.* **13**, 1699–1703.

Sumesh, R. V., Muthu, M., Almansour, A. I., Kumar, R. S., Arumugam, N., Athimoolam, S., Jeya Yasmi Prabha, E. A. & Kumar, R. R. (2016). *ACS Comb. Sci.* **18**, 262–270.

Sundar, J. K., Rajesh, S. M., Sivamani, J., Perumal, S. & Natarajan, S. (2011). *Chem. Cent. J.* **5**, 45.

Wolff, S. K., Grimwood, D. J., McKinnon, J. J., Turner, M. J., Jayatilaka, D. & Spackman, M. A. (2012). *CrystalExplorer*. The University of Western Australia.

supporting information

Acta Cryst. (2018). E**74**, 660-663 [https://doi.org/10.1107/S2056989018005455]

Crystal structure and Hirshfeld surface analysis of 4′-(2-chlorophenyl)-1′-methyl-3′′-phenyl-7′′,8′′-dihydro-5′′*H*-dispiro[indoline-3,2′-pyrrolidine-3′,6′′-isoquinoline]-2,5′′-dione

R. Vishnupriya, C. Selva Meenatchi, J. Suresh, R. V. Sumesh, R. Ranjith Kumar and P. L. Nilantha Lakshman

Computing details

Data collection: *APEX2* (Bruker, 2004); cell refinement: *SAINT* (Bruker, 2004); data reduction: *SAINT* (Bruker, 2004); program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *PLATON* (Spek, 2009); software used to prepare material for publication: *SHELXL97* (Sheldrick, 2008) and *PLATON* (Spek, 2009).

4′-(2-Chlorophenyl)-1′-methyl-3′′-phenyl-7′′,8′′-dihydro-5′′*H*-dispiro[indoline-3,2′-pyrrolidine-3′,6′′-isoquinoline]-2,5′′-dione

Crystal data

$C_{32}H_{26}ClN_3O_2$
M_r = 520.01
Triclinic, $P\overline{1}$
Hall symbol: -P 1
a = 6.7722 (4) Å
b = 11.5017 (8) Å
c = 16.6305 (11) Å
α = 80.224 (3)°
β = 84.618 (3)°
γ = 81.077 (3)°
V = 1258.09 (14) Å^3
Z = 2
$F(000)$ = 544
D_x = 1.373 Mg m^{-3}
Mo $K\alpha$ radiation, λ = 0.71073 Å
Cell parameters from 4659 reflections
θ = 2–26°
μ = 0.19 mm^{-1}
T = 293 K
Block, colourless
0.23 × 0.21 × 0.19 mm

Data collection

Bruker Kappa APEXII diffractometer
Radiation source: fine-focus sealed tube
Graphite monochromator
Detector resolution: 0 pixels mm^{-1}
ω and φ scans
Absorption correction: multi-scan (SADABS; Bruker, 2004)
T_{min} = 0.967, T_{max} = 0.974
25368 measured reflections
4659 independent reflections
3577 reflections with $I > 2\sigma(I)$
R_{int} = 0.035
θ_{max} = 25.5°, θ_{min} = 2.0°
h = −8→8
k = −13→13
l = −20→20

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.047$
$wR(F^2) = 0.133$
$S = 1.05$
4659 reflections
347 parameters
0 restraints
Primary atom site location: structure-invariant direct methods
Secondary atom site location: difference Fourier map
Hydrogen site location: inferred from neighbouring sites
H atoms treated by a mixture of independent and constrained refinement
$w = 1/[\sigma^2(F_o^2) + (0.057P)^2 + 0.8008P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max} = 0.37$ e Å^{-3}
$\Delta\rho_{min} = -0.46$ e Å^{-3}

Special details

Geometry. All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.

Refinement. Refinement of F^2 against ALL reflections. The weighted R-factor wR and goodness of fit S are based on F^2, conventional R-factors R are based on F, with F set to zero for negative F^2. The threshold expression of $F^2 > 2$sigma(F^2) is used only for calculating R-factors(gt) etc. and is not relevant to the choice of reflections for refinement. R-factors based on F^2 are statistically about twice as large as those based on F, and R- factors based on ALL data will be even larger.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

	x	*y*	*z*	U_{iso}*/U_{eq}
C2	0.2424 (3)	0.02521 (19)	0.28318 (12)	0.0341 (5)
C3	0.2874 (3)	0.15629 (19)	0.28084 (12)	0.0308 (4)
C4	0.4045 (3)	0.1455 (2)	0.36013 (12)	0.0346 (5)
H4	0.5413	0.1597	0.3411	0.041*
C5	0.4193 (4)	0.0154 (2)	0.39905 (14)	0.0439 (6)
H5A	0.5457	−0.0115	0.4239	0.053*
H5B	0.3102	0.0026	0.4402	0.053*
C21	0.2282 (3)	−0.01793 (19)	0.20329 (13)	0.0354 (5)
C22	0.3670 (4)	−0.0337 (2)	0.13896 (15)	0.0456 (6)
H22	0.4960	−0.0160	0.1401	0.055*
C23	0.3124 (4)	−0.0761 (2)	0.07238 (16)	0.0545 (7)
H23	0.4052	−0.0861	0.0283	0.065*
C24	0.1226 (4)	−0.1037 (2)	0.07072 (16)	0.0544 (7)
H24	0.0882	−0.1317	0.0254	0.065*
C25	−0.0169 (4)	−0.0903 (2)	0.13520 (16)	0.0487 (6)
H25	−0.1452	−0.1093	0.1343	0.058*
C26	0.0384 (3)	−0.04795 (19)	0.20120 (13)	0.0364 (5)
C27	0.0290 (3)	0.01083 (19)	0.32584 (13)	0.0366 (5)
C31	0.4322 (3)	0.18485 (19)	0.20612 (12)	0.0321 (5)
C6	0.3840 (4)	−0.1718 (2)	0.35516 (18)	0.0606 (7)
H03A	0.3757	−0.2075	0.3077	0.091*
H03B	0.2642	−0.1783	0.3904	0.091*
H03C	0.4979	−0.2120	0.3840	0.091*
C32	0.3517 (3)	0.25452 (19)	0.13036 (12)	0.0317 (4)

C33	0.4809 (3)	0.2861 (2)	0.06304 (13)	0.0402 (5)
H33	0.6185	0.2756	0.0679	0.048*
C34	0.4035 (3)	0.3327 (2)	−0.01031 (13)	0.0438 (6)
H34	0.4870	0.3581	−0.0554	0.053*
C35	0.1978 (3)	0.34183 (19)	−0.01695 (12)	0.0340 (5)
C36	0.1461 (3)	0.28141 (17)	0.12155 (12)	0.0292 (4)
C37	0.0024 (3)	0.26574 (19)	0.19474 (12)	0.0322 (5)
H37A	−0.0604	0.1955	0.1945	0.039*
H37B	−0.1020	0.3341	0.1916	0.039*
C38	0.1032 (3)	0.25252 (19)	0.27456 (12)	0.0316 (4)
H38A	0.0069	0.2330	0.3199	0.038*
H38B	0.1434	0.3283	0.2794	0.038*
C41	0.3264 (3)	0.2350 (2)	0.41643 (12)	0.0355 (5)
C42	0.3936 (3)	0.3452 (2)	0.40547 (14)	0.0418 (5)
C43	0.3308 (4)	0.4279 (2)	0.45654 (16)	0.0517 (6)
H43	0.3777	0.5012	0.4465	0.062*
C44	0.1979 (4)	0.4016 (3)	0.52262 (16)	0.0548 (7)
H44	0.1572	0.4560	0.5585	0.066*
C45	0.1265 (4)	0.2950 (3)	0.53485 (15)	0.0556 (7)
H45	0.0353	0.2773	0.5790	0.067*
C46	0.1880 (3)	0.2129 (2)	0.48247 (14)	0.0444 (6)
H46	0.1356	0.1413	0.4916	0.053*
C51	0.1096 (3)	0.37258 (19)	−0.09725 (13)	0.0364 (5)
C52	0.2260 (4)	0.3562 (2)	−0.16886 (14)	0.0507 (6)
H52	0.3628	0.3303	−0.1668	0.061*
C53	0.1402 (5)	0.3779 (3)	−0.24306 (15)	0.0594 (7)
H53	0.2192	0.3664	−0.2907	0.071*
C54	−0.0620 (5)	0.4166 (3)	−0.24678 (15)	0.0588 (7)
H54	−0.1200	0.4305	−0.2967	0.071*
C55	−0.1772 (4)	0.4346 (2)	−0.17684 (15)	0.0515 (6)
H55	−0.3135	0.4619	−0.1795	0.062*
C56	−0.0939 (3)	0.4129 (2)	−0.10239 (14)	0.0413 (5)
H56	−0.1743	0.4253	−0.0553	0.050*
N1	0.4056 (3)	−0.04573 (17)	0.32992 (11)	0.0408 (4)
N2	−0.0728 (3)	−0.03406 (17)	0.27448 (12)	0.0399 (4)
N3	0.0704 (2)	0.32058 (15)	0.04888 (10)	0.0322 (4)
O1	−0.0328 (2)	0.03246 (16)	0.39312 (10)	0.0503 (4)
O2	0.6092 (2)	0.14584 (15)	0.20669 (10)	0.0455 (4)
Cl1	0.56220 (11)	0.38517 (7)	0.32331 (5)	0.0654 (2)
H2	−0.202 (4)	−0.037 (2)	0.2839 (16)	0.059 (8)*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
C2	0.0293 (10)	0.0390 (12)	0.0336 (11)	−0.0051 (9)	−0.0064 (8)	−0.0024 (9)
C3	0.0238 (9)	0.0399 (11)	0.0288 (10)	−0.0040 (8)	−0.0060 (8)	−0.0039 (8)
C4	0.0265 (10)	0.0461 (12)	0.0321 (11)	−0.0048 (9)	−0.0062 (8)	−0.0068 (9)
C5	0.0437 (12)	0.0480 (14)	0.0381 (12)	0.0033 (10)	−0.0142 (10)	−0.0041 (10)

C21	0.0349 (11)	0.0349 (11)	0.0365 (11)	−0.0025 (9)	−0.0064 (9)	−0.0058 (9)
C22	0.0405 (12)	0.0499 (14)	0.0487 (14)	−0.0068 (10)	−0.0001 (10)	−0.0158 (11)
C23	0.0680 (17)	0.0517 (15)	0.0463 (14)	−0.0080 (13)	0.0043 (12)	−0.0201 (12)
C24	0.0723 (18)	0.0476 (15)	0.0484 (15)	−0.0105 (13)	−0.0138 (13)	−0.0154 (12)
C25	0.0502 (14)	0.0431 (13)	0.0579 (15)	−0.0120 (11)	−0.0174 (12)	−0.0097 (11)
C26	0.0371 (11)	0.0313 (11)	0.0407 (12)	−0.0042 (9)	−0.0087 (9)	−0.0029 (9)
C27	0.0366 (11)	0.0351 (11)	0.0351 (12)	−0.0064 (9)	−0.0044 (9)	0.0050 (9)
C31	0.0233 (10)	0.0418 (12)	0.0334 (11)	−0.0073 (8)	−0.0033 (8)	−0.0094 (9)
C6	0.0669 (17)	0.0406 (14)	0.0716 (18)	0.0026 (12)	−0.0241 (14)	0.0002 (13)
C32	0.0255 (10)	0.0400 (12)	0.0311 (11)	−0.0075 (8)	0.0002 (8)	−0.0085 (9)
C33	0.0277 (10)	0.0571 (14)	0.0371 (12)	−0.0108 (10)	0.0009 (9)	−0.0083 (10)
C34	0.0382 (12)	0.0615 (15)	0.0319 (12)	−0.0167 (11)	0.0049 (9)	−0.0030 (10)
C35	0.0378 (11)	0.0358 (11)	0.0299 (11)	−0.0081 (9)	−0.0009 (9)	−0.0070 (9)
C36	0.0273 (9)	0.0314 (10)	0.0295 (10)	−0.0062 (8)	−0.0032 (8)	−0.0044 (8)
C37	0.0225 (9)	0.0412 (12)	0.0313 (11)	−0.0030 (8)	−0.0028 (8)	−0.0022 (9)
C38	0.0259 (10)	0.0391 (11)	0.0289 (10)	−0.0036 (8)	−0.0008 (8)	−0.0042 (8)
C41	0.0297 (10)	0.0457 (13)	0.0319 (11)	−0.0033 (9)	−0.0105 (8)	−0.0056 (9)
C42	0.0379 (12)	0.0531 (14)	0.0371 (12)	−0.0082 (10)	−0.0098 (9)	−0.0089 (10)
C43	0.0530 (14)	0.0519 (15)	0.0537 (15)	−0.0054 (12)	−0.0185 (12)	−0.0122 (12)
C44	0.0598 (16)	0.0609 (17)	0.0444 (14)	0.0075 (13)	−0.0139 (12)	−0.0198 (12)
C45	0.0507 (15)	0.0758 (19)	0.0382 (13)	−0.0021 (13)	0.0010 (11)	−0.0114 (12)
C46	0.0414 (12)	0.0531 (14)	0.0386 (12)	−0.0078 (11)	−0.0024 (10)	−0.0060 (11)
C51	0.0463 (12)	0.0335 (11)	0.0308 (11)	−0.0118 (9)	−0.0039 (9)	−0.0030 (9)
C52	0.0576 (15)	0.0596 (16)	0.0351 (13)	−0.0106 (12)	−0.0014 (11)	−0.0071 (11)
C53	0.080 (2)	0.0679 (18)	0.0300 (13)	−0.0144 (15)	−0.0011 (12)	−0.0050 (12)
C54	0.080 (2)	0.0622 (17)	0.0358 (14)	−0.0165 (15)	−0.0193 (13)	0.0025 (12)
C55	0.0562 (15)	0.0499 (15)	0.0478 (15)	−0.0106 (12)	−0.0181 (12)	0.0047 (11)
C56	0.0492 (13)	0.0392 (12)	0.0362 (12)	−0.0093 (10)	−0.0062 (10)	−0.0035 (9)
N1	0.0401 (10)	0.0395 (10)	0.0421 (11)	0.0021 (8)	−0.0145 (8)	−0.0053 (8)
N2	0.0318 (10)	0.0430 (11)	0.0457 (11)	−0.0109 (8)	−0.0048 (8)	−0.0027 (8)
N3	0.0324 (9)	0.0357 (9)	0.0295 (9)	−0.0060 (7)	−0.0039 (7)	−0.0060 (7)
O1	0.0482 (9)	0.0646 (11)	0.0376 (9)	−0.0161 (8)	0.0046 (7)	−0.0035 (8)
O2	0.0219 (7)	0.0657 (11)	0.0470 (9)	−0.0041 (7)	−0.0028 (6)	−0.0048 (8)
Cl1	0.0626 (4)	0.0716 (5)	0.0654 (5)	−0.0297 (4)	0.0096 (3)	−0.0096 (3)

Geometric parameters (Å, º)

C2—N1	1.469 (3)	C33—H33	0.9300
C2—C21	1.511 (3)	C34—C35	1.394 (3)
C2—C27	1.569 (3)	C34—H34	0.9300
C2—C3	1.577 (3)	C35—N3	1.342 (3)
C3—C31	1.532 (3)	C35—C51	1.479 (3)
C3—C38	1.532 (3)	C36—N3	1.337 (3)
C3—C4	1.579 (3)	C36—C37	1.490 (3)
C4—C41	1.510 (3)	C37—C38	1.523 (3)
C4—C5	1.518 (3)	C37—H37A	0.9700
C4—H4	0.9800	C37—H37B	0.9700
C5—N1	1.463 (3)	C38—H38A	0.9700

C5—H5A	0.9700	C38—H38B	0.9700
C5—H5B	0.9700	C41—C42	1.389 (3)
C21—C22	1.373 (3)	C41—C46	1.391 (3)
C21—C26	1.387 (3)	C42—C43	1.375 (4)
C22—C23	1.385 (3)	C42—Cl1	1.743 (2)
C22—H22	0.9300	C43—C44	1.377 (4)
C23—C24	1.375 (4)	C43—H43	0.9300
C23—H23	0.9300	C44—C45	1.364 (4)
C24—C25	1.374 (4)	C44—H44	0.9300
C24—H24	0.9300	C45—C46	1.384 (4)
C25—C26	1.378 (3)	C45—H45	0.9300
C25—H25	0.9300	C46—H46	0.9300
C26—N2	1.391 (3)	C51—C52	1.389 (3)
C27—O1	1.210 (3)	C51—C56	1.390 (3)
C27—N2	1.358 (3)	C52—C53	1.381 (3)
C31—O2	1.213 (2)	C52—H52	0.9300
C31—C32	1.475 (3)	C53—C54	1.376 (4)
C6—N1	1.465 (3)	C53—H53	0.9300
C6—H03A	0.9600	C54—C55	1.366 (4)
C6—H03B	0.9600	C54—H54	0.9300
C6—H03C	0.9600	C55—C56	1.377 (3)
C32—C33	1.389 (3)	C55—H55	0.9300
C32—C36	1.394 (3)	C56—H56	0.9300
C33—C34	1.364 (3)	N2—H2	0.88 (3)

N1—C2—C21	112.06 (17)	C35—C34—H34	120.4
N1—C2—C27	113.20 (17)	N3—C35—C34	121.76 (19)
C21—C2—C27	101.09 (16)	N3—C35—C51	116.63 (18)
N1—C2—C3	102.01 (16)	C34—C35—C51	121.59 (19)
C21—C2—C3	118.75 (17)	N3—C36—C32	122.40 (18)
C27—C2—C3	110.19 (16)	N3—C36—C37	117.68 (17)
C31—C3—C38	108.09 (16)	C32—C36—C37	119.91 (17)
C31—C3—C2	107.53 (16)	C36—C37—C38	112.47 (16)
C38—C3—C2	115.01 (16)	C36—C37—H37A	109.1
C31—C3—C4	108.09 (15)	C38—C37—H37A	109.1
C38—C3—C4	114.82 (16)	C36—C37—H37B	109.1
C2—C3—C4	102.89 (15)	C38—C37—H37B	109.1
C41—C4—C5	115.76 (18)	H37A—C37—H37B	107.8
C41—C4—C3	115.84 (16)	C37—C38—C3	113.25 (17)
C5—C4—C3	105.59 (17)	C37—C38—H38A	108.9
C41—C4—H4	106.3	C3—C38—H38A	108.9
C5—C4—H4	106.3	C37—C38—H38B	108.9
C3—C4—H4	106.3	C3—C38—H38B	108.9
N1—C5—C4	103.22 (17)	H38A—C38—H38B	107.7
N1—C5—H5A	111.1	C42—C41—C46	115.9 (2)
C4—C5—H5A	111.1	C42—C41—C4	120.99 (19)
N1—C5—H5B	111.1	C46—C41—C4	123.1 (2)
C4—C5—H5B	111.1	C43—C42—C41	122.9 (2)

H5A—C5—H5B	109.1	C43—C42—Cl1	116.8 (2)
C22—C21—C26	119.4 (2)	C41—C42—Cl1	120.30 (18)
C22—C21—C2	131.5 (2)	C42—C43—C44	119.6 (3)
C26—C21—C2	109.14 (18)	C42—C43—H43	120.2
C21—C22—C23	119.2 (2)	C44—C43—H43	120.2
C21—C22—H22	120.4	C45—C44—C43	119.2 (2)
C23—C22—H22	120.4	C45—C44—H44	120.4
C24—C23—C22	120.7 (2)	C43—C44—H44	120.4
C24—C23—H23	119.6	C44—C45—C46	120.9 (2)
C22—C23—H23	119.6	C44—C45—H45	119.6
C25—C24—C23	120.8 (2)	C46—C45—H45	119.6
C25—C24—H24	119.6	C45—C46—C41	121.4 (2)
C23—C24—H24	119.6	C45—C46—H46	119.3
C24—C25—C26	118.2 (2)	C41—C46—H46	119.3
C24—C25—H25	120.9	C52—C51—C56	118.4 (2)
C26—C25—H25	120.9	C52—C51—C35	120.8 (2)
C25—C26—C21	121.8 (2)	C56—C51—C35	120.7 (2)
C25—C26—N2	128.1 (2)	C53—C52—C51	120.6 (3)
C21—C26—N2	110.08 (19)	C53—C52—H52	119.7
O1—C27—N2	125.8 (2)	C51—C52—H52	119.7
O1—C27—C2	126.6 (2)	C54—C53—C52	120.2 (2)
N2—C27—C2	107.54 (18)	C54—C53—H53	119.9
O2—C31—C32	119.56 (18)	C52—C53—H53	119.9
O2—C31—C3	121.31 (18)	C55—C54—C53	119.7 (2)
C32—C31—C3	119.01 (16)	C55—C54—H54	120.2
N1—C6—H03A	109.5	C53—C54—H54	120.2
N1—C6—H03B	109.5	C54—C55—C56	120.8 (2)
H03A—C6—H03B	109.5	C54—C55—H55	119.6
N1—C6—H03C	109.5	C56—C55—H55	119.6
H03A—C6—H03C	109.5	C55—C56—C51	120.4 (2)
H03B—C6—H03C	109.5	C55—C56—H56	119.8
C33—C32—C36	118.10 (19)	C51—C56—H56	119.8
C33—C32—C31	120.06 (18)	C5—N1—C6	112.86 (19)
C36—C32—C31	121.61 (18)	C5—N1—C2	105.95 (17)
C34—C33—C32	119.1 (2)	C6—N1—C2	114.76 (18)
C34—C33—H33	120.4	C27—N2—C26	112.06 (18)
C32—C33—H33	120.4	C27—N2—H2	120.9 (18)
C33—C34—C35	119.3 (2)	C26—N2—H2	125.6 (18)
C33—C34—H34	120.4	C36—N3—C35	118.38 (17)

N1—C2—C3—C31	87.78 (18)	C33—C34—C35—C51	−169.7 (2)
C21—C2—C3—C31	−35.9 (2)	C33—C32—C36—N3	9.5 (3)
C27—C2—C3—C31	−151.73 (16)	C31—C32—C36—N3	−164.92 (19)
N1—C2—C3—C38	−151.78 (16)	C33—C32—C36—C37	−170.98 (19)
C21—C2—C3—C38	84.5 (2)	C31—C32—C36—C37	14.6 (3)
C27—C2—C3—C38	−31.3 (2)	N3—C36—C37—C38	−165.11 (18)
N1—C2—C3—C4	−26.19 (19)	C32—C36—C37—C38	15.4 (3)
C21—C2—C3—C4	−149.88 (17)	C36—C37—C38—C3	−51.8 (2)

C27—C2—C3—C4	94.30 (18)	C31—C3—C38—C37	55.5 (2)
C31—C3—C4—C41	117.6 (2)	C2—C3—C38—C37	−64.7 (2)
C38—C3—C4—C41	−3.1 (3)	C4—C3—C38—C37	176.20 (16)
C2—C3—C4—C41	−128.80 (18)	C5—C4—C41—C42	147.3 (2)
C31—C3—C4—C5	−112.83 (19)	C3—C4—C41—C42	−88.3 (2)
C38—C3—C4—C5	126.44 (19)	C5—C4—C41—C46	−31.5 (3)
C2—C3—C4—C5	0.7 (2)	C3—C4—C41—C46	93.0 (2)
C41—C4—C5—N1	154.80 (17)	C46—C41—C42—C43	0.7 (3)
C3—C4—C5—N1	25.2 (2)	C4—C41—C42—C43	−178.2 (2)
N1—C2—C21—C22	−55.7 (3)	C46—C41—C42—Cl1	−178.29 (16)
C27—C2—C21—C22	−176.6 (2)	C4—C41—C42—Cl1	2.8 (3)
C3—C2—C21—C22	62.8 (3)	C41—C42—C43—C44	1.1 (4)
N1—C2—C21—C26	122.16 (19)	Cl1—C42—C43—C44	−179.90 (18)
C27—C2—C21—C26	1.3 (2)	C42—C43—C44—C45	−1.9 (4)
C3—C2—C21—C26	−119.2 (2)	C43—C44—C45—C46	0.9 (4)
C26—C21—C22—C23	1.7 (3)	C44—C45—C46—C41	1.0 (4)
C2—C21—C22—C23	179.5 (2)	C42—C41—C46—C45	−1.7 (3)
C21—C22—C23—C24	−0.7 (4)	C4—C41—C46—C45	177.1 (2)
C22—C23—C24—C25	−0.3 (4)	N3—C35—C51—C52	−157.6 (2)
C23—C24—C25—C26	0.4 (4)	C34—C35—C51—C52	21.0 (3)
C24—C25—C26—C21	0.7 (3)	N3—C35—C51—C56	19.1 (3)
C24—C25—C26—N2	−175.9 (2)	C34—C35—C51—C56	−162.3 (2)
C22—C21—C26—C25	−1.8 (3)	C56—C51—C52—C53	−0.9 (4)
C2—C21—C26—C25	−180.0 (2)	C35—C51—C52—C53	175.9 (2)
C22—C21—C26—N2	175.4 (2)	C51—C52—C53—C54	0.2 (4)
C2—C21—C26—N2	−2.8 (2)	C52—C53—C54—C55	0.7 (4)
N1—C2—C27—O1	58.7 (3)	C53—C54—C55—C56	−0.9 (4)
C21—C2—C27—O1	178.8 (2)	C54—C55—C56—C51	0.2 (4)
C3—C2—C27—O1	−54.8 (3)	C52—C51—C56—C55	0.7 (3)
N1—C2—C27—N2	−119.41 (19)	C35—C51—C56—C55	−176.1 (2)
C21—C2—C27—N2	0.6 (2)	C4—C5—N1—C6	−170.69 (19)
C3—C2—C27—N2	127.08 (18)	C4—C5—N1—C2	−44.3 (2)
C38—C3—C31—O2	158.3 (2)	C21—C2—N1—C5	172.38 (18)
C2—C3—C31—O2	−77.0 (2)	C27—C2—N1—C5	−74.1 (2)
C4—C3—C31—O2	33.5 (3)	C3—C2—N1—C5	44.3 (2)
C38—C3—C31—C32	−25.8 (2)	C21—C2—N1—C6	−62.4 (3)
C2—C3—C31—C32	98.9 (2)	C27—C2—N1—C6	51.1 (3)
C4—C3—C31—C32	−150.66 (18)	C3—C2—N1—C6	169.51 (19)
O2—C31—C32—C33	−6.9 (3)	O1—C27—N2—C26	179.5 (2)
C3—C31—C32—C33	177.10 (19)	C2—C27—N2—C26	−2.4 (2)
O2—C31—C32—C36	167.4 (2)	C25—C26—N2—C27	−179.7 (2)
C3—C31—C32—C36	−8.6 (3)	C21—C26—N2—C27	3.4 (3)
C36—C32—C33—C34	−5.4 (3)	C32—C36—N3—C35	−4.4 (3)
C31—C32—C33—C34	169.2 (2)	C37—C36—N3—C35	176.14 (18)
C32—C33—C34—C35	−3.3 (4)	C34—C35—N3—C36	−4.9 (3)
C33—C34—C35—N3	8.8 (4)	C51—C35—N3—C36	173.66 (18)

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
C22—H22···O2	0.93	2.57	3.227 (3)	128
C38—H38*A*···O1	0.97	2.46	3.135 (3)	127
C37—H37*A*···O2^{i}	0.97	2.38	3.159 (3)	137
N2—H2···O2^{i}	0.88 (3)	2.50 (2)	2.911 (3)	109.0 (19)

Symmetry code: (i) $x-1, y, z$.