

Diammonium tricadmium tris(sulfate) dihydroxide dihydrate

Xin Yin

Department of Chemistry, East China University of Science and Technology, School of Chemistry and Molecular Engineering, Mei Long Road 130, Shanghai 200237, People's Republic of China

Correspondence e-mail: yoshikiyin@ecust.edu.cn

Received 23 March 2011; accepted 7 April 2011

Key indicators: single-crystal X-ray study; $T = 296$ K; mean $\sigma(\text{S—O}) = 0.005$ Å; R factor = 0.027; wR factor = 0.066; data-to-parameter ratio = 15.0.

The title compound, $(\text{NH}_4)_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$, has been obtained serendipitously. It is isotypic with the heavier alkali analogues $M_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$ ($M = \text{K}, \text{Rb}, \text{Cs}$). The structure contains two Cd^{2+} ions, one in a general position and one with site symmetry m . The former Cd^{2+} ion is coordinated by three O atoms of three SO_4 groups, two hydroxide O atoms and one water O atom, the latter Cd^{2+} ion by four O atoms of four SO_4 groups and two hydroxide O atoms, both in a distorted octahedral coordination geometry. This arrangement leads to the formation of a layered framework extending parallel to (100), with the ammonium cations situated in the voids. O—H...O hydrogen bonds involving the water molecules, hydroxide groups and sulfate O atoms, as well as N—H...O hydrogen bonds between ammonium cations and sulfate O atoms consolidate the crystal packing.

Related literature

For the isotypic K and Cs analogues, see: Louer & Louer (1982), and for the Rb analogue, see: Swain & Guru Row (2006).

Experimental

Crystal data

$(\text{NH}_4)_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$
 $M_r = 731.51$
 Orthorhombic, $Cmc2_1$
 $a = 18.906$ (3) Å
 $b = 7.9483$ (11) Å
 $c = 9.9809$ (13) Å

$V = 1499.8$ (4) Å³
 $Z = 4$
 Mo $K\alpha$ radiation
 $\mu = 4.72$ mm^{−1}
 $T = 296$ K
 $0.12 \times 0.10 \times 0.08$ mm

Data collection

Bruker SMART CCD diffractometer
 Absorption correction: multi-scan (*SADABS*; Sheldrick, 2003)
 $T_{\min} = 0.601$, $T_{\max} = 0.704$

7060 measured reflections
 1770 independent reflections
 1739 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.051$

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.027$
 $wR(F^2) = 0.066$
 $S = 1.08$
 1770 reflections
 118 parameters
 1 restraint

H-atom parameters constrained
 $\Delta\rho_{\max} = 0.68$ e Å^{−3}
 $\Delta\rho_{\min} = -1.31$ e Å^{−3}
 Absolute structure: Flack (1983), 825 Friedel pairs
 Flack parameter: -0.07 (4)

Table 1

Hydrogen-bond geometry (Å, °).

$D\cdots H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
O10—H10B...O7 ⁱ	0.85	2.25	3.087 (5)	167
O10—H10B...O5 ⁱⁱ	0.85	2.36	2.985 (6)	131
O9—H9A...O6 ⁱⁱⁱ	0.85	2.18	3.029 (7)	173
O8—H8A...O5 ⁱⁱ	0.85	2.56	3.322 (9)	150
O8—H8A...O5 ⁱ	0.85	2.56	3.322 (9)	150
N1—H1B...O10 ^{iv}	0.90	2.26	2.948 (6)	133
N1—H1D...O4 ⁱⁱ	0.90	2.18	3.077 (5)	180
N1—H1C...O4 ^v	0.90	2.19	3.074 (7)	168
N1—H1A...O3 ^{vi}	0.90	2.38	2.995 (6)	126
N1—H1D...O2 ⁱⁱ	0.90	2.64	3.196 (7)	121

Symmetry codes: (i) $-x+1, -y+1, z-\frac{1}{2}$; (ii) $x, -y+1, z-\frac{1}{2}$; (iii) $x, y-1, z$; (iv) $x, y+1, z$; (v) $-x+\frac{3}{2}, -y+\frac{3}{2}, z-\frac{1}{2}$; (vi) $-x+\frac{3}{2}, y+\frac{3}{2}, z$.

Data collection: *SMART* (Bruker, 2001); cell refinement: *SAINT-Plus* (Bruker, 2003); data reduction: *SAINT-Plus*; program(s) used to solve structure: *SHELXTL* (Sheldrick, 2008); program(s) used to refine structure: *SHELXTL*; molecular graphics: *Mercury* (Macrae *et al.*, 2006) and *DIAMOND* (Brandenburg, 2006); software used to prepare material for publication: *SHELXTL*.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: WM2470).

References

- Brandenburg, K. (2006). *DIAMOND*. Crystal Impact GbR, Bonn, Germany.
 Bruker (2001). *SMART*. Bruker AXS Inc., Madison, Wisconsin, USA.
 Bruker (2003). *SAINT-Plus*. Bruker AXS Inc., Madison, Wisconsin, USA.
 Flack, H. D. (1983). *Acta Cryst.* **A39**, 876–881.
 Louer, M. & Louer, D. (1982). *Rev. Chim. Miner.* **19**, 162–171.
 Macrae, C. F., Edgington, P. R., McCabe, P., Pidcock, E., Shields, G. P., Taylor, R., Towler, M. & van de Streek, J. (2006). *J. Appl. Cryst.* **39**, 453–457.
 Sheldrick, G. M. (2003). *SADABS*. University of Göttingen, Germany.
 Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.
 Swain, D. & Guru Row, T. N. (2006). *Acta Cryst.* **E62**, i74–i76.

supporting information

Acta Cryst. (2011). E67, i31 [https://doi.org/10.1107/S1600536811012979]

Diammonium tricadmium tris(sulfate) dihydroxide dihydrate**Xin Yin****S1. Comment**

The title compound, $(\text{NH}_4)_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$, (I), formed accidentally under hydrothermal reaction conditions. Our intended target product was to synthesis a coordination compound from 1*H*-benzimidazole-5,6-dicarboxylate and $\text{CdSO}_4 \cdot 8/3\text{H}_2\text{O}$. The presence of ammonium ions in the finally obtained compound points to an internal redox process that presumably has caused a (partly) reduction of the nitrogen atoms of 1*H*-benzimidazole-5,6-dicarboxylate or the nitrate anions. $(\text{NH}_4)_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$ is isotypic with other $M_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$ members ($M = \text{K}$, Cs (Louer & Louer, 1982); $M = \text{Rb}$ (Swain & Guru Row, 2006)).

The asymmetric unit of (I) is illustrated in Fig. 1. The crystal structure of $(\text{NH}_4)_2\text{Cd}_3(\text{SO}_4)_3(\text{OH})_2(\text{H}_2\text{O})_2$ is made up from two different Cd^{2+} ions (one on a general position (Cd1), one with site symmetry m (Cd2)), two sulfate ions (likewise one on a general position and the other with site symmetry m), two hydroxide groups, one water molecule and one NH_4^+ cation. Both Cd^{2+} cations are six-coordinated in an octahedral coordination geometry. Cd2 is coordinated by four sulfate ions and two hydroxide ions, while Cd1 is coordinated by three sulfate ions, two hydroxide anions and one water molecule. There are four types of oxygen atoms in the crystal structure of the title compound. The O3 atom of one SO_4^{2-} anion is solely bound to the S atom, O8 and O9 represent the oxygen atoms of hydroxide groups shared by three Cd atoms, O10 is the water O atom bound to one Cd atom and all other O atoms represent sulfate O atoms coordinated to only one Cd atom.

As can be seen in Fig. 2, the $\text{Cd}(1)\text{O}_6$ polyhedra are connected by sharing edges of OH groups. $\text{Cd}(2)\text{O}_6$ octahedra and SO_4 tetrahedra are linked to these dimers *via* common corners, thus forming a two-dimensional network extending parallel to the *bc* plane. The NH_4^+ cations are situated in the voids of the layers. Through formation of $\text{N}-\text{H}\cdots\text{O}$ and $\text{O}-\text{H}\cdots\text{O}$ hydrogen bonds a three-dimensional structure is formed. Since all water and hydroxide groups and most of the sulfate O atoms are involved in hydrogen bonding, the resulting network can be considered as relatively stable (Table 2, Fig. 3).

S2. Experimental

All reagents were obtained from commercial sources and used without further purification. A mixture of $\text{CdSO}_4 \cdot 8/3\text{H}_2\text{O}$ (0.2565 g, 1.0 mmol), 1*H*-benzimidazole-5,6-dicarboxylate (0.1236 g, 0.6 mmol), CH_3CN (6 ml) and 4 ml water were added to a 23 ml Teflon-lined stainless container, which was heated to 423 K and held at that temperature for 5 days. After cooling to room temperature in 24 h, colourless crystals were recovered by filtration (yield 49% based on $\text{CdSO}_4 \cdot 8/3\text{H}_2\text{O}$).

S3. Refinement

The H atoms were localized from a difference Fourier map. Their coordinates were refined independently with $\text{O}-\text{H}$ distances restrained to 0.85 (2) Å and the $\text{H}-\text{H} = 1.30$ (2) Å for the water H atoms. The isotropic temperature parameters

of the H atoms were refined with 1.2 U_{eq} of the parent atom. H atoms of the ammonium cation were placed in calculated positions, with N—H = 0.90 Å, $U_{iso}(H) = 1.2 U_{eq}(N)$. The deepest hole in the final Fourier map is 0.8 Å from Cd2.

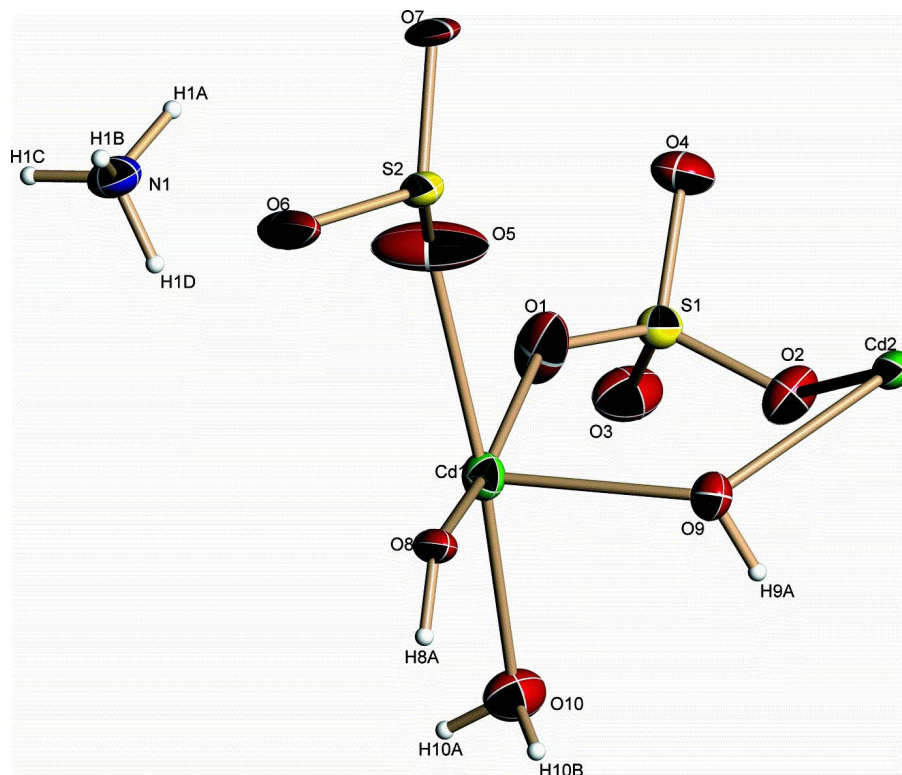


Figure 1

The asymmetric unit of (I), with displacement parameters shown at the 30% probability level.

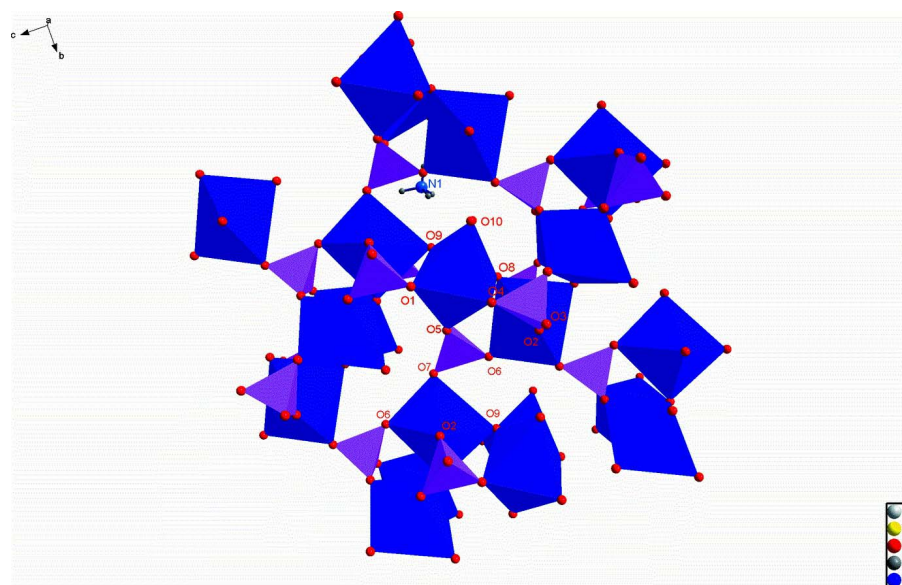


Figure 2

View of the two-dimensional network structure of (I) parallel to (100) in the polyhedral representation.

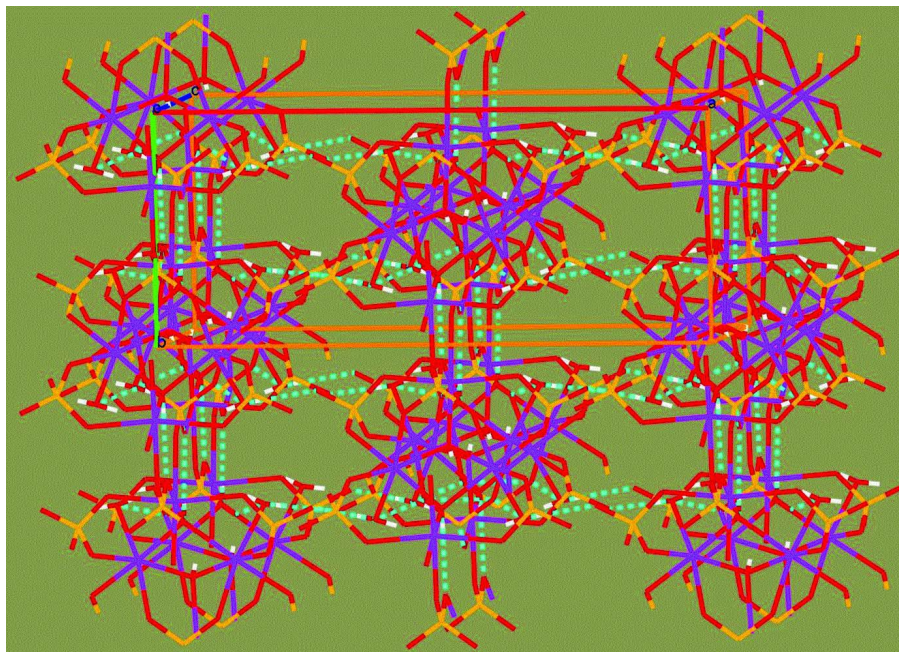


Figure 3

Three-dimensional supramolecular structure of (I), built up through hydrogen bonding. NH_4^+ ions have been omitted for clarity.

Diammonium tricadmium tris(sulfate) dihydroxide dihydrate

Crystal data

$\text{Cd}_3\text{H}_6\text{O}_{16}\text{S}_3 \cdot 2\text{NH}_4$

$M_r = 731.51$

Orthorhombic, $Cmc2_1$

Hall symbol: $C\ 2c\ -2$

$a = 18.906\ (3)\ \text{\AA}$

$b = 7.9483\ (11)\ \text{\AA}$

$c = 9.9809\ (13)\ \text{\AA}$

$V = 1499.8\ (4)\ \text{\AA}^3$

$Z = 4$

$F(000) = 1392$

$D_x = 3.240\ \text{Mg m}^{-3}$

Mo $K\alpha$ radiation, $\lambda = 0.71073\ \text{\AA}$

Cell parameters from 12815 reflections

$\theta = 1.7\text{--}27.5^\circ$

$\mu = 4.72\ \text{mm}^{-1}$

$T = 296\ \text{K}$

Block, colourless

$0.12 \times 0.10 \times 0.08\ \text{mm}$

Data collection

Bruker SMART CCD

diffractometer

Radiation source: fine-focus sealed tube

Graphite monochromator

φ and ω -scans

Absorption correction: multi-scan

(*SADABS*; Sheldrick, 2003)

$T_{\min} = 0.601$, $T_{\max} = 0.704$

7060 measured reflections

1770 independent reflections

1739 reflections with $I > 2\sigma(I)$

$R_{\text{int}} = 0.051$

$\theta_{\max} = 27.5^\circ$, $\theta_{\min} = 3.5^\circ$

$h = -24 \rightarrow 24$

$k = -10 \rightarrow 10$

$l = -12 \rightarrow 12$

*Refinement*Refinement on F^2

Least-squares matrix: full

 $R[F^2 > 2\sigma(F^2)] = 0.027$ $wR(F^2) = 0.066$ $S = 1.08$

1770 reflections

118 parameters

1 restraint

Primary atom site location: structure-invariant
direct methodsSecondary atom site location: difference Fourier
mapHydrogen site location: inferred from
neighbouring sites

H-atom parameters constrained

 $w = 1/[\sigma^2(F_o^2) + (0.0328P)^2 + 1.1583P]$ where $P = (F_o^2 + 2F_c^2)/3$ $(\Delta/\sigma)_{\max} < 0.001$ $\Delta\rho_{\max} = 0.68 \text{ e } \text{\AA}^{-3}$ $\Delta\rho_{\min} = -1.31 \text{ e } \text{\AA}^{-3}$ Absolute structure: Flack (1983), 825 Friedel
pairsAbsolute structure parameter: -0.07 (4)*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 $F^2 > \sigma(F^2)$ 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 ($\text{\AA}^2$)

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
Cd1	0.588435 (18)	0.46065 (4)	0.29502 (5)	0.01981 (11)
Cd2	0.5000	0.19102 (5)	0.58110 (4)	0.01744 (12)
S1	0.67635 (6)	0.30002 (13)	0.57340 (14)	0.0184 (2)
S2	0.5000	0.8103 (2)	0.41513 (16)	0.0192 (4)
O1	0.6589 (3)	0.4252 (6)	0.4718 (4)	0.0387 (11)
O2	0.6223 (2)	0.1661 (4)	0.5730 (5)	0.0299 (8)
O3	0.7446 (2)	0.2229 (5)	0.5454 (5)	0.0357 (11)
O4	0.6794 (2)	0.3814 (5)	0.7053 (4)	0.0299 (9)
O5	0.5621 (3)	0.7036 (8)	0.4165 (6)	0.0583 (18)
O6	0.5000	0.9205 (6)	0.3000 (7)	0.0500 (19)
O7	0.5000	0.9098 (6)	0.5395 (5)	0.0303 (13)
O8	0.5000	0.5445 (5)	0.1571 (5)	0.0192 (11)
H8A	0.5000	0.4922	0.0828	0.029*
O9	0.5000	0.2910 (6)	0.3712 (5)	0.0201 (10)
H9A	0.5000	0.1896	0.3440	0.030*
O10	0.6329 (2)	0.2327 (5)	0.1789 (4)	0.0293 (8)
H10A	0.6695	0.2468	0.1308	0.044*
H10B	0.5985	0.2025	0.1297	0.044*
N1	0.6921 (3)	0.9615 (4)	0.3464 (5)	0.0238 (10)
H1A	0.6950	0.9457	0.4356	0.029*
H1B	0.6538	1.0244	0.3276	0.029*
H1C	0.7312	1.0147	0.3174	0.029*
H1D	0.6883	0.8612	0.3052	0.029*

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

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Cd1	0.02190 (18)	0.01799 (18)	0.01954 (18)	0.00123 (11)	−0.00023 (14)	0.00305 (13)
Cd2	0.0246 (3)	0.0116 (2)	0.0161 (2)	0.000	0.000	−0.00027 (18)
S1	0.0206 (6)	0.0174 (5)	0.0172 (5)	0.0020 (4)	−0.0014 (5)	0.0002 (4)
S2	0.0299 (10)	0.0120 (7)	0.0157 (8)	0.000	0.000	−0.0020 (5)
O1	0.051 (3)	0.034 (2)	0.032 (2)	−0.014 (2)	−0.024 (2)	0.0156 (18)
O2	0.028 (2)	0.0217 (15)	0.040 (2)	−0.0028 (14)	−0.0029 (18)	−0.0014 (18)
O3	0.027 (2)	0.036 (3)	0.045 (2)	0.0036 (19)	0.0040 (16)	−0.0123 (17)
O4	0.036 (2)	0.034 (2)	0.0201 (17)	0.0036 (18)	−0.0002 (15)	−0.0073 (15)
O5	0.059 (4)	0.066 (3)	0.051 (3)	0.042 (3)	−0.027 (3)	−0.034 (3)
O6	0.120 (6)	0.016 (2)	0.014 (2)	0.000	0.000	−0.001 (3)
O7	0.063 (4)	0.011 (2)	0.016 (2)	0.000	0.000	−0.0070 (19)
O8	0.031 (3)	0.014 (2)	0.012 (2)	0.000	0.000	−0.0018 (16)
O9	0.023 (3)	0.016 (2)	0.021 (2)	0.000	0.000	0.0034 (17)
O10	0.024 (2)	0.0293 (19)	0.034 (2)	0.0021 (16)	−0.0009 (16)	−0.0066 (17)
N1	0.034 (3)	0.016 (2)	0.022 (2)	0.0022 (15)	−0.0038 (19)	−0.0032 (17)

Geometric parameters ($\text{\AA}$, $^\circ$)

Cd1—O1	2.228 (4)	S2—O6	1.444 (6)
Cd1—O8	2.266 (3)	S2—O5 ⁱⁱ	1.449 (5)
Cd1—O9	2.278 (3)	S2—O5	1.449 (5)
Cd1—O10	2.309 (4)	S2—O7	1.472 (5)
Cd1—O4 ⁱ	2.310 (4)	O4—Cd1 ^v	2.310 (4)
Cd1—O5	2.333 (5)	O6—Cd2 ^{vi}	2.358 (6)
Cd1—Cd1 ⁱⁱ	3.3439 (8)	O7—Cd2 ^{vii}	2.274 (5)
Cd2—O8 ⁱⁱⁱ	2.235 (4)	O8—Cd2 ^{vi}	2.235 (4)
Cd2—O9	2.241 (5)	O8—Cd1 ⁱⁱ	2.266 (3)
Cd2—O7 ^{iv}	2.274 (5)	O8—H8A	0.8500
Cd2—O2	2.323 (4)	O9—Cd1 ⁱⁱ	2.278 (3)
Cd2—O2 ⁱⁱ	2.323 (4)	O9—H9A	0.8501
Cd2—O6 ⁱⁱⁱ	2.358 (6)	O10—H10A	0.8500
Cd2—H9A	2.3665	O10—H10B	0.8501
S1—O3	1.456 (4)	N1—H1A	0.9000
S1—O1	1.459 (4)	N1—H1B	0.9001
S1—O4	1.468 (4)	N1—H1C	0.9001
S1—O2	1.475 (4)	N1—H1D	0.9000
O1—Cd1—O8	163.57 (18)	O2—Cd2—Cd1 ⁱⁱⁱ	120.64 (10)
O1—Cd1—O9	95.73 (17)	O2 ⁱⁱ —Cd2—Cd1 ⁱⁱⁱ	69.55 (10)
O8—Cd1—O9	80.52 (14)	O6 ⁱⁱⁱ —Cd2—Cd1 ⁱⁱⁱ	76.00 (12)
O1—Cd1—O10	94.62 (17)	Cd1 ^v —Cd2—Cd1 ⁱⁱⁱ	51.115 (14)
O8—Cd1—O10	101.21 (15)	O8 ⁱⁱⁱ —Cd2—H9A	110.1
O9—Cd1—O10	88.27 (16)	O9—Cd2—H9A	21.0
O1—Cd1—O4 ⁱ	86.03 (15)	O7 ^{iv} —Cd2—H9A	79.2
O8—Cd1—O4 ⁱ	98.85 (13)	O2—Cd2—H9A	88.0

O9—Cd1—O4 ⁱ	175.79 (16)	O2 ⁱⁱ —Cd2—H9A	88.0
O10—Cd1—O4 ⁱ	87.77 (15)	O6 ⁱⁱⁱ —Cd2—H9A	157.7
O1—Cd1—O5	79.68 (19)	Cd1 ^v —Cd2—H9A	123.7
O8—Cd1—O5	85.11 (16)	Cd1 ⁱⁱⁱ —Cd2—H9A	123.7
O9—Cd1—O5	99.2 (2)	O3—S1—O1	110.7 (3)
O10—Cd1—O5	171.0 (2)	O3—S1—O4	108.8 (3)
O4 ⁱ —Cd1—O5	84.9 (2)	O1—S1—O4	109.4 (3)
O1—Cd1—Cd1 ⁱⁱ	126.71 (14)	O3—S1—O2	108.0 (2)
O8—Cd1—Cd1 ⁱⁱ	42.45 (9)	O1—S1—O2	109.5 (3)
O9—Cd1—Cd1 ⁱⁱ	42.79 (8)	O4—S1—O2	110.3 (3)
O10—Cd1—Cd1 ⁱⁱ	111.34 (10)	O6—S2—O5 ⁱⁱ	111.2 (3)
O4 ⁱ —Cd1—Cd1 ⁱⁱ	138.11 (10)	O6—S2—O5	111.2 (3)
O5—Cd1—Cd1 ⁱⁱ	77.68 (16)	O5 ⁱⁱ —S2—O5	108.3 (6)
O1—Cd1—Cd2 ^{vi}	141.66 (12)	O6—S2—O7	110.2 (3)
O8—Cd1—Cd2 ^{vi}	30.33 (10)	O5 ⁱⁱ —S2—O7	107.9 (2)
O9—Cd1—Cd2 ^{vi}	106.86 (9)	O5—S2—O7	107.9 (2)
O10—Cd1—Cd2 ^{vi}	116.18 (10)	S1—O1—Cd1	140.5 (3)
O4 ⁱ —Cd1—Cd2 ^{vi}	73.69 (10)	S1—O2—Cd2	128.9 (2)
O5—Cd1—Cd2 ^{vi}	66.61 (14)	S1—O4—Cd1 ^v	123.9 (2)
Cd1 ⁱⁱ —Cd1—Cd2 ^{vi}	64.443 (7)	S2—O5—Cd1	130.8 (3)
O8 ⁱⁱⁱ —Cd2—O9	89.07 (18)	S2—O6—Cd2 ^{vi}	120.6 (3)
O8 ⁱⁱⁱ —Cd2—O7 ^{iv}	170.68 (18)	S2—O7—Cd2 ^{vii}	133.0 (3)
O9—Cd2—O7 ^{iv}	100.25 (17)	Cd2 ^{vi} —O8—Cd1 ⁱⁱ	118.87 (13)
O8 ⁱⁱⁱ —Cd2—O2	95.29 (9)	Cd2 ^{vi} —O8—Cd1	118.87 (13)
O9—Cd2—O2	89.88 (12)	Cd1 ⁱⁱ —O8—Cd1	95.09 (18)
O7 ^{iv} —Cd2—O2	84.82 (8)	Cd2 ^{vi} —O8—H8A	99.4
O8 ⁱⁱⁱ —Cd2—O2 ⁱⁱ	95.29 (9)	Cd1 ⁱⁱ —O8—H8A	112.7
O9—Cd2—O2 ⁱⁱ	89.88 (12)	Cd1—O8—H8A	112.7
O7 ^{iv} —Cd2—O2 ⁱⁱ	84.82 (9)	Cd2—O9—Cd1 ⁱⁱ	121.45 (15)
O2—Cd2—O2 ⁱⁱ	169.42 (18)	Cd2—O9—Cd1	121.45 (15)
O8 ⁱⁱⁱ —Cd2—O6 ⁱⁱⁱ	92.24 (18)	Cd1 ⁱⁱ —O9—Cd1	94.41 (17)
O9—Cd2—O6 ⁱⁱⁱ	178.69 (19)	Cd2—O9—H9A	87.8
O7 ^{iv} —Cd2—O6 ⁱⁱⁱ	78.44 (18)	Cd1 ⁱⁱ —O9—H9A	117.0
O2—Cd2—O6 ⁱⁱⁱ	90.00 (12)	Cd1—O9—H9A	117.0
O2 ⁱⁱ —Cd2—O6 ⁱⁱⁱ	90.00 (12)	Cd1—O10—H10A	118.4
O8 ⁱⁱⁱ —Cd2—Cd1 ^v	30.80 (7)	Cd1—O10—H10B	103.5
O9—Cd2—Cd1 ^v	105.18 (11)	H10A—O10—H10B	109.5
O7 ^{iv} —Cd2—Cd1 ^v	143.41 (9)	H1A—N1—H1B	109.5
O2—Cd2—Cd1 ^v	69.55 (10)	H1A—N1—H1C	109.5
O2 ⁱⁱ —Cd2—Cd1 ^v	120.64 (10)	H1B—N1—H1C	109.5
O6 ⁱⁱⁱ —Cd2—Cd1 ^v	76.00 (12)	H1A—N1—H1D	109.5
O8 ⁱⁱⁱ —Cd2—Cd1 ⁱⁱⁱ	30.80 (7)	H1B—N1—H1D	109.5
O9—Cd2—Cd1 ⁱⁱⁱ	105.18 (11)	H1C—N1—H1D	109.5
O7 ^{iv} —Cd2—Cd1 ⁱⁱⁱ	143.41 (9)		
O3—S1—O1—Cd1	105.4 (5)	O5—S2—O7—Cd2 ^{vii}	121.6 (4)
O4—S1—O1—Cd1	−134.6 (5)	O1—Cd1—O8—Cd2 ^{vi}	72.2 (6)
O2—S1—O1—Cd1	−13.6 (6)	O9—Cd1—O8—Cd2 ^{vi}	150.2 (2)

O8—Cd1—O1—S1	106.0 (6)	O10—Cd1—O8—Cd2 ^{vi}	−123.5 (2)
O9—Cd1—O1—S1	30.2 (6)	O4 ⁱ —Cd1—O8—Cd2 ^{vi}	−34.0 (2)
O10—Cd1—O1—S1	−58.5 (6)	O5—Cd1—O8—Cd2 ^{vi}	50.0 (3)
O4 ⁱ —Cd1—O1—S1	−146.0 (6)	Cd1 ⁱⁱ —Cd1—O8—Cd2 ^{vi}	127.1 (3)
O5—Cd1—O1—S1	128.5 (6)	O1—Cd1—O8—Cd1 ⁱⁱ	−54.8 (6)
Cd1 ⁱⁱ —Cd1—O1—S1	62.5 (6)	O9—Cd1—O8—Cd1 ⁱⁱ	23.12 (17)
Cd2 ^{vi} —Cd1—O1—S1	156.8 (4)	O10—Cd1—O8—Cd1 ⁱⁱ	109.44 (16)
O3—S1—O2—Cd2	−171.0 (3)	O4 ⁱ —Cd1—O8—Cd1 ⁱⁱ	−161.09 (15)
O1—S1—O2—Cd2	−50.3 (4)	O5—Cd1—O8—Cd1 ⁱⁱ	−77.1 (2)
O4—S1—O2—Cd2	70.2 (4)	Cd2 ^{vi} —Cd1—O8—Cd1 ⁱⁱ	−127.1 (3)
O8 ⁱⁱⁱ —Cd2—O2—S1	−18.0 (4)	O8 ⁱⁱⁱ —Cd2—O9—Cd1 ⁱⁱ	−59.33 (18)
O9—Cd2—O2—S1	71.1 (4)	O7 ^{iv} —Cd2—O9—Cd1 ⁱⁱ	120.67 (18)
O7 ^{iv} —Cd2—O2—S1	171.4 (4)	O2—Cd2—O9—Cd1 ⁱⁱ	−154.6 (2)
O2 ⁱⁱ —Cd2—O2—S1	159.8 (9)	O2 ⁱⁱ —Cd2—O9—Cd1 ⁱⁱ	36.0 (2)
O6 ⁱⁱⁱ —Cd2—O2—S1	−110.2 (4)	Cd1 ^v —Cd2—O9—Cd1 ⁱⁱ	−85.89 (17)
Cd1 ^v —Cd2—O2—S1	−35.2 (3)	Cd1 ⁱⁱⁱ —Cd2—O9—Cd1 ⁱⁱ	−32.8 (2)
Cd1 ⁱⁱⁱ —Cd2—O2—S1	−36.5 (4)	O8 ⁱⁱⁱ —Cd2—O9—Cd1	59.33 (18)
O3—S1—O4—Cd1 ^v	175.6 (3)	O7 ^{iv} —Cd2—O9—Cd1	−120.67 (18)
O1—S1—O4—Cd1 ^v	54.5 (3)	O2—Cd2—O9—Cd1	−36.0 (2)
O2—S1—O4—Cd1 ^v	−66.0 (3)	O2 ⁱⁱ —Cd2—O9—Cd1	154.6 (2)
O6—S2—O5—Cd1	−77.9 (6)	Cd1 ^v —Cd2—O9—Cd1	32.8 (2)
O5 ⁱⁱ —S2—O5—Cd1	44.7 (8)	Cd1 ⁱⁱⁱ —Cd2—O9—Cd1	85.89 (17)
O7—S2—O5—Cd1	161.1 (5)	O1—Cd1—O9—Cd2	9.6 (2)
O1—Cd1—O5—S2	−156.4 (6)	O8—Cd1—O9—Cd2	−154.3 (2)
O8—Cd1—O5—S2	17.4 (6)	O10—Cd1—O9—Cd2	104.0 (2)
O9—Cd1—O5—S2	−62.2 (6)	O5—Cd1—O9—Cd2	−70.9 (2)
O4 ⁱ —Cd1—O5—S2	116.8 (6)	Cd1 ⁱⁱ —Cd1—O9—Cd2	−131.3 (3)
Cd1 ⁱⁱ —Cd1—O5—S2	−24.9 (5)	Cd2 ^{vi} —Cd1—O9—Cd2	−139.10 (15)
Cd2 ^{vi} —Cd1—O5—S2	42.3 (5)	O1—Cd1—O9—Cd1 ⁱⁱ	140.89 (19)
O5 ⁱⁱ —S2—O6—Cd2 ^{vi}	−60.4 (3)	O8—Cd1—O9—Cd1 ⁱⁱ	−22.97 (17)
O5—S2—O6—Cd2 ^{vi}	60.4 (3)	O10—Cd1—O9—Cd1 ⁱⁱ	−124.63 (17)
O7—S2—O6—Cd2 ^{vi}	180.0	O5—Cd1—O9—Cd1 ⁱⁱ	60.45 (19)
O6—S2—O7—Cd2 ^{vii}	0.000 (2)	Cd2 ^{vi} —Cd1—O9—Cd1 ⁱⁱ	−7.76 (18)
O5 ⁱⁱ —S2—O7—Cd2 ^{vii}	−121.6 (4)		

Symmetry codes: (i) $x, -y+1, z-1/2$; (ii) $-x+1, y, z$; (iii) $-x+1, -y+1, z+1/2$; (iv) $x, y-1, z$; (v) $x, -y+1, z+1/2$; (vi) $-x+1, -y+1, z-1/2$; (vii) $x, y+1, z$.

Hydrogen-bond geometry ($\text{\AA}, ^\circ$)

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
O10—H10B $\cdots$ O7 ^{vi}	0.85	2.25	3.087 (5)	167
O10—H10B $\cdots$ O5 ⁱ	0.85	2.36	2.985 (6)	131
O9—H9A $\cdots$ O6 ^{iv}	0.85	2.18	3.029 (7)	173
O8—H8A $\cdots$ O5 ⁱ	0.85	2.56	3.322 (9)	150
O8—H8A $\cdots$ O5 ^{vi}	0.85	2.56	3.322 (9)	150
N1—H1B $\cdots$ O10 ^{vii}	0.90	2.26	2.948 (6)	133
N1—H1D $\cdots$ O4 ⁱ	0.90	2.18	3.077 (5)	180
N1—H1C $\cdots$ O4 ^{viii}	0.90	2.19	3.074 (7)	168

N1—H1A···O3 ^{ix}	0.90	2.38	2.995 (6)	126
N1—H1D···O2 ⁱ	0.90	2.64	3.196 (7)	121

Symmetry codes: (i) $x, -y+1, z-1/2$; (iv) $x, y-1, z$; (vi) $-x+1, -y+1, z-1/2$; (vii) $x, y+1, z$; (viii) $-x+3/2, -y+3/2, z-1/2$; (ix) $-x+3/2, y+1/2, z$.