



# Crystal structure of metronidazolium tetra- chloridoaurate(III)

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Canada**Keywords:** crystal structure; gold; metronidazole; flagyl; tetrachloridoaurate(III); O—H...Cl hydrogen bonding**CCDC reference:** 1404845**Supporting information:** this article has supporting information at journals.iucr.org/e

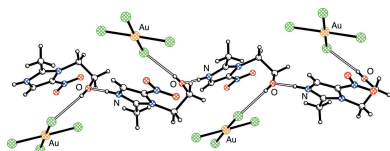
Metronidazole (MET) [systematic names: 1-(2-hydroxyethyl)-2-methyl-5-nitro-1*H*-imidazole and 2-(2-methyl-5-nitro-1*H*-imidazol-1-yl)ethanol] is a medication that is used to treat infections from a variety of anaerobic organisms. As with other imidazole derivatives, metronidazole is also susceptible to protonation. However, there are few reports of the structures of metronidazolium derivatives. In the title compound, (C<sub>6</sub>H<sub>10</sub>N<sub>3</sub>O<sub>3</sub>)[AuCl<sub>4</sub>] [systematic name: 1-(2-hydroxyethyl)-2-methyl-5-nitro-1*H*-imidazol-3-ium tetrachloridoaurate(III)], the asymmetric unit consists of a metronidazolium cation, [H(MET)]<sup>+</sup>, and a tetrachloridoaurate(III) anion, [AuCl<sub>4</sub>]<sup>−</sup>, in which the Au<sup>III</sup> ion is in a slightly distorted square-planar coordination environment. In the cation, the nitro group is essentially coplanar with the imidazole ring, as indicated by an O=C—N—C=C torsion angle of −0.2 (4)°, while the hydroxyethyl group is in a coiled conformation, with an O(H)—C—C—N torsion angle of 62.3 (3)°. In the crystal, the anion and cation are linked by an intermolecular O—H...Cl hydrogen bond. In addition, the N—H group of the metronidazolium ion serves as a hydrogen-bond donor to the O atom of the hydroxyethyl group of a symmetry-related molecule, leading to the formation of chains along [010].

## 1. Chemical context

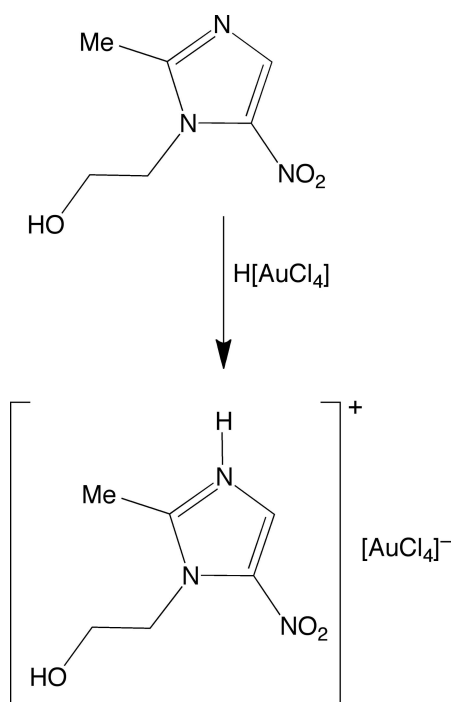
Metronidazole (MET), marketed as flagyl, and also known by the systematic names 1-(2-hydroxyethyl)-2-methyl-5-nitro-1*H*-imidazole and 2-(2-methyl-5-nitro-1*H*-imidazol-1-yl)ethanol, is a medication that has been used for the treatment of parasitic infections, such as trichomoniasis, amoebiasis and giardiasis, and is also effective against anaerobic bacteria (Freeman *et al.*, 1997; Miljkovic *et al.*, 2014; Soares *et al.*, 2012; Samuelson, 1999; Lofmark *et al.*, 2010; Contreras *et al.*, 2009). Metronidazole possesses a variety of functional groups, and the two-coordinate nitrogen atom of the imidazole ring has been shown to be an effective ligand for a variety of metals (Contreras *et al.*, 2009). This nitrogen atom is also susceptible to protonation, but there are few structures of metronidazolium derivatives reported in the literature (Yang, 2008; Wang *et al.*, 2010). We describe herein the structure of metronidazolium tetrachloridoaurate(III), which is obtained by the addition of MET to H[AuCl<sub>4</sub>].

## 2. Structural commentary

The asymmetric unit of [H(MET)][AuCl<sub>4</sub>] consists of a metronidazolium cation, [H(MET)]<sup>+</sup>, hydrogen-bonded to a square-planar tetrachloridoaurate(III) anion, [AuCl<sub>4</sub>]<sup>−</sup>, by an O—H...Cl hydrogen bond as illustrated in Fig. 1. The O3...Cl3 distance of 3.169 (2) Å is comparable to the values



in other tetrachloridoaurate(III) derivatives that exhibit O—H...Cl hydrogen bonds. As an illustration, bis{2-[(2-hydroxyethyl)iminomethyl]phenolato}gold(III) tetrachloridoaurate(III) possesses an O—H...Cl hydrogen bond between a hydroxyethyl group and  $[\text{AuCl}_4]^-$ , with an O(H)...Cl distance of 3.365 Å (Nockemann *et al.*, 2007). For further reference, the average O...Cl distance in compounds that have O—H...Cl interactions is 3.196 (3) Å (Steiner, 2002). The nitro group is almost coplanar with the imidazole ring, as indicated by an O1—N3—C2—C1 torsion angle of  $-0.2(4)^\circ$ , while the hydroxyethyl group exhibits an O3—C6—C5—N2 torsion angle of  $62.3(3)^\circ$ , describing a coiled conformation.



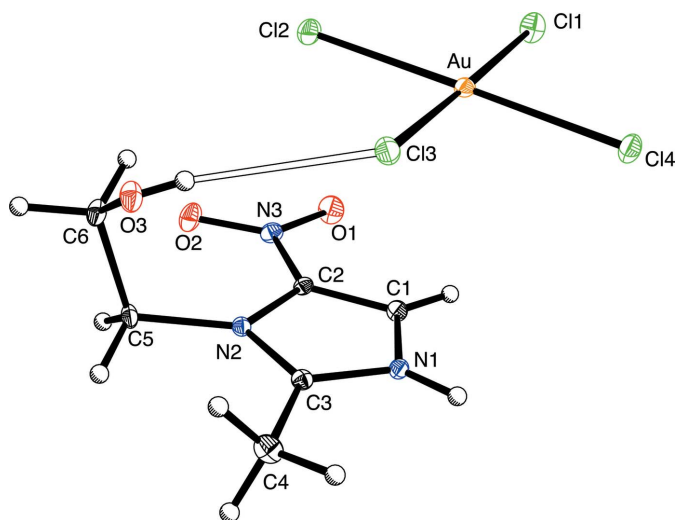
### 3. Supramolecular features

In the crystal, the N—H group of the metronidazolium ion serves as a hydrogen-bond donor to the oxygen atom of the hydroxyethyl group of a symmetry-related molecule, forming a chain along [010] in which each O—H group is O—H...Cl hydrogen bonded to a  $[\text{AuCl}_4]^-$  ion (Table 1 and Fig. 2). The N...O distance of 2.729 (3) Å associated with the hydrogen bond is comparable to that observed for metronidazole [2.816 (2) Å] (Blaton *et al.*, 1979; Galván-Tejada *et al.*, 2002). However, an important difference between the hydrogen

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

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
$\text{N1}-\text{H01}\cdots\text{O3}^i$	0.94 (4)	1.81 (4)	2.729 (3)	166 (3)
$\text{O3}-\text{H3}\cdots\text{Cl3}$	0.67 (4)	2.54 (4)	3.169 (2)	158 (4)

Symmetry code: (i)  $-x + \frac{3}{2}, y + \frac{1}{2}, -z + \frac{3}{2}$ .



**Figure 1**

The asymmetric unit of the title compound, shown with 20% probability displacement ellipsoids. The O3—H3...Cl3 hydrogen bond is shown as an open bond.

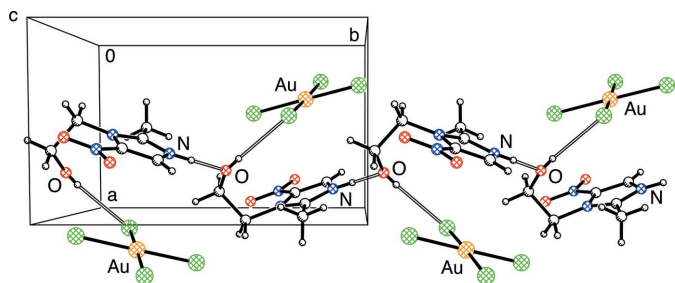
bonds in metronidazole and metronidazolium is that the alcohol O—H group is the hydrogen-bond donor for metronidazole (*i.e.* O—H...N), while the N—H group is the hydrogen-bond donor for metronidazolium (*i.e.* N—H...O).

### 4. Database survey

Metronidazolium derivatives that feature other counter-ions, *e.g.* 3-carboxy-4-hydroxybenzenesulfonate and perchlorate have been reported (Yang, 2008; Wang *et al.*, 2010), as have a variety of tetrachloridoaurate(III) complexes (Johnson & Steed, 1998; Pluzhnik-Gladyr *et al.*, 2014; Fazaeli *et al.*, 2010).

### 5. Synthesis and crystallization

Crystals of composition  $[\text{H}(\text{MET})][\text{AuCl}_4]$  were obtained by combining  $\text{HAuCl}_4 \cdot \text{H}_2\text{O}$  (0.12 mmol) with MET (0.20 mmol) in MeOH (2 ml), followed by evaporation of MeOH, and crystallization from  $\text{Et}_2\text{O}$ .



**Figure 2**

Part of the crystal structure showing a hydrogen-bonded chain (open bonds) along [010].

## 6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. H atoms bonded to C atoms were refined with a riding model, with C–H = 0.95–0.99 Å and  $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$  or  $1.5U_{\text{eq}}(\text{C}_{\text{methyl}})$ . H atoms bonded to N and O atoms were refined independently with isotropic displacement parameters.

## Acknowledgements

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## References

- Blaton, N. M., Peeters, O. M. & De Ranter, C. J. (1979). *Acta Cryst.* **B35**, 2465–2467.
- Bruker (2013). *APEX2*, *SAINT* and *SADABS*. Bruker AXS Inc., Madison, Wisconsin, USA.
- Contreras, R., Flores-Parra, A., Mijangos, E., Téllez, F., López-Sandoval, H. & Barba-Behrens, N. (2009). *Coord. Chem. Rev.* **253**, 1979–1999.
- Fazaeli, Y., Amani, V., Amini, M. M. & Khavasi, H. R. (2010). *Acta Cryst.* **E66**, m212.
- Freeman, C. D., Klutman, N. E. & Lamp, K. C. (1997). *Drugs*, **54**, 679–708.
- Galván-Tejada, N., Bernès, S., Castillo-Blum, S. E., Nöth, H., Vicente, R. & Barba-Behrens, N. (2002). *J. Inorg. Biochem.* **91**, 339–348.
- Johnson, K. & Steed, J. W. (1998). *Chem. Commun.* pp. 1479–1480.
- Lofmark, S., Edlund, C. & Nord, C. E. (2010). *Clin. Infect. Dis.* **50** (Suppl 1), S16–S23.
- Miljkovic, V., Arsic, B., Bojanic, Z., Nikolic, G., Nikolic, L. J., Lj., Kalicanin, B. & Savic, V. (2014). *Pharmazie*, **69**, 571–577.
- Nockemann, P., Van Hecke, K., Van Meervelt, L. & Binnemans, K. (2007). *Acta Cryst.* **E63**, m402–m404.
- Pluzhnik-Gladyr, S. M., Kravtsov, V. C., Fonari, M. S. & Kamalov, G. L. (2014). *Dalton Trans.* **43**, 7087–7095.
- Samuelson, J. (1999). *Antimicrob. Agents Chemother.* **43**, 1533–1541.
- Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.

Table 2

Experimental details.

Crystal data	
Chemical formula	(C <sub>6</sub> H <sub>10</sub> N <sub>3</sub> O <sub>3</sub> )[AuCl <sub>4</sub> ]
$M_r$	510.94
Crystal system, space group	Monoclinic, $P2_1/n$
Temperature (K)	130
$a, b, c$ (Å)	7.324 (2), 11.972 (4), 15.667 (5)
$\beta$ (°)	94.384 (4)
$V$ (Å <sup>3</sup> )	1369.6 (8)
$Z$	4
Radiation type	Mo $K\alpha$
$\mu$ (mm <sup>-1</sup> )	11.52
Crystal size (mm)	0.23 × 0.04 × 0.02
Data collection	
Diffractometer	Bruker APEXII CCD
Absorption correction	Multi-scan ( <i>SADABS</i> ; Bruker, 2013)
$T_{\text{min}}, T_{\text{max}}$	0.426, 0.746
No. of measured, independent and observed [ $I > 2\sigma(I)$ ] reflections	22024, 4214, 3673
$R_{\text{int}}$	0.041
$(\sin \theta/\lambda)_{\text{max}}$ (Å <sup>-1</sup> )	0.718
Refinement	
$R[F^2 > 2\sigma(F^2)], wR(F^2), S$	0.021, 0.045, 1.16
No. of reflections	4214
No. of parameters	163
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{\text{max}}, \Delta\rho_{\text{min}}$ (e Å <sup>-3</sup> )	1.30, -1.22

Computer programs: *APEX2* and *SAINT* (Bruker, 2013), *SHELXS97* and *SHELXL* (Sheldrick, 2008), *SHELXL2014* (Sheldrick, 2015).

- Sheldrick, G. M. (2015). *Acta Cryst.* **C71**, 3–8.
- Soares, G. M. S., Figueiredo, L. C., Faveri, M., Cortelli, S. C., Duarte, P. M. & Feres, M. (2012). *J. Appl. Oral Sci.* **20**, 295–309.
- Steiner, T. (2002). *Angew. Chem. Int. Ed.* **41**, 49–76.
- Wang, Y.-T., Chu, X.-L., Yan, S.-C. & Tang, G.-M. (2010). *Acta Cryst.* **E66**, o2647.
- Yang, B. (2008). *Acta Cryst.* **E64**, o1338–o1339.

## supporting information

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## Crystal structure of metronidazolium tetrachloridoaurate(III)

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### Computing details

Data collection: *APEX2* (Bruker, 2013); cell refinement: *SAINT* (Bruker, 2013); data reduction: *SAINT* (Bruker, 2013); program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL2014* (Sheldrick, 2015); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXTL* (Sheldrick, 2008).

### 1-(2-Hydroxyethyl)-2-methyl-5-nitro-1*H*-imidazol-3-ium tetrachloridoaurate(III)

#### Crystal data

(C<sub>6</sub>H<sub>10</sub>N<sub>3</sub>O<sub>3</sub>)[AuCl<sub>4</sub>]

$M_r = 510.94$

Monoclinic,  $P2_1/n$

$a = 7.324$  (2) Å

$b = 11.972$  (4) Å

$c = 15.667$  (5) Å

$\beta = 94.384$  (4)°

$V = 1369.6$  (8) Å<sup>3</sup>

$Z = 4$

$F(000) = 952$

$D_x = 2.478$  Mg m<sup>-3</sup>

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

Cell parameters from 9874 reflections

$\theta = 2.6$ – $30.6$ °

$\mu = 11.52$  mm<sup>-1</sup>

$T = 130$  K

Plate, yellow

$0.23 \times 0.04 \times 0.02$  mm

#### Data collection

Bruker APEXII CCD  
diffractometer

$\varphi$  and  $\omega$  scans

Absorption correction: multi-scan  
(*SADABS*; Bruker, 2013)

$T_{\min} = 0.426$ ,  $T_{\max} = 0.746$

22024 measured reflections

4214 independent reflections

3673 reflections with  $I > 2\sigma(I)$

$R_{\text{int}} = 0.041$

$\theta_{\max} = 30.7$ °,  $\theta_{\min} = 2.1$ °

$h = -10$ → $10$

$k = -17$ → $17$

$l = -22$ → $22$

#### Refinement

Refinement on  $F^2$

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)] = 0.021$

$wR(F^2) = 0.045$

$S = 1.16$

4214 reflections

163 parameters

0 restraints

Hydrogen site location: mixed

H atoms treated by a mixture of independent  
and constrained refinement

$w = 1/[\sigma^2(F_o^2) + (0.0129P)^2]$

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

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

$\Delta\rho_{\max} = 1.30$  e Å<sup>-3</sup>

$\Delta\rho_{\min} = -1.22$  e Å<sup>-3</sup>

*Special details*

**Geometry.** All e.s.d.'s (except the e.s.d. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell e.s.d.'s are taken into account individually in the estimation of e.s.d.'s in distances, angles and torsion angles; correlations between e.s.d.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell e.s.d.'s is used for estimating e.s.d.'s 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>	$U_{\text{iso}}^*/U_{\text{eq}}$
Au	0.36629 (2)	0.79983 (2)	0.58625 (2)	0.01868 (4)
Cl1	0.26070 (11)	0.84595 (7)	0.45047 (5)	0.03247 (17)
Cl2	0.44092 (10)	0.62541 (6)	0.54111 (5)	0.03012 (16)
Cl3	0.46029 (10)	0.75210 (6)	0.72389 (5)	0.02610 (15)
Cl4	0.29498 (10)	0.97418 (6)	0.63205 (5)	0.02831 (15)
O1	0.8047 (3)	0.7553 (2)	0.41611 (14)	0.0367 (5)
O2	0.9242 (3)	0.60835 (18)	0.47815 (14)	0.0331 (5)
O3	0.7450 (3)	0.55236 (18)	0.73360 (15)	0.0265 (5)
H3	0.684 (5)	0.591 (3)	0.719 (2)	0.042 (13)*
N1	0.8446 (3)	0.89061 (19)	0.65413 (15)	0.0175 (4)
H01	0.810 (5)	0.953 (3)	0.685 (2)	0.042 (10)*
N2	0.9387 (3)	0.72022 (17)	0.63739 (14)	0.0159 (4)
N3	0.8670 (3)	0.70319 (19)	0.47846 (15)	0.0223 (5)
C1	0.8127 (4)	0.8685 (2)	0.56913 (17)	0.0191 (5)
H1A	0.7604	0.9173	0.5261	0.023*
C2	0.8708 (3)	0.7626 (2)	0.55853 (17)	0.0158 (5)
C3	0.9200 (4)	0.8016 (2)	0.69521 (17)	0.0170 (5)
C4	0.9783 (4)	0.7982 (3)	0.78720 (19)	0.0272 (6)
H4A	0.9318	0.8643	0.8154	0.041*
H4B	1.1123	0.7972	0.7949	0.041*
H4C	0.9295	0.7307	0.8126	0.041*
C5	1.0107 (4)	0.6070 (2)	0.65912 (18)	0.0198 (5)
H5A	1.0863	0.6102	0.7142	0.024*
H5B	1.0904	0.5822	0.6145	0.024*
C6	0.8579 (4)	0.5230 (2)	0.66604 (18)	0.0227 (6)
H6A	0.7818	0.5199	0.6111	0.027*
H6B	0.9111	0.4479	0.6773	0.027*

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

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
Au	0.01490 (5)	0.01746 (6)	0.02409 (6)	-0.00147 (4)	0.00416 (4)	-0.00253 (4)
Cl1	0.0438 (4)	0.0304 (4)	0.0234 (4)	0.0042 (3)	0.0037 (3)	-0.0009 (3)
Cl2	0.0286 (4)	0.0222 (3)	0.0400 (4)	0.0024 (3)	0.0057 (3)	-0.0092 (3)
Cl3	0.0255 (3)	0.0251 (3)	0.0272 (4)	0.0036 (3)	-0.0008 (3)	-0.0012 (3)
Cl4	0.0360 (4)	0.0193 (3)	0.0292 (4)	0.0033 (3)	0.0002 (3)	-0.0038 (3)
O1	0.0516 (15)	0.0375 (13)	0.0193 (11)	0.0047 (11)	-0.0090 (10)	-0.0008 (10)
O2	0.0468 (14)	0.0221 (11)	0.0309 (12)	0.0056 (10)	0.0058 (10)	-0.0077 (9)
O3	0.0250 (11)	0.0233 (11)	0.0327 (13)	0.0053 (9)	0.0109 (9)	0.0075 (9)

N1	0.0172 (10)	0.0152 (10)	0.0203 (11)	-0.0003 (9)	0.0023 (9)	-0.0003 (9)
N2	0.0146 (10)	0.0157 (10)	0.0175 (11)	0.0000 (8)	0.0021 (8)	0.0014 (8)
N3	0.0253 (12)	0.0233 (12)	0.0181 (12)	-0.0032 (10)	0.0010 (9)	-0.0019 (9)
C1	0.0217 (13)	0.0198 (13)	0.0157 (12)	0.0003 (10)	-0.0001 (10)	0.0012 (10)
C2	0.0184 (12)	0.0152 (11)	0.0138 (12)	-0.0023 (10)	0.0008 (9)	-0.0006 (9)
C3	0.0146 (12)	0.0188 (12)	0.0180 (13)	-0.0012 (10)	0.0038 (10)	0.0002 (10)
C4	0.0292 (16)	0.0355 (17)	0.0167 (14)	0.0031 (13)	0.0011 (12)	-0.0009 (12)
C5	0.0181 (12)	0.0170 (12)	0.0245 (14)	0.0051 (10)	0.0026 (10)	0.0064 (10)
C6	0.0254 (14)	0.0164 (13)	0.0271 (15)	0.0029 (11)	0.0072 (12)	0.0046 (11)

*Geometric parameters (Å, °)*

Au—C11	2.2752 (10)	N2—C5	1.485 (3)
Au—C14	2.2807 (9)	N3—C2	1.441 (3)
Au—C12	2.2844 (9)	C1—C2	1.351 (4)
Au—C13	2.2855 (10)	C1—H1A	0.9500
O1—N3	1.218 (3)	C3—C4	1.472 (4)
O2—N3	1.210 (3)	C4—H4A	0.9800
O3—C6	1.436 (3)	C4—H4B	0.9800
O3—H3	0.67 (4)	C4—H4C	0.9800
N1—C3	1.341 (3)	C5—C6	1.515 (4)
N1—C1	1.360 (3)	C5—H5A	0.9900
N1—H01	0.94 (4)	C5—H5B	0.9900
N2—C3	1.345 (3)	C6—H6A	0.9900
N2—C2	1.392 (3)	C6—H6B	0.9900
C11—Au—C14	90.14 (3)	N1—C3—N2	108.2 (2)
C11—Au—C12	90.27 (3)	N1—C3—C4	124.7 (2)
C14—Au—C12	179.36 (3)	N2—C3—C4	127.0 (2)
C11—Au—C13	177.66 (3)	C3—C4—H4A	109.5
C14—Au—C13	89.52 (3)	C3—C4—H4B	109.5
C12—Au—C13	90.09 (3)	H4A—C4—H4B	109.5
C6—O3—H3	108 (3)	C3—C4—H4C	109.5
C3—N1—C1	110.4 (2)	H4A—C4—H4C	109.5
C3—N1—H01	120 (2)	H4B—C4—H4C	109.5
C1—N1—H01	129 (2)	N2—C5—C6	111.8 (2)
C3—N2—C2	106.6 (2)	N2—C5—H5A	109.3
C3—N2—C5	124.1 (2)	C6—C5—H5A	109.3
C2—N2—C5	129.3 (2)	N2—C5—H5B	109.3
O2—N3—O1	125.9 (3)	C6—C5—H5B	109.3
O2—N3—C2	118.9 (2)	H5A—C5—H5B	107.9
O1—N3—C2	115.2 (2)	O3—C6—C5	111.1 (2)
C2—C1—N1	105.7 (2)	O3—C6—H6A	109.4
C2—C1—H1A	127.1	C5—C6—H6A	109.4
N1—C1—H1A	127.1	O3—C6—H6B	109.4
C1—C2—N2	109.1 (2)	C5—C6—H6B	109.4
C1—C2—N3	125.8 (2)	H6A—C6—H6B	108.0
N2—C2—N3	125.1 (2)		

*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>
N1—H01···O3 <sup>i</sup>	0.94 (4)	1.81 (4)	2.729 (3)	166 (3)
O3—H3···Cl3	0.67 (4)	2.54 (4)	3.169 (2)	158 (4)

Symmetry code: (i)  $-x+3/2, y+1/2, -z+3/2$ .