



Received 3 August 2020

Accepted 3 August 2020

Edited by A. V. Yatsenko, Moscow State  
University, Russia**Keywords:** crystal structure; nitroflavone; anti-  
cancer agent;  $\pi$ - $\pi$  interactions; DFT calcula-  
tions.**CCDC reference:** 2021153**Supporting information:** this article has  
supporting information at journals.iucr.org/e

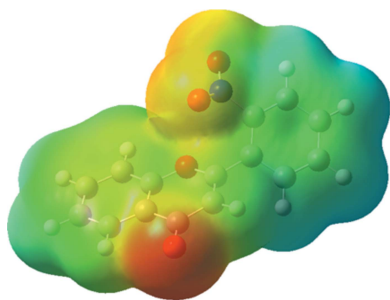
# Structural (at 100 K) and DFT studies of 2'-nitroflavone

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The geometry of the title molecule [systematic name: 2-(2-nitrophenyl)-4*H*-chromen-4-one], C<sub>15</sub>H<sub>9</sub>NO<sub>4</sub>, is determined by two dihedral angles formed by the mean plane of phenyl ring with the mean planes of chromone moiety and nitro group, being 50.73 (5) and 30.89 (7)°, respectively. The crystal packing is determined by  $\pi$ - $\pi$  interactions and C-H...O contacts. The results of DFT calculations at the B3LYP/6-31G\* level of theory provided an explanation of the unusually large dihedral angle between the chromone moiety and the phenyl group. The electrostatic potential map on the molecular surface was calculated in order to determine the potential binding sites to receptors.

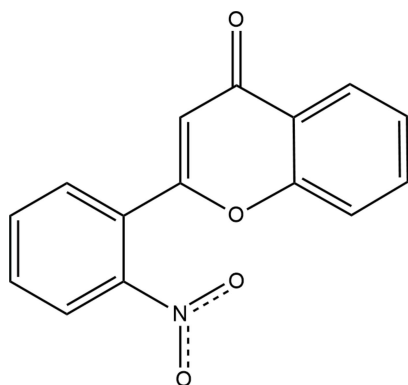
## 1. Chemical context

The naturally occurring group of heterocyclic compounds known as flavonoids has received considerable attention over the past 15 years. The synthesis and applications of flavones and their derivatives have been studied extensively because of their diverse pharmaceutical properties. Besides their physiological role in plants (Agati *et al.*, 2012), this class of compounds has demonstrated antiallergic, antiviral, anxiolytic and anti-inflammatory activities (Manthey *et al.*, 2001). Several synthetic flavonoids and their nitro derivatives, including a few halogen-substituted compounds, have been found to act as highly competitive ligands for benzodiazepine receptors, suggesting a possible use as anxiolytic drugs (Marder *et al.*, 1995). Most importantly, several nitro derivatives of flavones have been reported to possess antiproliferative properties against human and murine cancerous cells, by the mechanism of induced apoptosis (Blank *et al.*, 2004). Moreover, some flavonoids have been found to be capable of restoring the viability of human vascular endothelial cells, thus providing both cytoprotective and cytotoxic effects on normal and cancerous cells, respectively (Ramos, 2008). The title compound, 2'-nitroflavone, has previously been shown to effectively inhibit human and murine tumor cell activity without affecting the non-tumor cells. Induced apoptosis molecular mechanisms have been studied *in vitro* for HeLa human cervix carcinoma (Cárdenas *et al.*, 2008) and *in vivo* in murine adenocarcinoma cells (Cárdenas *et al.*, 2009). Several haematological cancer cell lines were used in the cytotoxicity evaluation of the title compound, along with a culture of healthy peripheral blood mononuclear cells (PBMCs); the IC<sub>50</sub> values (drug concentrations needed to induce a 50% inhibition of cell growth) after 2'-nitroflavone treatment



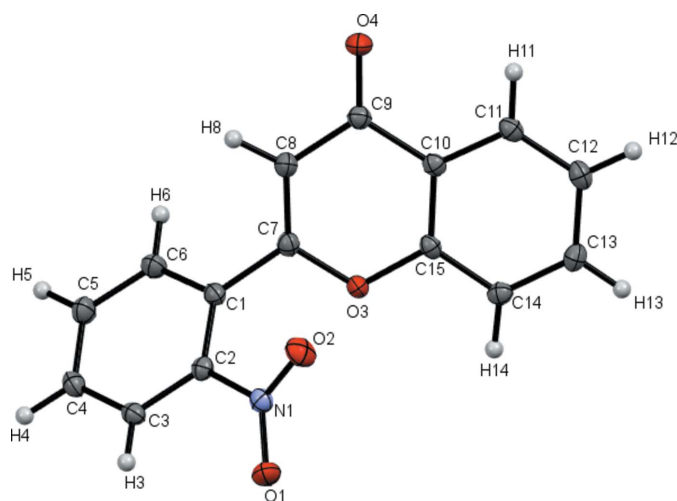
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ranged from  $1 \pm 0.5 \mu\text{mol L}^{-1}$  to  $9 \pm 1.4 \mu\text{mol/L}$  for various neoplastic cells, while the healthy cells  $\text{IC}_{50}$  was found to be over  $80 \mu\text{mol L}^{-1}$ , effectively leaving the cells intact under the concentrations sufficient for cancerous cells (Cárdenas *et al.*, 2012). Despite the evident importance of nitroflavone derivatives, structural studies until now have been limited to only one reported nitroflavone-based compound (Kendi *et al.*, 1996). In this work, a combined study consisting of X-ray diffraction (XRD) structural analysis and quantum-chemical DFT calculations was carried out in order to obtain insight into the structure–property relationship, and more specifically the effect of the nitro substituent in the *ortho*-position of the phenyl moiety of a flavone.



## 2. Structural commentary

The molecular structure of 2'-nitroflavone is presented in Fig. 1. The mean plane of the benzene ring makes dihedral angles of  $50.73(5)$  and  $30.89(7)^\circ$  with the mean planes of the chromone moiety and the nitro group, respectively. The dihedral angle between mean planes of the chromone and benzene groups is unusually large when compared to other *ortho*-substituted flavone derivatives. For instance, the mol-



**Figure 1**  
A view of the molecular structure of the title compound with the atom-labeling scheme. Displacement ellipsoids are drawn at the 50% probability level.

**Table 1**  
Hydrogen-bond geometry ( $\text{\AA}$ ,  $^\circ$ ).

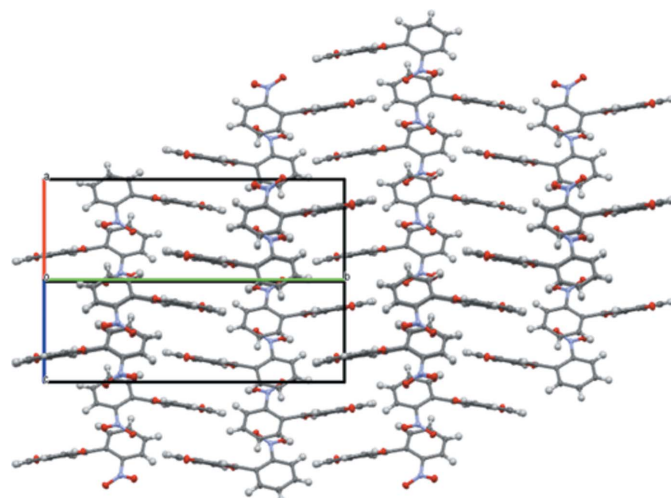
$D-H \cdots A$	$D-H$	$H \cdots A$	$D \cdots A$	$D-H \cdots A$
$C3-H3 \cdots O4^i$	0.933 (17)	2.675 (16)	3.198 (3)	116.1 (12)
$C4-H4 \cdots O4^i$	0.971 (16)	2.446 (16)	3.109 (3)	125.3 (12)

Symmetry code: (i)  $-x + 1, y + \frac{1}{2}, -z + \frac{5}{2}$ .

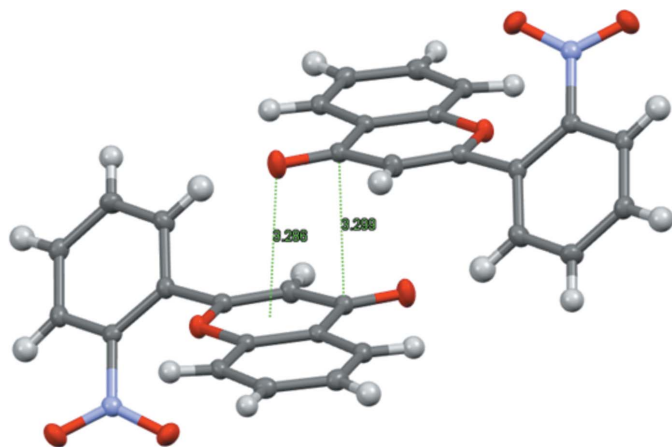
ecule of 2'-methoxyflavone was reported to be almost planar, with a dihedral angle of  $2.9^\circ$  (Wallet *et al.*, 1990). Even in the flavonoid with a bulky carbazole substituent in the same position, this dihedral angle is only  $29.2^\circ$  (Zheng, 2018). The length of the single bond between the chromone and benzene moieties is  $1.469(2) \text{\AA}$ , indicating some  $\pi$ - $\pi$  conjugation. The unusually large dihedral angle in the title molecule can be attributed to the steric tension between the nitro group and the chromone oxygen atom, whereas in the carbazole derivative this substituent is twisted far enough from the plane of the benzene ring to avoid it coming into close proximity with the flavone core.

## 3. Supramolecular features

In the crystal, the title molecules form a parquet-like structure, with alternating layers of coplanar chromone backbones (Fig. 2). The presence of  $\pi$ - $\pi$  interactions in the crystal packing can be suggested from the short intermolecular distance of  $3.299(4) \text{\AA}$  between the overlapping C9 atoms from opposing molecules. Moreover, a short contact of  $3.286(3) \text{\AA}$  between the carbonyl oxygen atom and the centroid of the opposing heterocyclic ring is found, which suggests an interaction of the oxygen atom with the  $\pi$ -system (Fig. 3). Such an intermolecular interaction was found in the crystal structure of chiral amino alcohol with a pentafluorophenyl group (Korenaga *et al.*, 2003). Two short  $C-H \cdots O$  contacts also occur, indicating at additional structural stability (Table 1).



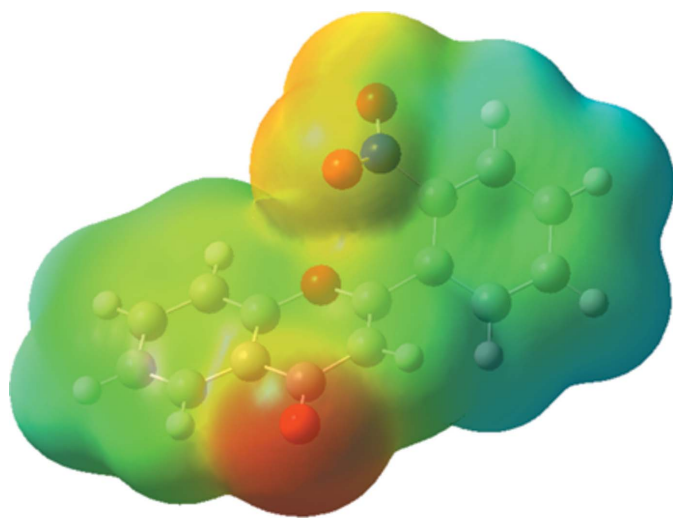
**Figure 2**  
Parquet-like molecular packing in the title structure.



**Figure 3**  
Short intermolecular C...C and C–O... $\pi$  contacts in the crystal of the title compound.

#### 4. Database survey

A search of the Cambridge Crystallographic Database (CSD version 5.40, update of September 19; Groom *et al.*, 2016) for the title molecule yielded no entries. A single nitroflavone entry, for 2'-methyl-3'-nitroflavone, was found (REZROD; Kendi *et al.*, 1996). A search for flavone-core molecules with only an *ortho*-substituted phenyl ring returned a total of six entries, three of which correspond to the compound with a methoxy group in the 2'-position [KEPLAS (Wallet *et al.*, 1990), KEPLAS01 (McKendall *et al.*, 2008), KEPLAS02 (Zia *et al.*, 2020)]; more specifically, one of the entries represents a structure of a possible polymorph, while the other two correspond to the same form. The other three correspond to carbazole (XIJVAQ; Zheng, 2018), hydroxy (YUDWEZ; Seetharaman & Rajan, 1995) and ethyl glycolate (PIGXUB; Goyal *et al.*, 2018) substituents. Most of these molecules



**Figure 4**  
Electrostatic potential on the van der Waals surface of the title compound.

**Table 2**

Experimental (XRD) and calculated (DFT) dihedral angles ( $^{\circ}$ ) between the phenyl and chromone moieties in the title molecule (I), the 2'-methoxy derivative (II) and the 2'-carbazole derivative (III).

	XRD	DFT
(I)	50.73 (5)	47.56
(II)	2.89 (7)	22.16
(III)	29.21 (6)	40.13

**Table 3**

Experimental (XRD) and calculated (DFT) lengths of single bonds ( $\text{\AA}$ ) between the phenyl and chromone moieties in the title molecule (I), the 2'-methoxy derivative (II) and the 2'-carbazole derivative (III).

	XRD	DFT
(I)	1.469 (2)	1.482
(II)	1.475 (4)	1.477
(III)	1.478 (2)	1.481

**Table 4**

Experimental (XRD) and calculated (DFT) dihedral/torsion angles ( $^{\circ}$ ) between the phenyl group and the substituent in the 2'-position in the title molecule (I), the methoxy derivative (II) and the carbazole derivative (III).

	XRD	DFT
(I)	30.89 (7)	31.83
(II)	174.3 (2)	176.78
(III)	69.95 (9)	66.40

exhibit only slight deviations from planarity, with the exception of carbazole-substituted molecule.

#### 5. DFT calculations

In an attempt to get further insight into structure and properties of the title molecule (I), a DFT study was carried out at the B3LYP/6-31G\* level of theory with *GAUSSIAN 16* (Frisch *et al.*, 2016) software. The geometry of the ground state was optimized, using the XRD data as a starting point. The optimized geometry was confirmed to be the minimum by vibrational frequency analysis. Two previously described flavonoids, with methoxy (II) and carbazole (III) substituents in the 2'-position, were also optimized and compared with the XRD data. Selected geometrical parameters are presented in Tables 2–4.

The calculated parameters are in satisfactory agreement with those obtained experimentally. The range of calculated dihedral angles between the moieties comprising the flavone core is narrower than that observed in the crystal structures, but still demonstrates the same trend with the title compound having the largest angle.

Considering the importance of the biological functions of the title compound, including its ability to competitively bind to benzodiazepine receptors, the electrostatic potential on the van der Waals surface was calculated (Fig. 4). While initially we had expected the nitro group to be the negative charge concentration site, it turned out to be the oxygen of the

chromone moiety. We speculate that it could be the binding part in this molecule's interaction with benzodiazepine receptors.

## 6. Synthesis and crystallization

The synthesis of the title compound was performed as described in the literature (Barros & Silva, 2006). The obtained product was recrystallized by slow evaporation from ethanol solution.

## 7. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 5. Data collection was performed at 100 K. All hydrogen atoms were located from the difference-Fourier map and freely refined.

## Funding information

Funding for this research was provided by: National Science Foundation (award No. DMR-0934212; award No. DMR-1523611, PREM); National Institutes of Health (award No. 1R21NS084353-01).

## References

Agati, G., Azzarello, E., Pollastri, S. & Tattini, M. (2012). *Plant Sci.* **196**, 67–76.

Barros, A. I. R. N. A. & Silva, A. M. S. (2006). *Monatsh. Chem.* **137**, 1505–1528.

Blank, V. C., Poli, C., Marder, M. & Roguin, L. P. (2004). *Bioorg. Med. Chem. Lett.* **14**, 133–136.

Bruker (2016). *APEX3* and *SAINT*. Bruker AXS Inc., Madison, Wisconsin, USA.

Cárdenas, M. G., Blank, V. C., Marder, M. & Roguin, L. P. (2008). *Cancer Lett.* **268**, 146–157.

Cárdenas, M. G., Blank, V. C., Marder, M. N. & Roguin, L. P. (2012). *Anticancer Drugs*, **23**, 815–826.

Cárdenas, M. G., Zotta, E., Marder, M. & Roguin, L. P. (2009). *Int. J. Cancer*, **125**, 222–228.

Frisch, M. J., Trucks, G. W., Schlegel, H. B., Scuseria, G. E., Robb, M. A., Cheeseman, J. R., Montgomery, J. A. Jr, Vreven, T., Kudin, K. N., Burant, J. C., Millam, J. M., Iyengar, S. S., Tomasi, J., Barone, V., Mennucci, B., Cossi, M., Scalmani, G., Rega, N., Petersson, G. A., Nakatsuji, H., Hada, M., Ehara, M., Toyota, K., Fukuda, R., Hasegawa, J., Ishida, M., Nakajima, T., Honda, Y., Kitao, O., Nakai, H., Klene, M., Li, X., Knox, J. E., Hratchian, H. P., Cross, J. B., Bakken, V., Adamo, C., Jaramillo, J., Gomperts, R., Stratmann, R. E., Yazyev, O., Austin, A. J., Cammi, R., Pomelli, C., Ochterski, J. W., Ayala, P. Y., Morokuma, K., Voth, G. A., Salvador, P., Dannenberg, J. J., Zakrzewski, V. G., Dapprich, S., Daniels, A. D., Strain, M. C., Farkas, O., Malick, D. K., Rabuck, A. D., Raghavachari, K., Foresman, J. B., Ortiz, J. V., Cui, Q., Baboul, A. G., Clifford, S., Cioslowski, J., Stefanov, B. B., Liu, G., Liashenko, A., Piskorz, P., Komaromi, I., Martin, R. L., Fox, D. J., Keith, T., Al-Laham, M. A., Peng, C. Y., Nanayakkara, A., Challacombe, M., Gill, P. M. W., Johnson, B., Chen, W., Wong, M. W., Gonzalez, C. &

Table 5

Experimental details.

Crystal data	
Chemical formula	C <sub>15</sub> H <sub>9</sub> NO <sub>4</sub>
<i>M<sub>r</sub></i>	267.23
Crystal system, space group	Monoclinic, <i>P</i> <sub>2</sub> <sub>1</sub> / <i>c</i>
Temperature (K)	100
<i>a</i> , <i>b</i> , <i>c</i> (Å)	8.079 (7), 20.134 (17), 7.915 (7)
β (°)	116.647 (18)
<i>V</i> (Å <sup>3</sup> )	1150.6 (16)
<i>Z</i>	4
Radiation type	Mo <i>K</i> α
μ (mm <sup>-1</sup> )	0.11
Crystal size (mm)	0.35 × 0.28 × 0.25
Data collection	
Diffractometer	Bruker APEXII CCD
No. of measured, independent and observed [ <i>I</i> > 2σ( <i>I</i> )] reflections	9944, 2491, 2248
<i>R</i> <sub>int</sub>	0.034
(sin θ/λ) <sub>max</sub> (Å <sup>-1</sup> )	0.650
Refinement	
<i>R</i> [ <i>F</i> <sup>2</sup> > 2σ( <i>F</i> <sup>2</sup> )], <i>wR</i> ( <i>F</i> <sup>2</sup> ), <i>S</i>	0.035, 0.093, 1.05
No. of reflections	2491
No. of parameters	217
H-atom treatment	All H-atom parameters refined
Δρ <sub>max</sub> , Δρ <sub>min</sub> (e Å <sup>-3</sup> )	0.30, -0.23

Computer programs: *APEX3* and *SAINT* (Bruker, 2016), *SHELXT2017/1* (Sheldrick, 2015a), *SHELXL2017/1* (Sheldrick, 2015b) and *Mercury* (Macrae *et al.*, 2020).

Pople, J. A. (2016). *GAUSSIAN016*. Rev. C.01. Gaussian Inc., Wallingford, CT, USA. <http://www.gaussian.com>.

Goyal, N., Do, C., Donahue, J. P., Mague, J. T. & Foroozesh, M. (2018). *IUCrData*, **3**, x180993.

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

Kendi, E., Özbey, S., Tunçbilek, M. & Ertan, R. (1996). *Cryst. Res. Technol.* **31**, 611–615.

Korenaga, T., Tanaka, H., Ema, T. & Sakai, T. (2003). *J. Fluor. Chem.* **122**, 201–205.

Macrae, C. F., Sovago, I., Cottrell, S. J., Galek, P. T. A., McCabe, P., Pidcock, E., Platings, M., Shields, G. P., Stevens, J. S., Towler, M. & Wood, P. A. (2020). *J. Appl. Cryst.* **53**, 226–235.

Manthey, J., Grohmann, K. & Guthrie, N. (2001). *Curr. Med. Chem.* **8**, 135–153.

Marder, M., Viola, H., Wasowski, C., Wolfman, C., Waterman, P. G., Medina, J. H. & Paladini, A. C. (1995). *Bioorg. Med. Chem. Lett.* **5**, 2717–2720.

McKendall, M., Smith, T., Anh, K., Ellis, J., McGee, T., Foroozesh, M., Zhu, N. & Stevens, C. L. K. (2008). *J. Chem. Crystallogr.* **38**, 231–237.

Ramos, S. (2008). *Mol. Nutr. Food Res.* **52**, 507–526.

Seetharaman, J. & Rajan, S. S. (1995). *Z. Kristallogr.* **210**, 104–106.

Sheldrick, G. M. (2015a). *Acta Cryst. A* **71**, 3–8.

Sheldrick, G. M. (2015b). *Acta Cryst. C* **71**, 3–8.

Wallet, J.-C., Gaydou, E. M., Jaud, J. & Baldy, A. (1990). *Acta Cryst. C* **46**, 1536–1540.

Zheng, Z. K. (2018). CSD Communication (refcode XIJVAQ). CCDC, Cambridge, England.

Zia, M., Khalid, M., Hameed, S., Irran, E. & Naseer, M. M. (2020). *J. Mol. Struct.* 1207 Article 127811.

## supporting information

*Acta Cryst.* (2020). E76, 1417-1420 [https://doi.org/10.1107/S2056989020010713]

## Structural (at 100 K) and DFT studies of 2'-nitroflavone

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## Computing details

Data collection: *APEX3* (Bruker, 2016); cell refinement: *SAINTE* (Bruker, 2016); data reduction: *SAINTE* (Bruker, 2016); program(s) used to solve structure: *SHELXT2017/1* (Sheldrick, 2015a); program(s) used to refine structure: *SHELXL2017/1* (Sheldrick, 2015b); molecular graphics: *Mercury* (Macrae *et al.*, 2020); software used to prepare material for publication: *Mercury* (Macrae *et al.*, 2020).

## 2-(2-Nitrophenyl)-4H-chromen-4-one

## Crystal data

$C_{15}H_9NO_4$

$M_r = 267.23$

Monoclinic,  $P2_1/c$

$a = 8.079$  (7) Å

$b = 20.134$  (17) Å

$c = 7.915$  (7) Å

$\beta = 116.647$  (18)°

$V = 1150.6$  (16) Å<sup>3</sup>

$Z = 4$

$F(000) = 552$

$D_x = 1.543$  Mg m<sup>-3</sup>

Mo  $K\alpha$  radiation,  $\lambda = 0.71073$  Å

Cell parameters from 1326 reflections

$\theta = 3.1\text{--}32.1^\circ$

$\mu = 0.11$  mm<sup>-1</sup>

$T = 100$  K

Block-shaped, white

$0.35 \times 0.28 \times 0.25$  mm

## Data collection

Bruker APEXII CCD  
diffractometer

$\varphi$  and  $\omega$  scans

9944 measured reflections

2491 independent reflections

2248 reflections with  $I > 2\sigma(I)$

$R_{\text{int}} = 0.034$

$\theta_{\text{max}} = 27.5^\circ$ ,  $\theta_{\text{min}} = 2.0^\circ$

$h = -10 \rightarrow 6$

$k = -16 \rightarrow 26$

$l = -10 \rightarrow 8$

## Refinement

Refinement on  $F^2$

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)] = 0.035$

$wR(F^2) = 0.093$

$S = 1.05$

2491 reflections

217 parameters

0 restraints

Primary atom site location: iterative

Hydrogen site location: difference Fourier map

All H-atom parameters refined

$w = 1/[\sigma^2(F_o^2) + (0.0401P)^2 + 0.551P]$

where  $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{\text{max}} = 0.001$

$\Delta\rho_{\text{max}} = 0.30$  e Å<sup>-3</sup>

$\Delta\rho_{\text{min}} = -0.23$  e Å<sup>-3</sup>

*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.

*Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters ( $\text{\AA}^2$ )*

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
O3	0.22049 (12)	0.13047 (4)	0.89731 (12)	0.0160 (2)
O4	0.48862 (13)	-0.02543 (4)	1.23925 (13)	0.0229 (2)
O1	0.04077 (13)	0.29953 (4)	0.98796 (14)	0.0230 (2)
O2	0.11312 (14)	0.20433 (4)	1.12606 (14)	0.0243 (2)
C7	0.37958 (17)	0.13828 (6)	1.06058 (17)	0.0154 (2)
C10	0.22802 (17)	0.01385 (6)	0.96633 (16)	0.0146 (2)
C9	0.40481 (17)	0.02123 (6)	1.13800 (17)	0.0160 (2)
C15	0.14347 (17)	0.06830 (5)	0.85277 (17)	0.0144 (2)
C14	-0.02257 (17)	0.06319 (6)	0.68804 (17)	0.0163 (2)
C2	0.33977 (17)	0.26206 (6)	1.08494 (16)	0.0148 (2)
C13	-0.10846 (18)	0.00246 (6)	0.63791 (17)	0.0182 (3)
C1	0.44677 (17)	0.20715 (6)	1.09092 (16)	0.0154 (2)
N1	0.15066 (15)	0.25441 (5)	1.06335 (14)	0.0164 (2)
C8	0.47167 (18)	0.08861 (6)	1.17707 (17)	0.0175 (3)
C11	0.13820 (18)	-0.04727 (6)	0.91170 (17)	0.0168 (3)
C6	0.62821 (18)	0.21870 (6)	1.12309 (18)	0.0194 (3)
C3	0.40847 (18)	0.32564 (6)	1.10911 (17)	0.0165 (3)
C5	0.69942 (19)	0.28224 (6)	1.14845 (19)	0.0204 (3)
C4	0.58971 (18)	0.33551 (6)	1.14135 (17)	0.0185 (3)
C12	-0.02751 (18)	-0.05292 (6)	0.75091 (18)	0.0186 (3)
H13	-0.221 (2)	-0.0009 (7)	0.527 (2)	0.019 (4)*
H11	0.196 (2)	-0.0854 (7)	0.994 (2)	0.020 (4)*
H8	0.585 (2)	0.0986 (8)	1.292 (2)	0.024 (4)*
H14	-0.071 (2)	0.1017 (8)	0.610 (2)	0.020 (4)*
H3	0.334 (2)	0.3611 (8)	1.110 (2)	0.025 (4)*
H4	0.638 (2)	0.3804 (8)	1.162 (2)	0.025 (4)*
H5	0.825 (2)	0.2894 (7)	1.172 (2)	0.022 (4)*
H12	-0.090 (2)	-0.0948 (8)	0.716 (2)	0.024 (4)*
H6	0.706 (2)	0.1816 (8)	1.128 (2)	0.027 (4)*

*Atomic displacement parameters ( $\text{\AA}^2$ )*

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
O3	0.0160 (5)	0.0119 (4)	0.0168 (4)	-0.0011 (3)	0.0043 (4)	-0.0001 (3)
O4	0.0205 (5)	0.0164 (4)	0.0244 (5)	0.0012 (3)	0.0034 (4)	0.0050 (3)
O1	0.0174 (5)	0.0199 (4)	0.0291 (5)	0.0041 (3)	0.0083 (4)	0.0014 (4)
O2	0.0265 (5)	0.0205 (4)	0.0309 (5)	-0.0026 (4)	0.0175 (5)	0.0039 (4)
C7	0.0149 (6)	0.0148 (5)	0.0168 (5)	-0.0012 (4)	0.0073 (5)	-0.0026 (4)
C10	0.0151 (6)	0.0138 (5)	0.0166 (5)	0.0006 (4)	0.0086 (5)	-0.0012 (4)

C9	0.0158 (6)	0.0151 (5)	0.0173 (5)	0.0008 (4)	0.0077 (5)	0.0007 (4)
C15	0.0161 (6)	0.0125 (5)	0.0169 (5)	-0.0010 (4)	0.0094 (5)	-0.0021 (4)
C14	0.0164 (6)	0.0163 (5)	0.0164 (5)	0.0021 (4)	0.0076 (5)	0.0005 (4)
C2	0.0150 (6)	0.0162 (5)	0.0132 (5)	-0.0006 (4)	0.0062 (5)	-0.0005 (4)
C13	0.0158 (6)	0.0215 (6)	0.0159 (5)	-0.0023 (5)	0.0059 (5)	-0.0034 (4)
C1	0.0173 (6)	0.0129 (5)	0.0146 (5)	-0.0005 (4)	0.0059 (5)	-0.0006 (4)
N1	0.0174 (5)	0.0156 (5)	0.0162 (5)	0.0000 (4)	0.0076 (4)	-0.0020 (4)
C8	0.0165 (6)	0.0160 (6)	0.0169 (5)	-0.0005 (4)	0.0046 (5)	-0.0014 (4)
C11	0.0191 (6)	0.0139 (5)	0.0195 (6)	0.0006 (4)	0.0106 (5)	-0.0009 (4)
C6	0.0182 (7)	0.0156 (6)	0.0236 (6)	0.0009 (5)	0.0087 (5)	-0.0017 (5)
C3	0.0201 (6)	0.0130 (5)	0.0161 (5)	0.0010 (4)	0.0078 (5)	0.0000 (4)
C5	0.0163 (7)	0.0195 (6)	0.0252 (6)	-0.0023 (5)	0.0092 (5)	-0.0012 (5)
C4	0.0211 (7)	0.0142 (5)	0.0201 (6)	-0.0032 (5)	0.0091 (5)	-0.0012 (4)
C12	0.0215 (7)	0.0157 (5)	0.0209 (6)	-0.0037 (5)	0.0115 (5)	-0.0043 (4)

*Geometric parameters (Å, °)*

O3—C7	1.3626 (17)	C2—C3	1.3741 (19)
O3—C15	1.3717 (16)	C13—C12	1.3950 (19)
O4—C9	1.2233 (16)	C1—C6	1.390 (2)
O1—N1	1.2224 (15)	C11—C12	1.377 (2)
O2—N1	1.2208 (15)	C6—C5	1.380 (2)
C7—C1	1.4690 (19)	C3—C4	1.383 (2)
C7—C8	1.3373 (18)	C5—C4	1.3765 (19)
C10—C9	1.4722 (19)	C14—H14	0.958 (15)
C10—C15	1.3877 (18)	C13—H13	0.944 (16)
C10—C11	1.3950 (19)	C11—H11	0.979 (15)
C9—C8	1.4415 (19)	C6—H6	0.964 (17)
C15—C14	1.3932 (19)	C3—H3	0.933 (17)
C14—C13	1.3736 (19)	C5—H5	0.953 (17)
C2—C1	1.3911 (18)	C4—H4	0.971 (16)
C2—N1	1.467 (2)	C12—H12	0.957 (16)
C7—O3—C15	118.38 (9)	C12—C11—C10	120.95 (12)
O3—C7—C1	112.72 (10)	C5—C6—C1	121.21 (12)
C8—C7—O3	124.33 (11)	C2—C3—C4	119.18 (11)
C8—C7—C1	122.86 (12)	C4—C5—C6	119.85 (14)
C15—C10—C9	120.66 (11)	C5—C4—C3	120.30 (12)
C15—C10—C11	117.36 (12)	C11—C12—C13	120.55 (12)
C11—C10—C9	121.98 (11)	C13—C14—H14	121.7 (9)
O4—C9—C10	123.36 (12)	C15—C14—H14	119.2 (9)
O4—C9—C8	122.56 (13)	C14—C13—H13	119.0 (9)
C8—C9—C10	114.08 (10)	C12—C13—H13	121.3 (9)
O3—C15—C10	121.31 (12)	C7—C8—H8	119.2 (9)
O3—C15—C14	116.32 (10)	C9—C8—H8	119.7 (9)
C10—C15—C14	122.37 (11)	C12—C11—H11	121.7 (9)
C13—C14—C15	119.06 (11)	C10—C11—H11	117.3 (9)
C1—C2—N1	121.28 (11)	C5—C6—H6	119.4 (10)

C3—C2—C1	121.98 (13)	C1—C6—H6	119.4 (10)
C3—C2—N1	116.64 (11)	C2—C3—H3	119.6 (10)
C14—C13—C12	119.70 (13)	C4—C3—H3	121.1 (10)
C2—C1—C7	124.49 (12)	C4—C5—H5	119.8 (9)
C6—C1—C7	118.02 (11)	C6—C5—H5	120.4 (9)
C6—C1—C2	117.47 (11)	C5—C4—H4	120.9 (10)
O1—N1—C2	117.98 (11)	C3—C4—H4	118.8 (10)
O2—N1—O1	123.63 (12)	C11—C12—H12	120.5 (9)
O2—N1—C2	118.35 (10)	C13—C12—H12	118.9 (9)
C7—C8—C9	121.12 (12)		
O3—C7—C1—C2	52.15 (16)	C2—C1—C6—C5	0.11 (19)
O3—C7—C1—C6	-126.13 (13)	C2—C3—C4—C5	0.21 (18)
O3—C7—C8—C9	-1.1 (2)	C1—C7—C8—C9	-177.40 (11)
O3—C15—C14—C13	-178.69 (11)	C1—C2—N1—O1	-152.23 (12)
O4—C9—C8—C7	178.00 (12)	C1—C2—N1—O2	29.74 (16)
C7—O3—C15—C10	-2.47 (17)	C1—C2—C3—C4	-0.34 (18)
C7—O3—C15—C14	177.77 (10)	C1—C6—C5—C4	-0.2 (2)
C7—C1—C6—C5	178.51 (12)	N1—C2—C1—C7	5.50 (17)
C10—C9—C8—C7	-1.92 (18)	N1—C2—C1—C6	-176.22 (10)
C10—C15—C14—C13	1.55 (19)	N1—C2—C3—C4	176.21 (10)
C10—C11—C12—C13	0.61 (19)	C8—C7—C1—C2	-131.15 (14)
C9—C10—C15—O3	-0.57 (18)	C8—C7—C1—C6	50.57 (18)
C9—C10—C15—C14	179.18 (11)	C11—C10—C9—O4	3.2 (2)
C9—C10—C11—C12	179.73 (11)	C11—C10—C9—C8	-176.84 (11)
C15—O3—C7—C1	-179.96 (10)	C11—C10—C15—O3	178.98 (11)
C15—O3—C7—C8	3.39 (18)	C11—C10—C15—C14	-1.27 (18)
C15—C10—C9—O4	-177.23 (12)	C6—C5—C4—C3	0.07 (19)
C15—C10—C9—C8	2.69 (17)	C3—C2—C1—C7	-178.11 (11)
C15—C10—C11—C12	0.18 (18)	C3—C2—C1—C6	0.18 (18)
C15—C14—C13—C12	-0.71 (19)	C3—C2—N1—O1	31.19 (15)
C14—C13—C12—C11	-0.33 (19)	C3—C2—N1—O2	-146.84 (12)

*Hydrogen-bond geometry (Å, °)*

<i>D</i> —H... <i>A</i>	<i>D</i> —H	H... <i>A</i>	<i>D</i> ... <i>A</i>	<i>D</i> —H... <i>A</i>
C3—H3...O4 <sup>i</sup>	0.933 (17)	2.675 (16)	3.198 (3)	116.1 (12)
C4—H4...O4 <sup>i</sup>	0.971 (16)	2.446 (16)	3.109 (3)	125.3 (12)

Symmetry code: (i)  $-x+1, y+1/2, -z+5/2$ .