

Creatininium bis(pyridine-2,6-dicarboxylato)chromate(III) pyridine-2,6-dicarboxylic acid hexahydrate

Hossein Aghabozorg,^a Zohreh Derikvand,^a Marilyn M. Olmstead^{b*} and Jafar Attar Gharamaleki^a

^aFaculty of Chemistry, Tarbiat Moallem University, Tehran, Iran, and ^bDepartment of Chemistry, University of California, One Shields Avenue, Davis, CA 95616-5292, USA

Correspondence e-mail: olmstead@chem.ucdavis.edu

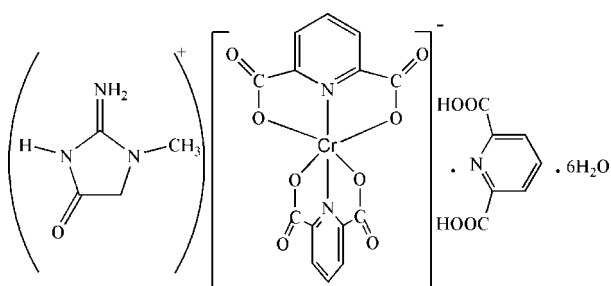
Received 25 August 2008; accepted 28 August 2008

Key indicators: single-crystal X-ray study; $T = 90$ K; mean $\sigma(\text{C}-\text{C}) = 0.002$ Å; R factor = 0.028; wR factor = 0.077; data-to-parameter ratio = 12.4.

The title compound, $(\text{C}_4\text{H}_8\text{N}_3\text{O})[\text{Cr}(\text{C}_7\text{H}_3\text{NO}_4)_2] \cdot \text{C}_7\text{H}_5\text{NO}_4 \cdot 6\text{H}_2\text{O}$, was obtained by the reaction of $\text{Cr}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ with pyridine-2,6-dicarboxylic acid (pydcH_2) and creatinine (creat) in aqueous solution (molar ratio 1:2:2). The cation is a protonated creatinine (creatH^+) while the anion is a bis- pydc^{2-} Cr^{III} complex. The Cr^{III} is coordinated by four oxygen and two nitrogen atoms of two (pydc)²⁻ groups and has a distorted octahedral coordination environment. The structure also contains a neutral molecule of pydcH_2 that is hydrogen bonded to the creatH^+ and six molecules of water. Extensive intermolecular interactions, including seventeen classical hydrogen bonds, two weak $\text{C}-\text{H} \cdots \text{O}$ bonds, and $\text{C}-\text{O} \cdots \pi$ stacking interactions, with $\text{O} \cdots$ centroid distances of 3.211 (13) and 3.300 (12) Å, connect the various components in the crystal structure.

Related literature

For a recent review on proton-transfer compounds and their structures, see: Aghabozorg, Manteghi *et al.* (2008). For related creatininium structures, see: Aghabozorg, Ramezani-pour *et al.* (2008); Moghimi *et al.* (2004, 2005).



Experimental

Crystal data

$(\text{C}_4\text{H}_8\text{N}_3\text{O})[\text{Cr}(\text{C}_7\text{H}_3\text{NO}_4)_2] \cdot \text{C}_7\text{H}_5\text{NO}_4 \cdot 6\text{H}_2\text{O}$
 $M_r = 771.56$
 Triclinic, $P\bar{1}$
 $a = 9.0860$ (5) Å
 $b = 13.6274$ (8) Å
 $c = 14.7301$ (8) Å
 $\alpha = 65.481$ (2)°
 $\beta = 74.685$ (2)°
 $\gamma = 77.644$ (2)°
 $V = 1589.10$ (15) Å³
 $Z = 2$
 Mo $K\alpha$ radiation
 $\mu = 0.46$ mm⁻¹
 $T = 90$ (2) K
 $0.33 \times 0.32 \times 0.10$ mm

Data collection

Bruker SMART APEXII diffractometer
 Absorption correction: multi-scan (*SADABS*; Sheldrick, 1996)
 $T_{\text{min}} = 0.864$, $T_{\text{max}} = 0.956$
 20278 measured reflections
 7266 independent reflections
 6654 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.019$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.028$
 $wR(F^2) = 0.077$
 $S = 1.01$
 7266 reflections
 584 parameters
 All H-atom parameters refined
 $\Delta\rho_{\text{max}} = 0.41$ e Å⁻³
 $\Delta\rho_{\text{min}} = -0.46$ e Å⁻³

Table 1

Selected geometric parameters (Å, °).

Cr1—N1	1.9733 (11)	Cr1—O3	1.9942 (10)
Cr1—N2	1.9769 (11)	Cr1—O1	1.9947 (9)
Cr1—O5	1.9842 (9)	Cr1—O7	1.9974 (9)
N1—Cr1—N2	172.88 (4)	N2—Cr1—O1	105.30 (4)
N1—Cr1—O5	106.16 (4)	O5—Cr1—O1	93.27 (4)
N2—Cr1—O5	79.39 (4)	O3—Cr1—O1	157.91 (4)
N1—Cr1—O3	78.84 (4)	N1—Cr1—O7	96.08 (4)
N2—Cr1—O3	96.78 (4)	N2—Cr1—O7	78.42 (4)
O5—Cr1—O3	91.39 (4)	O5—Cr1—O7	157.76 (4)
N1—Cr1—O1	79.13 (4)	O3—Cr1—O7	92.80 (4)

Table 2

Hydrogen-bond geometry (Å, °).

$D-\text{H} \cdots A$	$D-\text{H}$	$\text{H} \cdots A$	$D \cdots A$	$D-\text{H} \cdots A$
N4—H4A ⁱ ···O11	0.83 (2)	2.08 (2)	2.8934 (16)	167.3 (19)
N4—H4B ⁱ ···O9	0.85 (2)	1.98 (2)	2.8343 (16)	178.5 (8)
O10—H10A ⁱ ···O15	0.91 (2)	1.63 (2)	2.5382 (15)	176 (2)
O14—H14B ⁱ ···O8	0.83 (2)	2.01 (2)	2.8255 (16)	169 (2)
O15—H15A ⁱ ···O14	0.86 (2)	1.82 (2)	2.6718 (17)	168 (2)
O16—H16A ⁱ ···O4	0.78 (2)	2.07 (2)	2.8006 (15)	156 (2)
O17—H17B ⁱ ···O3	0.79 (2)	1.99 (2)	2.7758 (14)	172 (2)
O18—H18A ⁱ ···O2	0.84 (2)	1.98 (2)	2.7927 (15)	162 (2)
O19—H19A ⁱ ···O6	0.85 (3)	1.95 (3)	2.7763 (15)	164 (2)
N5—H5A ⁱ ···O16 ^j	0.85 (2)	1.87 (2)	2.7175 (16)	175 (2)
O12—H12A ⁱ ···O17 ⁱⁱ	0.91 (2)	1.66 (3)	2.5720 (14)	176 (2)
O14—H14A ⁱ ···O18 ⁱⁱⁱ	0.79 (3)	1.98 (3)	2.7546 (17)	167 (2)
O15—H15B ⁱ ···O7 ⁱⁱⁱ	0.77 (2)	2.16 (2)	2.9105 (15)	162 (2)
O16—H16B ⁱ ···O9 ^{iv}	0.83 (3)	2.05 (3)	2.8083 (15)	152 (2)
O17—H17A ⁱ ···O19 ^v	0.85 (2)	1.84 (2)	2.6916 (16)	178 (2)
O18—H18B ⁱ ···O8 ^{vi}	0.84 (3)	2.12 (3)	2.9558 (15)	171 (2)
O19—H19B ⁱ ···O13 ^{vii}	0.81 (2)	2.17 (2)	2.9531 (16)	162 (2)
C5—H5 ⁱ ···O7 ^{viii}	0.94 (2)	2.392 (19)	3.251 (2)	152.2 (15)
C10—H10 ⁱ ···O6 ⁱⁱ	0.929 (19)	2.283 (19)	3.0919 (17)	145.4 (18)

Symmetry codes: (i) $x, y + 1, z$; (ii) $-x + 1, -y + 1, -z$; (iii) $-x, -y + 1, -z + 1$; (iv) $x, y - 1, z$; (v) $x - 1, y, z$; (vi) $x + 1, y, z$; (vii) $x + 1, y - 1, z$; (viii) $-x, -y, -z + 1$.

Data collection: *APEX2* (Bruker, 2007); cell refinement: *SAINT* (Bruker, 2007); data reduction: *SAINT*; program(s) used to solve

structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXL97*.

The authors thank Tarbiat Moallem University for financial support and the University of California, Davis for the purchase of the X-ray diffractometer.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: SJ2533).

References

- Aghabozorg, H., Manteghi, F. & Sheshmani, S. (2008). *J. Iran. Chem. Soc.* **5**, 184–227.
- Aghabozorg, H., Ramezanipour, F., Soleimannejad, J., Sharif, M. A., Shokrollahi, A., Shamsipur, M., Moghimi, A., Attar Gharamaleki, J., Lippolis, V. & Blake, A. J. (2008). *Polish J. Chem.* **82**, 487–507.
- Bruker (2007). *APEX2* and *SAINT*. Bruker AXS Inc., Madison, Wisconsin, USA.
- Moghimi, A., Sharif, M. A. & Aghabozorg, H. (2004). *Acta Cryst.* **E60**, o1790–o1792.
- Moghimi, A., Sharif, M. A., Shokrollahi, A., Shamsipur, M. & Aghabozorg, H. (2005). *Z. Anorg. Allg. Chem.* **631**, 902–908.
- Sheldrick, G. M. (1996). *SADABS*. University of Göttingen, Germany.
- Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.

supplementary materials

Acta Cryst. (2008). E64, m1234-m1235 [doi:10.1107/S1600536808027700]

Creatinium bis(pyridine-2,6-dicarboxylato)chromate(III) pyridine-2,6-dicarboxylic acid hexahydrate

H. Aghabozorg, Z. Derikvand, M. M. Olmstead and J. Attar Gharamaleki

Comment

We have previously reported several structures that contain creatinine, pyridine-2,6-dicarboxylic acid and various metals such as: (creatH)(pydcH)H₂O (Moghimi *et al.*, 2004), (creatH)₂[Bi(pydc)₂]₂·4H₂O (Moghimi *et al.*, 2005) and (creatH)[Zn(pydc)(pydcH)]·4H₂O (Aghabozorg, Ramezanipour *et al.*, 2008). For more details and related literature see our recent review article (Aghabozorg, Manteghi *et al.*, 2008).

The asymmetric unit of the title compound Fig. 1, contains a [Cr(pydc)₂]⁻ anion, a (creatH)⁺ cation, a pydcH₂ molecule and six uncoordinated water molecules. In the anions, Cr^{III} has a N₂O₄ donor set with normal distances and angles (Table 1). The two (pydc)²⁻ planes form a dihedral angle of 89.64 (1)°, and thus are virtually perpendicular to each other.

As depicted in Fig. 2, the creatinium ion is evidently strongly associated with the neutral molecule of pydcH₂ through two N—H···O hydrogen bonds and the two units are bridged by one of the water molecules. There are also two rather strong hydrogen bonds between the two carboxylic acid OH groups of the pydcH₂ and molecules of water. The relevant O···O distances are 2.5382 (15) and 2.5720 (14) Å. This structural arrangement between cation and neutral pydcH₂ markedly differs from the arrangement in the ion pair creatH⁺pydcH⁻ previously reported in the structure of the creatH⁺pydcH⁻ monohydrate (Moghimi *et al.*, 2004). In the latter structure, only one intramolecular hydrogen bond is formed between one of the NH₂ H atoms and the carboxylate group. The other NH₂ H atom is hydrogen bonded to the molecule of water.

In addition to numerous strong hydrogen bonds, intermolecular interactions in the the title compound include weaker C—H···O interactions which link the anions together, shown in Fig. 3 and Table 2, as well as C—O···π stacking interactions between CO groups of carboxylate fragments and aromatic rings of (pydc)²⁻ with O···centroid distances of 3.211 (13) and 3.300 (12) Å (Fig. 4).

Experimental

The reaction between pyridine-2,6-dicarboxylic acid (100 mg, 1 mmol) in 10 ml water, creatinine (creat) (110 mg, 1 mmol) in 20 ml water and chromium(III) nitrate nonahydrate (100 mg, 0.5 mmol) in 5 ml water at 2:2:1 molar ratio gave violet crystals after slow evaporation of the solvent at the room temperature.

Refinement

All H atoms were freely refined with isotropic thermal parameters.

Figures

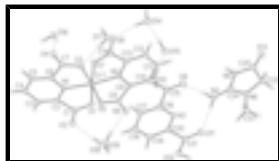


Fig. 1. A view of the asymmetric unit of the title compound with the atom numbering scheme. Displacement ellipsoids are drawn at the 50% probability level. Hydrogen bonds are shown as dashed lines.

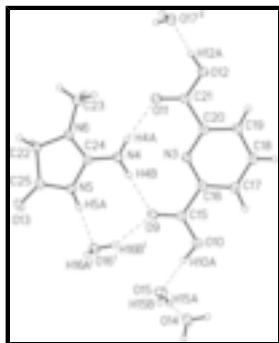


Fig. 2. Details of the hydrogen bonding between the creatininium cation, the neutral pydcH₂ molecule and the uncoordinated water molecules. Symmetry codes: (i) $x, 1 + y, z$, (ii) $1 - x, 1 - y, -z$.

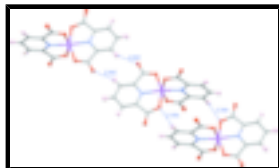


Fig. 3. One dimensional chains of [Cr(pydc)₂]⁻ anions that are generated by C–H...O hydrogen bonds.

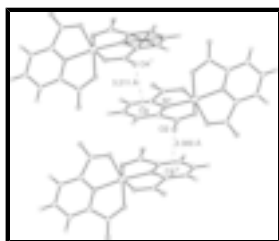


Fig. 4. C–O... π stacking interactions in the title compound. Distances are reported between O atoms and the centroid (Cg) of the N1/C2–C6 aromatic ring. Symmetry codes: (i) $1 - x, -y, 1 - z$, (ii) $(-x, -y, 1 - z)$.

Creatininium bis(pyridine-2,6-dicarboxylato)chromate(III) pyridine-2,6-dicarboxylic acid hexahydrate

Crystal data

(C₄H₈N₃O)[Cr(C₇H₃NO₄)₂]·C₇H₅NO₄·6H₂O

$M_r = 771.56$

Triclinic, $P\bar{1}$

Hall symbol: $-P\ 1$

$a = 9.0860$ (5) Å

$b = 13.6274$ (8) Å

$c = 14.7301$ (8) Å

$\alpha = 65.481$ (2)°

$\beta = 74.685$ (2)°

$\gamma = 77.644$ (2)°

$V = 1589.10$ (15) Å³

$Z = 2$

$F_{000} = 798$

$D_x = 1.612$ Mg m⁻³

Mo $K\alpha$ radiation

$\lambda = 0.71073$ Å

Cell parameters from 6379 reflections

$\theta = 3.0$ – 31.5 °

$\mu = 0.46$ mm⁻¹

$T = 90$ (2) K

Plate, violet

$0.33 \times 0.32 \times 0.10$ mm

Data collection

Bruker SMART APEXII diffractometer	7266 independent reflections
Radiation source: fine-focus sealed tube	6654 reflections with $I > 2\sigma(I)$
Monochromator: graphite	$R_{\text{int}} = 0.019$
Detector resolution: 8.3 pixels mm^{-1}	$\theta_{\text{max}} = 27.5^\circ$
$T = 90(2)$ K	$\theta_{\text{min}} = 2.7^\circ$
ω scans	$h = -11 \rightarrow 11$
Absorption correction: multi-scan (SADABS; Sheldrick, 1996)	$k = -17 \rightarrow 17$
$T_{\text{min}} = 0.864$, $T_{\text{max}} = 0.956$	$l = -19 \rightarrow 19$
20278 measured reflections	

Refinement

Refinement on F^2	Secondary atom site location: difference Fourier map
Least-squares matrix: full	Hydrogen site location: inferred from neighbouring sites
$R[F^2 > 2\sigma(F^2)] = 0.028$	All H-atom parameters refined
$wR(F^2) = 0.077$	$w = 1/[\sigma^2(F_o^2) + (0.0385P)^2 + 0.9325P]$
$S = 1.02$	where $P = (F_o^2 + 2F_c^2)/3$
7266 reflections	$(\Delta/\sigma)_{\text{max}} = 0.001$
584 parameters	$\Delta\rho_{\text{max}} = 0.41 \text{ e } \text{\AA}^{-3}$
Primary atom site location: structure-invariant direct methods	$\Delta\rho_{\text{min}} = -0.45 \text{ e } \text{\AA}^{-3}$
	Extinction correction: none

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.

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 $F^2 > \sigma(F^2)$ 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 (\AA^2)

	x	y	z	$U_{\text{iso}}^*/U_{\text{eq}}$
Cr1	0.25265 (2)	0.216209 (16)	0.359634 (15)	0.01061 (6)
O1	0.36533 (10)	0.23292 (7)	0.45071 (7)	0.01405 (18)
O2	0.46030 (11)	0.14296 (8)	0.59416 (7)	0.0175 (2)
O3	0.15065 (11)	0.14097 (8)	0.30655 (7)	0.01496 (19)

supplementary materials

O4	0.07696 (12)	-0.01935 (8)	0.33737 (8)	0.0200 (2)
O5	0.43892 (10)	0.22188 (7)	0.25150 (7)	0.01432 (19)
O6	0.55182 (11)	0.32381 (8)	0.09398 (7)	0.0181 (2)
O7	0.05282 (10)	0.26969 (7)	0.43082 (7)	0.01383 (18)
O8	-0.14469 (11)	0.40222 (8)	0.41140 (8)	0.0189 (2)
N1	0.26631 (12)	0.06706 (9)	0.46327 (8)	0.0116 (2)
N2	0.21136 (12)	0.36451 (9)	0.25887 (8)	0.0120 (2)
C1	0.38970 (14)	0.14811 (10)	0.53165 (10)	0.0130 (2)
C2	0.32378 (14)	0.04896 (10)	0.54427 (10)	0.0126 (2)
C3	0.31731 (15)	-0.05060 (11)	0.62527 (10)	0.0154 (3)
H3	0.3540 (19)	-0.0619 (13)	0.6818 (13)	0.016 (4)*
C4	0.25291 (15)	-0.13028 (11)	0.61755 (10)	0.0166 (3)
H4	0.2463 (19)	-0.1981 (14)	0.6707 (13)	0.017 (4)*
C5	0.19581 (15)	-0.11032 (11)	0.53165 (11)	0.0156 (3)
H5	0.150 (2)	-0.1614 (14)	0.5244 (13)	0.020 (4)*
C6	0.20238 (14)	-0.00750 (10)	0.45504 (10)	0.0131 (2)
C7	0.13731 (14)	0.03755 (11)	0.35899 (10)	0.0140 (2)
C8	0.44766 (15)	0.30926 (10)	0.16929 (10)	0.0133 (2)
C9	0.31394 (14)	0.39718 (10)	0.17162 (10)	0.0128 (2)
C10	0.28865 (16)	0.49990 (11)	0.09810 (10)	0.0154 (3)
H10	0.357 (2)	0.5255 (15)	0.0365 (14)	0.023 (4)*
C11	0.15425 (16)	0.56585 (11)	0.11809 (10)	0.0164 (3)
H11	0.135 (2)	0.6360 (15)	0.0687 (14)	0.023 (4)*
C12	0.04727 (15)	0.52912 (11)	0.20890 (10)	0.0152 (3)
H12	-0.0436 (19)	0.5732 (14)	0.2231 (12)	0.015 (4)*
C13	0.08062 (14)	0.42558 (10)	0.27889 (10)	0.0127 (2)
C14	-0.01527 (15)	0.36454 (10)	0.38121 (10)	0.0134 (2)
O13	0.05039 (12)	1.18680 (8)	-0.06791 (8)	0.0204 (2)
N4	0.39073 (15)	0.87378 (10)	0.02195 (10)	0.0175 (2)
H4A	0.476 (2)	0.8454 (16)	0.0006 (15)	0.029 (5)*
H4B	0.340 (2)	0.8382 (16)	0.0802 (16)	0.028 (5)*
N5	0.19415 (13)	1.02123 (9)	-0.00184 (9)	0.0156 (2)
H5A	0.140 (2)	0.9944 (16)	0.0570 (16)	0.032 (5)*
N6	0.39959 (13)	1.03426 (9)	-0.12569 (9)	0.0156 (2)
C22	0.30056 (16)	1.13631 (11)	-0.16289 (11)	0.0172 (3)
H22A	0.350 (2)	1.1955 (15)	-0.1755 (14)	0.024 (4)*
H22B	0.2690 (19)	1.1442 (13)	-0.2225 (13)	0.015 (4)*
C23	0.54951 (16)	1.00844 (13)	-0.18301 (11)	0.0193 (3)
H23A	0.540 (3)	0.9830 (19)	-0.2282 (19)	0.051 (7)*
H23B	0.617 (3)	0.959 (2)	-0.1406 (19)	0.055 (7)*
H23C	0.599 (3)	1.070 (2)	-0.217 (2)	0.065 (8)*
C24	0.33392 (15)	0.97084 (11)	-0.03381 (10)	0.0145 (2)
C25	0.16432 (16)	1.12269 (11)	-0.07475 (10)	0.0161 (3)
O9	0.22431 (12)	0.75720 (8)	0.21745 (8)	0.0222 (2)
O10	0.16856 (11)	0.60735 (8)	0.35557 (7)	0.0185 (2)
H10A	0.080 (3)	0.6511 (19)	0.3638 (17)	0.045 (6)*
O11	0.69061 (11)	0.75755 (8)	-0.01882 (8)	0.0204 (2)
O12	0.86113 (11)	0.60775 (8)	0.00786 (8)	0.0185 (2)
H12A	0.915 (3)	0.649 (2)	-0.0534 (19)	0.051 (7)*

N3	0.50100 (13)	0.65317 (9)	0.16037 (9)	0.0143 (2)
C15	0.25904 (15)	0.66364 (11)	0.27266 (10)	0.0158 (3)
C16	0.41037 (15)	0.59999 (11)	0.24827 (10)	0.0149 (3)
C17	0.44864 (16)	0.49323 (11)	0.31185 (10)	0.0167 (3)
H17	0.381 (2)	0.4595 (15)	0.3761 (14)	0.024 (4)*
C18	0.58702 (16)	0.43822 (11)	0.28135 (11)	0.0181 (3)
H18	0.613 (2)	0.3676 (16)	0.3202 (14)	0.023 (4)*
C19	0.68190 (16)	0.49118 (11)	0.18923 (11)	0.0167 (3)
H19	0.777 (2)	0.4580 (14)	0.1653 (13)	0.021 (4)*
C20	0.63432 (15)	0.59888 (11)	0.13218 (10)	0.0145 (2)
C21	0.73088 (15)	0.66371 (11)	0.03255 (10)	0.0152 (3)
O14	-0.28792 (14)	0.61850 (10)	0.36097 (10)	0.0268 (2)
H14A	-0.377 (3)	0.6268 (19)	0.3838 (18)	0.048 (7)*
H14B	-0.258 (3)	0.553 (2)	0.3801 (17)	0.041 (6)*
O15	-0.08716 (12)	0.72137 (9)	0.38192 (8)	0.0220 (2)
H15A	-0.160 (3)	0.6886 (18)	0.3832 (17)	0.040 (6)*
H15B	-0.098 (3)	0.7271 (18)	0.4335 (18)	0.039 (6)*
O16	0.00515 (12)	-0.05810 (9)	0.18249 (8)	0.0188 (2)
H16A	0.008 (3)	-0.0312 (19)	0.2190 (18)	0.041 (6)*
H16B	0.043 (3)	-0.122 (2)	0.2076 (18)	0.049 (7)*
O17	-0.02251 (12)	0.28295 (9)	0.16386 (8)	0.0189 (2)
H17A	-0.076 (3)	0.2496 (18)	0.1493 (16)	0.039 (6)*
H17B	0.029 (3)	0.2388 (19)	0.2012 (18)	0.041 (6)*
O18	0.59381 (13)	0.31757 (10)	0.57788 (9)	0.0256 (2)
H18A	0.571 (3)	0.2635 (19)	0.5733 (16)	0.040 (6)*
H18B	0.673 (3)	0.3345 (19)	0.5322 (19)	0.048 (7)*
O19	0.81371 (13)	0.17421 (9)	0.11655 (9)	0.0220 (2)
H19A	0.731 (3)	0.215 (2)	0.1020 (18)	0.050 (7)*
H19B	0.867 (3)	0.1690 (18)	0.0646 (18)	0.043 (6)*

Atomic displacement parameters (\AA^2)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Cr1	0.01120 (10)	0.00907 (10)	0.00929 (10)	-0.00114 (7)	-0.00217 (7)	-0.00125 (8)
O1	0.0153 (4)	0.0122 (4)	0.0137 (4)	-0.0024 (3)	-0.0039 (3)	-0.0029 (4)
O2	0.0175 (5)	0.0198 (5)	0.0164 (5)	-0.0028 (4)	-0.0066 (4)	-0.0059 (4)
O3	0.0158 (4)	0.0152 (4)	0.0136 (4)	-0.0018 (3)	-0.0041 (3)	-0.0045 (4)
O4	0.0214 (5)	0.0206 (5)	0.0232 (5)	-0.0033 (4)	-0.0063 (4)	-0.0118 (4)
O5	0.0134 (4)	0.0126 (4)	0.0127 (4)	-0.0005 (3)	-0.0017 (3)	-0.0016 (4)
O6	0.0162 (5)	0.0165 (5)	0.0146 (5)	-0.0017 (4)	0.0017 (4)	-0.0023 (4)
O7	0.0140 (4)	0.0125 (4)	0.0125 (4)	-0.0016 (3)	-0.0020 (3)	-0.0026 (4)
O8	0.0144 (5)	0.0185 (5)	0.0191 (5)	0.0005 (4)	-0.0003 (4)	-0.0055 (4)
N1	0.0101 (5)	0.0106 (5)	0.0120 (5)	-0.0004 (4)	-0.0012 (4)	-0.0034 (4)
N2	0.0126 (5)	0.0112 (5)	0.0116 (5)	-0.0019 (4)	-0.0032 (4)	-0.0030 (4)
C1	0.0110 (6)	0.0134 (6)	0.0124 (6)	-0.0004 (5)	-0.0004 (4)	-0.0044 (5)
C2	0.0092 (5)	0.0133 (6)	0.0131 (6)	0.0004 (4)	-0.0014 (4)	-0.0043 (5)
C3	0.0130 (6)	0.0161 (6)	0.0128 (6)	0.0011 (5)	-0.0018 (5)	-0.0029 (5)
C4	0.0145 (6)	0.0107 (6)	0.0163 (6)	0.0001 (5)	0.0008 (5)	-0.0003 (5)

supplementary materials

C5	0.0120 (6)	0.0117 (6)	0.0204 (7)	-0.0015 (5)	0.0006 (5)	-0.0057 (5)
C6	0.0097 (5)	0.0131 (6)	0.0154 (6)	-0.0002 (4)	-0.0004 (5)	-0.0061 (5)
C7	0.0109 (6)	0.0161 (6)	0.0144 (6)	0.0006 (5)	-0.0007 (5)	-0.0072 (5)
C8	0.0137 (6)	0.0120 (6)	0.0134 (6)	-0.0020 (5)	-0.0040 (5)	-0.0029 (5)
C9	0.0123 (6)	0.0132 (6)	0.0126 (6)	-0.0029 (5)	-0.0030 (5)	-0.0036 (5)
C10	0.0161 (6)	0.0142 (6)	0.0129 (6)	-0.0037 (5)	-0.0024 (5)	-0.0017 (5)
C11	0.0194 (7)	0.0105 (6)	0.0160 (6)	-0.0018 (5)	-0.0064 (5)	-0.0002 (5)
C12	0.0151 (6)	0.0132 (6)	0.0170 (6)	-0.0002 (5)	-0.0049 (5)	-0.0050 (5)
C13	0.0124 (6)	0.0134 (6)	0.0137 (6)	-0.0023 (5)	-0.0034 (5)	-0.0056 (5)
C14	0.0143 (6)	0.0134 (6)	0.0133 (6)	-0.0031 (5)	-0.0030 (5)	-0.0050 (5)
O13	0.0199 (5)	0.0185 (5)	0.0230 (5)	0.0060 (4)	-0.0071 (4)	-0.0104 (4)
N4	0.0171 (6)	0.0156 (6)	0.0160 (6)	0.0020 (5)	-0.0035 (5)	-0.0040 (5)
N5	0.0153 (5)	0.0152 (5)	0.0145 (6)	0.0010 (4)	-0.0026 (4)	-0.0054 (5)
N6	0.0154 (5)	0.0135 (5)	0.0152 (5)	0.0013 (4)	-0.0033 (4)	-0.0041 (4)
C22	0.0189 (7)	0.0134 (6)	0.0171 (6)	0.0017 (5)	-0.0046 (5)	-0.0046 (5)
C23	0.0163 (7)	0.0232 (7)	0.0163 (7)	0.0009 (5)	-0.0020 (5)	-0.0078 (6)
C24	0.0153 (6)	0.0153 (6)	0.0149 (6)	-0.0005 (5)	-0.0052 (5)	-0.0071 (5)
C25	0.0187 (6)	0.0158 (6)	0.0168 (6)	-0.0008 (5)	-0.0065 (5)	-0.0078 (5)
O9	0.0191 (5)	0.0192 (5)	0.0199 (5)	0.0038 (4)	-0.0009 (4)	-0.0042 (4)
O10	0.0149 (5)	0.0199 (5)	0.0187 (5)	-0.0026 (4)	0.0000 (4)	-0.0071 (4)
O11	0.0169 (5)	0.0182 (5)	0.0198 (5)	0.0005 (4)	-0.0032 (4)	-0.0027 (4)
O12	0.0156 (5)	0.0191 (5)	0.0175 (5)	0.0007 (4)	-0.0008 (4)	-0.0066 (4)
N3	0.0138 (5)	0.0145 (5)	0.0154 (5)	-0.0008 (4)	-0.0040 (4)	-0.0062 (4)
C15	0.0154 (6)	0.0177 (6)	0.0151 (6)	-0.0021 (5)	-0.0036 (5)	-0.0067 (5)
C16	0.0157 (6)	0.0154 (6)	0.0156 (6)	-0.0021 (5)	-0.0044 (5)	-0.0070 (5)
C17	0.0184 (6)	0.0154 (6)	0.0163 (6)	-0.0041 (5)	-0.0037 (5)	-0.0050 (5)
C18	0.0209 (7)	0.0124 (6)	0.0200 (7)	-0.0008 (5)	-0.0073 (5)	-0.0038 (5)
C19	0.0156 (6)	0.0155 (6)	0.0206 (7)	0.0006 (5)	-0.0057 (5)	-0.0084 (5)
C20	0.0148 (6)	0.0151 (6)	0.0155 (6)	-0.0017 (5)	-0.0048 (5)	-0.0066 (5)
C21	0.0139 (6)	0.0178 (6)	0.0161 (6)	-0.0014 (5)	-0.0046 (5)	-0.0077 (5)
O14	0.0180 (6)	0.0181 (6)	0.0398 (7)	0.0000 (4)	-0.0020 (5)	-0.0100 (5)
O15	0.0191 (5)	0.0293 (6)	0.0188 (5)	-0.0005 (4)	-0.0025 (4)	-0.0122 (5)
O16	0.0224 (5)	0.0170 (5)	0.0175 (5)	0.0006 (4)	-0.0048 (4)	-0.0080 (4)
O17	0.0174 (5)	0.0201 (5)	0.0166 (5)	0.0003 (4)	-0.0054 (4)	-0.0044 (4)
O18	0.0191 (5)	0.0295 (6)	0.0342 (6)	-0.0083 (4)	0.0033 (5)	-0.0204 (5)
O19	0.0187 (5)	0.0239 (5)	0.0215 (5)	0.0022 (4)	-0.0059 (4)	-0.0080 (4)

Geometric parameters (Å, °)

Cr1—N1	1.9733 (11)	N5—C25	1.3782 (17)
Cr1—N2	1.9769 (11)	N5—H5A	0.85 (2)
Cr1—O5	1.9842 (9)	N6—C24	1.3259 (17)
Cr1—O3	1.9942 (10)	N6—C23	1.4581 (18)
Cr1—O1	1.9947 (9)	N6—C22	1.4616 (17)
Cr1—O7	1.9974 (9)	C22—C25	1.5171 (19)
O1—C1	1.3009 (15)	C22—H22A	0.938 (19)
O2—C1	1.2262 (16)	C22—H22B	0.952 (17)
O3—C7	1.3106 (16)	C23—H23A	0.90 (3)
O4—C7	1.2176 (17)	C23—H23B	0.95 (3)

O5—C8	1.2975 (15)	C23—H23C	0.92 (3)
O6—C8	1.2283 (16)	O9—C15	1.2204 (17)
O7—C14	1.3039 (16)	O10—C15	1.3107 (17)
O8—C14	1.2244 (16)	O10—H10A	0.91 (2)
N1—C6	1.3329 (17)	O11—C21	1.2184 (17)
N1—C2	1.3366 (17)	O12—C21	1.3157 (16)
N2—C13	1.3365 (17)	O12—H12A	0.91 (2)
N2—C9	1.3373 (16)	N3—C20	1.3390 (17)
C1—C2	1.5160 (18)	N3—C16	1.3391 (17)
C2—C3	1.3861 (18)	C15—C16	1.5031 (18)
C3—C4	1.394 (2)	C16—C17	1.3926 (19)
C3—H3	0.920 (17)	C17—C18	1.386 (2)
C4—C5	1.395 (2)	C17—H17	0.970 (18)
C4—H4	0.932 (17)	C18—C19	1.393 (2)
C5—C6	1.3886 (18)	C18—H18	0.909 (19)
C5—H5	0.934 (18)	C19—C20	1.3942 (19)
C6—C7	1.5145 (18)	C19—H19	0.935 (18)
C8—C9	1.5172 (18)	C20—C21	1.5099 (19)
C9—C10	1.3859 (18)	O14—H14A	0.79 (3)
C10—C11	1.3949 (19)	O14—H14B	0.83 (2)
C10—H10	0.927 (19)	O15—H15A	0.86 (2)
C11—C12	1.3965 (19)	O15—H15B	0.77 (2)
C11—H11	0.944 (18)	O16—H16A	0.78 (2)
C12—C13	1.3858 (18)	O16—H16B	0.83 (3)
C12—H12	0.942 (17)	O17—H17A	0.85 (2)
C13—C14	1.5161 (18)	O17—H17B	0.79 (2)
O13—C25	1.2149 (17)	O18—H18A	0.84 (2)
N4—C24	1.3117 (18)	O18—H18B	0.84 (3)
N4—H4A	0.83 (2)	O19—H19A	0.85 (3)
N4—H4B	0.85 (2)	O19—H19B	0.81 (2)
N5—C24	1.3731 (17)		
N1—Cr1—N2	172.88 (4)	N2—C13—C14	110.86 (11)
N1—Cr1—O5	106.16 (4)	C12—C13—C14	128.84 (12)
N2—Cr1—O5	79.39 (4)	O8—C14—O7	124.76 (12)
N1—Cr1—O3	78.84 (4)	O8—C14—C13	121.81 (12)
N2—Cr1—O3	96.78 (4)	O7—C14—C13	113.42 (11)
O5—Cr1—O3	91.39 (4)	C24—N4—H4A	120.6 (14)
N1—Cr1—O1	79.13 (4)	C24—N4—H4B	120.3 (13)
N2—Cr1—O1	105.30 (4)	H4A—N4—H4B	119.1 (19)
O5—Cr1—O1	93.27 (4)	C24—N5—C25	110.51 (11)
O3—Cr1—O1	157.91 (4)	C24—N5—H5A	123.0 (14)
N1—Cr1—O7	96.08 (4)	C25—N5—H5A	126.3 (14)
N2—Cr1—O7	78.42 (4)	C24—N6—C23	125.88 (12)
O5—Cr1—O7	157.76 (4)	C24—N6—C22	110.40 (11)
O3—Cr1—O7	92.80 (4)	C23—N6—C22	123.72 (11)
O1—Cr1—O7	91.01 (4)	N6—C22—C25	102.34 (11)
C1—O1—Cr1	117.31 (8)	N6—C22—H22A	110.6 (11)
C7—O3—Cr1	117.92 (8)	C25—C22—H22A	111.4 (11)
C8—O5—Cr1	117.46 (8)	N6—C22—H22B	111.1 (10)

supplementary materials

C14—O7—Cr1	117.96 (8)	C25—C22—H22B	110.6 (10)
C6—N1—C2	123.01 (11)	H22A—C22—H22B	110.6 (15)
C6—N1—Cr1	118.48 (9)	N6—C23—H23A	111.2 (15)
C2—N1—Cr1	118.06 (9)	N6—C23—H23B	112.8 (15)
C13—N2—C9	123.11 (11)	H23A—C23—H23B	110 (2)
C13—N2—Cr1	118.99 (9)	N6—C23—H23C	109.5 (17)
C9—N2—Cr1	117.84 (9)	H23A—C23—H23C	109 (2)
O2—C1—O1	126.04 (12)	H23B—C23—H23C	104 (2)
O2—C1—C2	120.05 (11)	N4—C24—N6	126.64 (13)
O1—C1—C2	113.91 (11)	N4—C24—N5	122.86 (13)
N1—C2—C3	120.18 (12)	N6—C24—N5	110.49 (11)
N1—C2—C1	111.06 (11)	O13—C25—N5	125.75 (13)
C3—C2—C1	128.76 (12)	O13—C25—C22	128.00 (13)
C2—C3—C4	117.72 (12)	N5—C25—C22	106.25 (11)
C2—C3—H3	119.9 (11)	C15—O10—H10A	107.6 (14)
C4—C3—H3	122.4 (10)	C21—O12—H12A	110.0 (15)
C3—C4—C5	121.20 (12)	C20—N3—C16	117.38 (11)
C3—C4—H4	120.1 (10)	O9—C15—O10	124.43 (13)
C5—C4—H4	118.7 (11)	O9—C15—C16	122.17 (12)
C6—C5—C4	117.61 (12)	O10—C15—C16	113.34 (12)
C6—C5—H5	118.9 (11)	N3—C16—C17	123.71 (12)
C4—C5—H5	123.5 (11)	N3—C16—C15	114.63 (11)
N1—C6—C5	120.24 (12)	C17—C16—C15	121.64 (12)
N1—C6—C7	111.66 (11)	C18—C17—C16	118.11 (13)
C5—C6—C7	128.04 (12)	C18—C17—H17	121.6 (11)
O4—C7—O3	125.86 (12)	C16—C17—H17	120.3 (11)
O4—C7—C6	121.13 (12)	C17—C18—C19	119.22 (13)
O3—C7—C6	112.99 (11)	C17—C18—H18	119.9 (12)
O6—C8—O5	125.49 (12)	C19—C18—H18	120.8 (12)
O6—C8—C9	120.42 (11)	C18—C19—C20	118.15 (13)
O5—C8—C9	114.09 (11)	C18—C19—H19	122.6 (11)
N2—C9—C10	119.86 (12)	C20—C19—H19	119.2 (11)
N2—C9—C8	111.14 (11)	N3—C20—C19	123.42 (12)
C10—C9—C8	129.00 (12)	N3—C20—C21	114.59 (11)
C9—C10—C11	118.03 (12)	C19—C20—C21	122.00 (12)
C9—C10—H10	122.6 (11)	O11—C21—O12	124.35 (13)
C11—C10—H10	119.4 (11)	O11—C21—C20	122.94 (12)
C10—C11—C12	121.08 (12)	O12—C21—C20	112.71 (11)
C10—C11—H11	118.9 (11)	H14A—O14—H14B	109 (2)
C12—C11—H11	120.0 (11)	H15A—O15—H15B	110 (2)
C13—C12—C11	117.60 (12)	H16A—O16—H16B	106 (2)
C13—C12—H12	120.7 (10)	H17A—O17—H17B	108 (2)
C11—C12—H12	121.7 (10)	H18A—O18—H18B	104 (2)
N2—C13—C12	120.29 (12)	H19A—O19—H19B	108 (2)
N1—Cr1—O1—C1	-2.46 (9)	C5—C6—C7—O4	-4.4 (2)
N2—Cr1—O1—C1	171.81 (9)	N1—C6—C7—O3	-2.96 (15)
O5—Cr1—O1—C1	-108.30 (9)	C5—C6—C7—O3	174.13 (12)
O3—Cr1—O1—C1	-6.46 (16)	Cr1—O5—C8—O6	-176.91 (10)
O7—Cr1—O1—C1	93.54 (9)	Cr1—O5—C8—C9	2.87 (14)

N1—Cr1—O3—C7	0.88 (9)	C13—N2—C9—C10	1.76 (19)
N2—Cr1—O3—C7	-173.43 (9)	Cr1—N2—C9—C10	179.04 (10)
O5—Cr1—O3—C7	107.08 (9)	C13—N2—C9—C8	-177.99 (11)
O1—Cr1—O3—C7	4.89 (16)	Cr1—N2—C9—C8	-0.71 (14)
O7—Cr1—O3—C7	-94.76 (9)	O6—C8—C9—N2	178.40 (12)
N1—Cr1—O5—C8	172.87 (9)	O5—C8—C9—N2	-1.39 (16)
N2—Cr1—O5—C8	-2.55 (9)	O6—C8—C9—C10	-1.3 (2)
O3—Cr1—O5—C8	94.09 (9)	O5—C8—C9—C10	178.89 (13)
O1—Cr1—O5—C8	-107.51 (9)	N2—C9—C10—C11	-0.54 (19)
O7—Cr1—O5—C8	-6.78 (16)	C8—C9—C10—C11	179.17 (12)
N1—Cr1—O7—C14	-170.15 (9)	C9—C10—C11—C12	-0.8 (2)
N2—Cr1—O7—C14	5.26 (9)	C10—C11—C12—C13	0.9 (2)
O5—Cr1—O7—C14	9.50 (16)	C9—N2—C13—C12	-1.60 (19)
O3—Cr1—O7—C14	-91.09 (9)	Cr1—N2—C13—C12	-178.85 (9)
O1—Cr1—O7—C14	110.67 (9)	C9—N2—C13—C14	177.15 (11)
O5—Cr1—N1—C6	-90.96 (10)	Cr1—N2—C13—C14	-0.10 (14)
O3—Cr1—N1—C6	-2.76 (9)	C11—C12—C13—N2	0.21 (19)
O1—Cr1—N1—C6	178.77 (10)	C11—C12—C13—C14	-178.29 (12)
O7—Cr1—N1—C6	88.91 (10)	Cr1—O7—C14—O8	172.16 (10)
O5—Cr1—N1—C2	96.49 (9)	Cr1—O7—C14—C13	-6.72 (14)
O3—Cr1—N1—C2	-175.31 (10)	N2—C13—C14—O8	-174.56 (12)
O1—Cr1—N1—C2	6.22 (9)	C12—C13—C14—O8	4.0 (2)
O7—Cr1—N1—C2	-83.64 (9)	N2—C13—C14—O7	4.35 (15)
O5—Cr1—N2—C13	179.09 (10)	C12—C13—C14—O7	-177.04 (13)
O3—Cr1—N2—C13	88.95 (10)	C24—N6—C22—C25	1.04 (14)
O1—Cr1—N2—C13	-90.40 (10)	C23—N6—C22—C25	-178.54 (12)
O7—Cr1—N2—C13	-2.54 (9)	C23—N6—C24—N4	-0.3 (2)
O5—Cr1—N2—C9	1.70 (9)	C22—N6—C24—N4	-179.89 (13)
O3—Cr1—N2—C9	-88.45 (9)	C23—N6—C24—N5	178.95 (12)
O1—Cr1—N2—C9	92.21 (9)	C22—N6—C24—N5	-0.61 (15)
O7—Cr1—N2—C9	-179.93 (10)	C25—N5—C24—N4	179.15 (12)
Cr1—O1—C1—O2	177.87 (10)	C25—N5—C24—N6	-0.15 (16)
Cr1—O1—C1—C2	-1.13 (14)	C24—N5—C25—O13	-179.32 (13)
C6—N1—C2—C3	-0.63 (19)	C24—N5—C25—C22	0.81 (15)
Cr1—N1—C2—C3	171.56 (9)	N6—C22—C25—O13	179.04 (13)
C6—N1—C2—C1	179.57 (11)	N6—C22—C25—N5	-1.09 (14)
Cr1—N1—C2—C1	-8.24 (13)	C20—N3—C16—C17	1.25 (19)
O2—C1—C2—N1	-173.12 (11)	C20—N3—C16—C15	-176.95 (11)
O1—C1—C2—N1	5.95 (15)	O9—C15—C16—N3	-1.70 (19)
O2—C1—C2—C3	7.1 (2)	O10—C15—C16—N3	175.76 (11)
O1—C1—C2—C3	-173.83 (12)	O9—C15—C16—C17	-179.95 (13)
N1—C2—C3—C4	1.51 (19)	O10—C15—C16—C17	-2.48 (18)
C1—C2—C3—C4	-178.72 (12)	N3—C16—C17—C18	-1.4 (2)
C2—C3—C4—C5	-0.50 (19)	C15—C16—C17—C18	176.71 (12)
C3—C4—C5—C6	-1.35 (19)	C16—C17—C18—C19	0.1 (2)
C2—N1—C6—C5	-1.34 (19)	C17—C18—C19—C20	1.2 (2)
Cr1—N1—C6—C5	-173.49 (9)	C16—N3—C20—C19	0.16 (19)
C2—N1—C6—C7	176.01 (11)	C16—N3—C20—C21	-179.88 (11)
Cr1—N1—C6—C7	3.86 (14)	C18—C19—C20—N3	-1.4 (2)

supplementary materials

C4—C5—C6—N1	2.27 (19)	C18—C19—C20—C21	178.67 (12)
C4—C5—C6—C7	-174.60 (12)	N3—C20—C21—O11	-0.66 (19)
Cr1—O3—C7—O4	179.27 (10)	C19—C20—C21—O11	179.30 (13)
Cr1—O3—C7—C6	0.84 (13)	N3—C20—C21—O12	179.64 (11)
N1—C6—C7—O4	178.53 (12)	C19—C20—C21—O12	-0.40 (18)

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>
N4—H4A...O11	0.83 (2)	2.08 (2)	2.8934 (16)	167.3 (19)
N4—H4B...O9	0.85 (2)	1.98 (2)	2.8343 (16)	178.5 (8)
O10—H10A...O15	0.91 (2)	1.63 (2)	2.5382 (15)	176 (2)
O14—H14B...O8	0.83 (2)	2.01 (2)	2.8255 (16)	169 (2)
O15—H15A...O14	0.86 (2)	1.82 (2)	2.6718 (17)	168 (2)
O16—H16A...O4	0.78 (2)	2.07 (2)	2.8006 (15)	156 (2)
O17—H17B...O3	0.79 (2)	1.99 (2)	2.7758 (14)	172 (2)
O18—H18A...O2	0.84 (2)	1.98 (2)	2.7927 (15)	162 (2)
O19—H19A...O6	0.85 (3)	1.95 (3)	2.7763 (15)	164 (2)
N5—H5A...O16 ⁱ	0.85 (2)	1.87 (2)	2.7175 (16)	175 (2)
O12—H12A...O17 ⁱⁱ	0.91 (2)	1.66 (3)	2.5720 (14)	176 (2)
O14—H14A...O18 ⁱⁱⁱ	0.79 (3)	1.98 (3)	2.7546 (17)	167 (2)
O15—H15B...O7 ⁱⁱⁱ	0.77 (2)	2.16 (2)	2.9105 (15)	162 (2)
O16—H16B...O9 ^{iv}	0.83 (3)	2.05 (3)	2.8083 (15)	152 (2)
O17—H17A...O19 ^v	0.85 (2)	1.84 (2)	2.6916 (16)	178 (2)
O18—H18B...O8 ^{vi}	0.84 (3)	2.12 (3)	2.9558 (15)	171 (2)
O19—H19B...O13 ^{vii}	0.81 (2)	2.17 (2)	2.9531 (16)	162 (2)
C5—H5...O7 ^{viii}	0.94 (2)	2.392 (19)	3.251 (2)	152.2 (15)
C10—H10...O6 ⁱⁱ	0.929 (19)	2.283 (19)	3.0919 (17)	145.4 (18)

Symmetry codes: (i) $x, y+1, z$; (ii) $-x+1, -y+1, -z$; (iii) $-x, -y+1, -z+1$; (iv) $x, y-1, z$; (v) $x-1, y, z$; (vi) $x+1, y, z$; (vii) $x+1, y-1, z$; (viii) $-x, -y, -z+1$.

Fig. 1

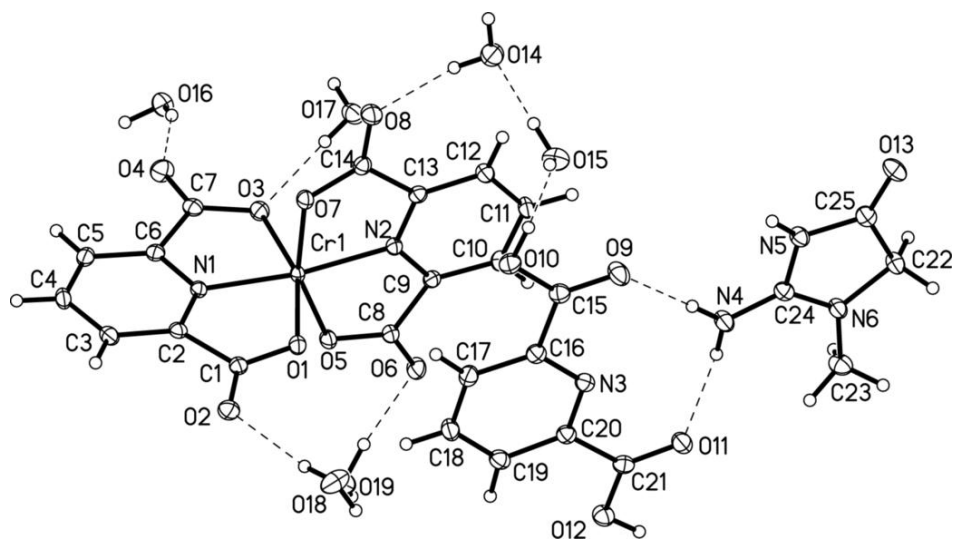


Fig. 2

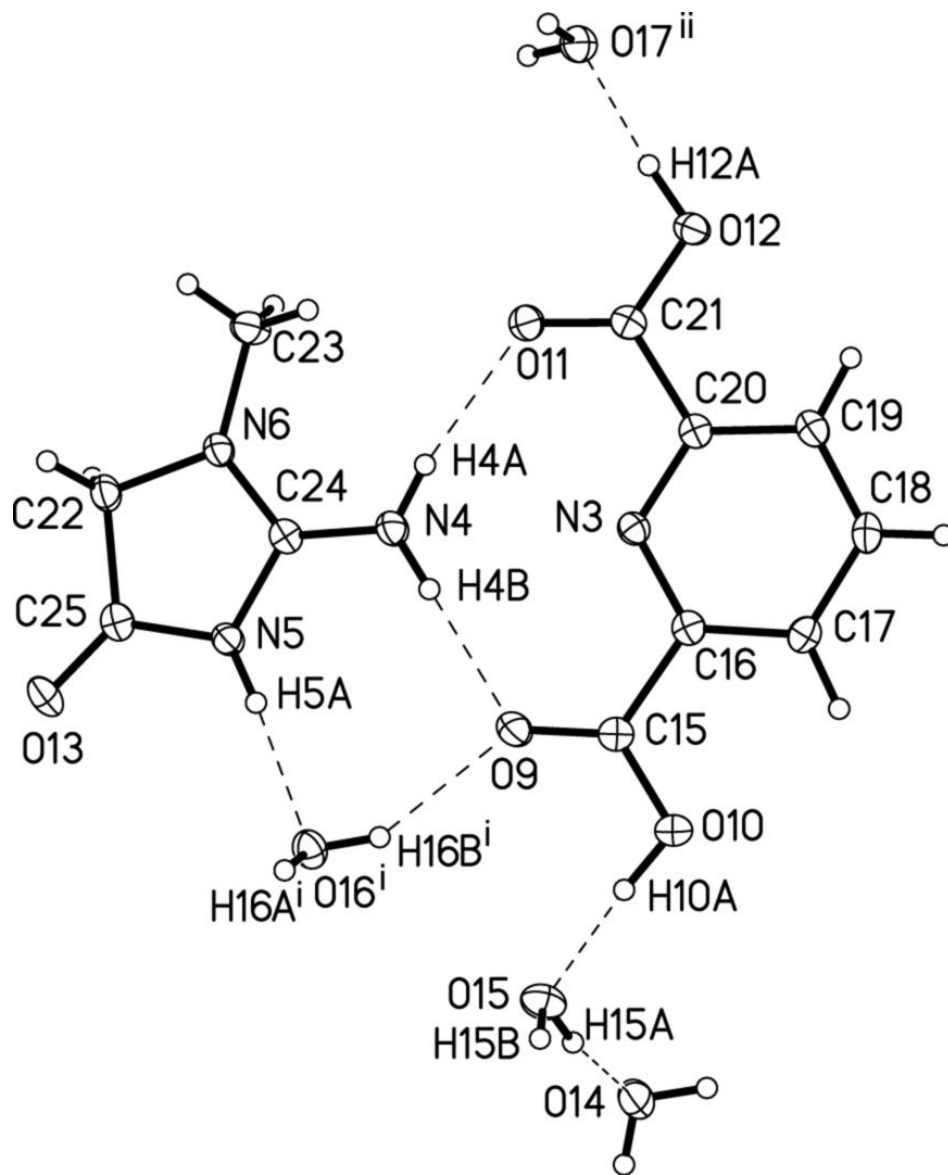


Fig. 3

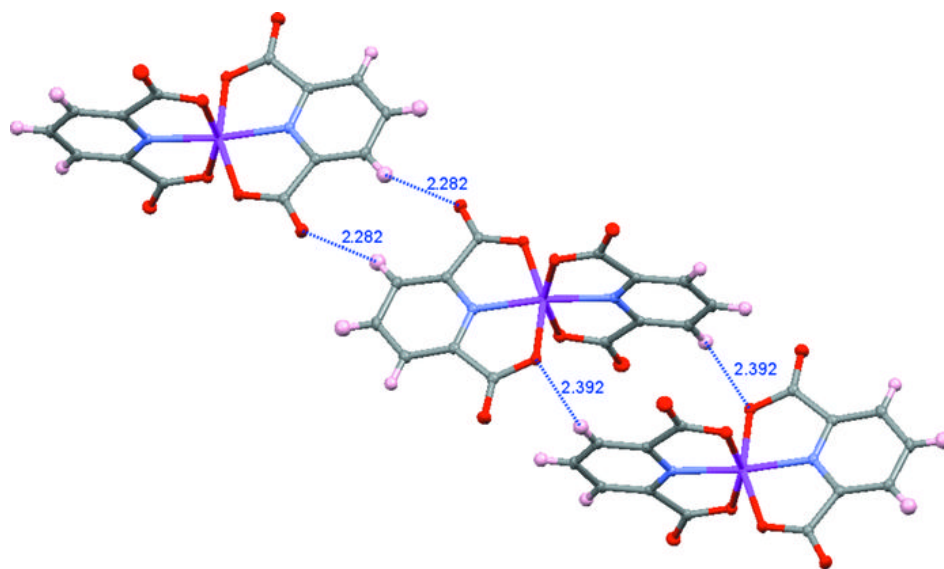


Fig. 4

