

# Tris(ethylenediamine)cobalt(II) bis(tetrahydroxy-pentaborate) dihydrate

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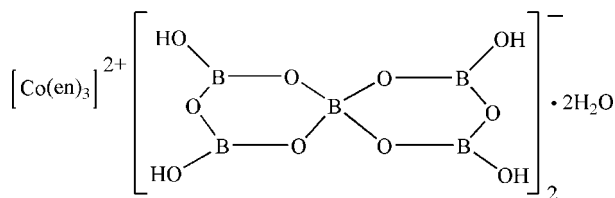
Received 13 February 2009; accepted 27 February 2009

Key indicators: single-crystal X-ray study;  $T = 293$  K; mean  $\sigma(\text{C}-\text{C}) = 0.012$  Å;  $R$  factor = 0.071;  $wR$  factor = 0.232; data-to-parameter ratio = 12.9.

The novel pentaborate with a transition-metal complex as counter-cation and with water of crystallization, tris(ethylenediamine)cobalt(II) bis[4,4',6,6'-tetrahydroxy-2,2'-spirobi(cyclotriboroxane)(1-)] dihydrate,  $[\text{Co}(\text{C}_2\text{H}_8\text{N}_2)_3][\text{B}_5\text{O}_6(\text{OH})_4]_2 \cdot 2\text{H}_2\text{O}$ , forms a three-dimensional supramolecular framework through  $\text{O}-\text{H} \cdots \text{O}$  hydrogen bonding among the  $[\text{B}_5\text{O}_6(\text{OH})_4]^-$  anions with large channels along the  $a$  axis in which the templating  $[\text{Co}(\text{en})_3]^{2+}$  cations (en = ethylenediamine) and water molecules are located. The crystal packing is consolidated by additional  $\text{O}-\text{H} \cdots \text{O}$  and  $\text{N}-\text{H} \cdots \text{O}$  hydrogen bonds.

## Related literature

For related structures, see: Liu *et al.* (2006); Sung *et al.* (2000); Touboul *et al.* (2003); Wang *et al.* (2005, 2006); Zhang *et al.* (2004). For background to the applications of borate compounds, see: Becker (1998). For related literature, see: Li *et al.* (1995, 2007).



## Experimental

### Crystal data

$[\text{Co}(\text{C}_2\text{H}_8\text{N}_2)_3][\text{B}_5\text{O}_6(\text{OH})_4]_2 \cdot 2\text{H}_2\text{O}$   
 $M_r = 711.44$   
Monoclinic,  $P2_1/c$   
 $a = 8.504$  (4) Å  
 $b = 23.127$  (10) Å  
 $c = 15.306$  (7) Å  
 $\beta = 93.549$  (7)°

$V = 3004$  (2) Å<sup>3</sup>  
 $Z = 4$   
Mo  $K\alpha$  radiation  
 $\mu = 0.67$  mm<sup>-1</sup>  
 $T = 293$  K  
 $0.50 \times 0.47 \times 0.29$  mm

### Data collection

Bruker SMART CCD area-detector diffractometer  
Absorption correction: multi-scan *SADABS* (Bruker, 2001)  
 $T_{\min} = 0.732$ ,  $T_{\max} = 0.830$   
15470 measured reflections  
5252 independent reflections  
2809 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.054$

### Refinement

$R[F^2 > 2\sigma(F^2)] = 0.071$   
 $wR(F^2) = 0.232$   
 $S = 1.02$   
5252 reflections  
406 parameters  
9 restraints  
H-atom parameters constrained  
 $\Delta\rho_{\max} = 1.68$  e Å<sup>-3</sup>  
 $\Delta\rho_{\min} = -0.70$  e Å<sup>-3</sup>

Table 1

Hydrogen-bond geometry (Å, °).

$D-\text{H} \cdots A$	$D-\text{H}$	$\text{H} \cdots A$	$D \cdots A$	$D-\text{H} \cdots A$
$\text{N1}-\text{H1A} \cdots \text{O15}^{\text{i}}$	0.90	2.36	3.188 (7)	154
$\text{N1}-\text{H1A} \cdots \text{O19}^{\text{j}}$	0.90	2.64	3.425 (7)	147
$\text{N1}-\text{H1B} \cdots \text{O11}^{\text{ii}}$	0.90	2.38	3.276 (7)	174
$\text{N2}-\text{H2A} \cdots \text{O8}^{\text{iii}}$	0.90	2.23	3.089 (7)	159
$\text{N2}-\text{H2B} \cdots \text{O21}^{\text{iv}}$	0.90	2.18	3.030 (10)	157
$\text{N3}-\text{H3A} \cdots \text{O2}^{\text{iii}}$	0.90	2.23	3.074 (7)	157
$\text{N4}-\text{H4A} \cdots \text{O20}^{\text{j}}$	0.90	2.49	3.199 (7)	136
$\text{N5}-\text{H5B} \cdots \text{O7}^{\text{iii}}$	0.90	2.34	3.085 (7)	140
$\text{N6}-\text{H6A} \cdots \text{O20}^{\text{j}}$	0.90	2.42	3.302 (7)	168
$\text{N6}-\text{H6B} \cdots \text{O22}^{\text{iv}}$	0.90	2.38	3.235 (12)	158
$\text{O7}-\text{H7} \cdots \text{O16}^{\text{v}}$	0.82	1.84	2.647 (5)	170
$\text{O8}-\text{H8} \cdots \text{O3}^{\text{iii}}$	0.82	1.87	2.687 (5)	170
$\text{O10}-\text{H10} \cdots \text{O13}^{\text{vi}}$	0.82	1.94	2.753 (6)	172
$\text{O18}-\text{H18} \cdots \text{O6}^{\text{vii}}$	0.82	1.88	2.687 (6)	170
$\text{O19}-\text{H19} \cdots \text{O14}^{\text{l}}$	0.82	1.89	2.691 (5)	164
$\text{O20}-\text{H20} \cdots \text{O1}^{\text{viii}}$	0.82	1.91	2.725 (5)	170
$\text{O22}-\text{H3} \cdots \text{O19}^{\text{ix}}$	0.85	2.45	2.993 (11)	122

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

Data collection: *SMART* (Bruker, 2001); cell refinement: *SAINT* (Bruker, 2001); 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: *SHELXTL*.

We acknowledge the Scientific Research Projects of Higher Education of Inner Mongolia (NJzy08217).

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: PV2140).

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**supplementary materials**

*Acta Cryst.* (2009). E65, m368 [ doi:10.1107/S1600536809007296 ]

## Tris(ethylenediamine)cobalt(II) bis(tetrahydroxypentaborate) dihydrate

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### Comment

The interest in borate compounds has been steadily growing because of their rich structural chemistry and interesting physical properties, such as nonlinear optical behavior for  $\beta$ -BaB<sub>2</sub>O<sub>4</sub> (BBO) and CsB<sub>3</sub>O<sub>5</sub>(CBO). To date, various metal borate systems including alkali metals, alkaline earth metals, rare earth and transition metals have been extensively studied. In contrast, the transition-metal complex templated borates are less explored. Only few such compounds such as [Cu(en)<sub>2</sub>][B<sub>7</sub>O<sub>13</sub>H<sub>3</sub>]<sub>n</sub> (Sung *et al.*, 2000), [Mn(C<sub>10</sub>H<sub>28</sub>N<sub>6</sub>)] [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub> (Zhang *et al.*, 2004), [Zn(DIEN)<sub>2</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub>, [B<sub>5</sub>O<sub>7</sub>(OH)<sub>3</sub>Zn(TREN)] (Wang *et al.*, 2005), [Co(DIEN)<sub>2</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub>, [B<sub>5</sub>O<sub>7</sub>(OH)<sub>3</sub>Co(TREN)], [Co<sub>2</sub>(TETA)<sub>3</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>4</sub> (Wang, *et al.*, 2006), and [Ni(C<sub>4</sub>H<sub>10</sub>N<sub>2</sub>)(C<sub>2</sub>H<sub>8</sub>N<sub>2</sub>)<sub>2</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub> (Liu *et al.*, 2006), have been reported. Many of such compounds were pentaborates and did not contain any crystalline water. In this work, we report the synthesis and structure of a novel hydrated borate, [Co(en)<sub>3</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub>·2H<sub>2</sub>O.

Single crystal X-ray analysis reveals that the title complex consists of one [Co(en)<sub>3</sub>]<sup>2+</sup>, two [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sup>-</sup> polyborate anions and two lattice water molecules as shown in Figure 1. The Co<sup>2+</sup> ion is bonded to six N atoms of three ligands of ethylenediamine molecules forming an octahedron. The Co—N distances range from 2.139 (6) to 0.2241 (6) Å and the N—Co—N angles are between 77.9 (2)–97.6 (2) and 165.1 (2)–172.7 (2)°. The isolated pentaborate anion is characterized by two B<sub>3</sub>O<sub>3</sub> rings that are linked by one common BO<sub>4</sub> tetrahedron. Each ring is formed by two BO<sub>3</sub> triangles and one slightly distorted common BO<sub>4</sub> tetrahedron. The terminal oxygen atoms are protonated. The bond distances B—O and bond angles O—B—O involving the tetrahedral B atoms (B1 and B6) range from 1.451 (8) to 1.488 (7) Å, and 107.5 (4) to 111.6 (4)°, respectively; the corresponding molecular dimensions for the trigonal B atoms (B2–B5 and B7–B10) are 1.347 (7)–1.385 (7) Å and 115.4 (4)–123.7 (5)°. The isolated pentaborate polyanion [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sup>-</sup> is also present in some alkali metal hydrated borates, such as *M*[B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]·2H<sub>2</sub>O (*M* = K, Rb, Cs, NH<sub>4</sub><sup>+</sup>) (Touboul *et al.*, 2003).

The [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sup>-</sup> anions are further connected through O—H···O hydrogen-bonding interactions of the hydroxyl groups with the bridged-oxygen atoms or the hydroxyl groups from other [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sup>-</sup> anions, forming a three-dimensional framework with channels along the *a* & *c*-axes. Especially, there are large channels containing a 12-membered boron rings along the *a*-axis, between which [Co(en)<sub>3</sub>]<sup>2+</sup> cations and lattice water molecules are intercalated (Fig. 2). The [Co(en)<sub>3</sub>]<sup>2+</sup> cations and lattice water molecules are located in the inorganic channels and interact with the polyborate framework both electrostatically and *via* hydrogen bonds N—H···O, with N···O distances in the range 3.030 (10) - 3.425 (7) Å. In addition, the H<sub>2</sub>O molecules interact not only with [Co(en)<sub>3</sub>]<sup>2+</sup> cations through N—H···O but also with [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sup>-</sup> anions through O—H···O; details of hydrogen bonds have been provided in Table 1.

## supplementary materials

The complex is a new pentaborate and features a three-dimensional supramolecular framework with large channels along the *a*-axis through O—H $\cdots$ O hydrogen-bonding among the [B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sup>-</sup> anions. These results enrich the field of structural chemistry of borates.

### Experimental

All reagents used in the synthesis were analytic grade and were used without further purification. A mixture of CoSO<sub>4</sub>·7H<sub>2</sub>O (0.7028 g), H<sub>3</sub>BO<sub>3</sub> (1.3724 g) and ethylenediamine (8.5 mL) was sealed in a 25 mL Teflon-lined stainless steel autoclave, and heated at 447 K for 7 days under autogenous pressure, then cooled to room temperature. The resulting orange columnar crystals suitable for single-crystal X-ray diffraction were obtained.

### Refinement

H atoms were positioned geometrically, and were placed in calculated positions in riding mode with hydroxy O—H = 0.82, water of crystallization O—H = 0.085 (using DFIX commands), amine N—H = 0.90 and methylene C—H = 0.97 Å and isotropic U<sub>iso</sub> = 1.5U<sub>eq</sub>(hydroxy O) and 1.2U<sub>eq</sub>(the rest of the parent atoms). The final difference map showed residual electron density in the close proximity of Co-atom and was essentially meaningless.

### Figures

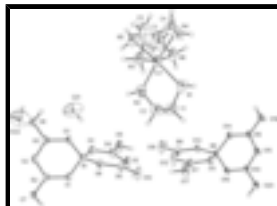


Fig. 1. The asymmetric unit structure of [Co(en)<sub>3</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub> · 2 H<sub>2</sub>O. Displacement ellipsoids are drawn at the 30% probability level.

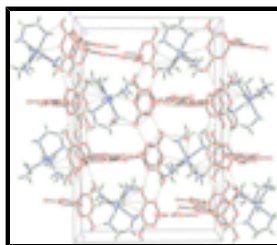


Fig. 2. View along axis *a* of [Co(en)<sub>3</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub> · 2 H<sub>2</sub>O, showing 12 - membered boron rings constructed by O—H $\cdots$ O hydrogen bonds.

### Tris(ethylenediamine)cobalt(II) bis(tetrahydroxypentaborate) dihydrate

#### Crystal data

[Co(C<sub>2</sub>H<sub>8</sub>N<sub>2</sub>)<sub>3</sub>][B<sub>5</sub>O<sub>6</sub>(OH)<sub>4</sub>]<sub>2</sub>·2H<sub>2</sub>O

*M<sub>r</sub>* = 711.44

Monoclinic, *P*2<sub>1</sub>/*c*

Hall symbol: -*P* 2ybc

*a* = 8.504 (4) Å

*b* = 23.127 (10) Å

*F*<sub>000</sub> = 1468

*D<sub>x</sub>* = 1.573 Mg m<sup>-3</sup>

Mo *K*α radiation

λ = 0.71073 Å

Cell parameters from 2705 reflections

θ = 2.2–23.6°

μ = 0.67 mm<sup>-1</sup>



## supplementary materials

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Co1	0.43617 (9)	0.63869 (4)	0.77983 (5)	0.0537 (3)
B1	0.1368 (7)	0.3764 (3)	0.5439 (4)	0.0351 (15)
B2	-0.0462 (7)	0.3228 (3)	0.4381 (4)	0.0362 (14)
B3	-0.0621 (8)	0.4253 (3)	0.4431 (4)	0.0454 (17)
B4	0.4227 (8)	0.3736 (3)	0.5801 (4)	0.0438 (17)
B5	0.2513 (7)	0.3623 (3)	0.6949 (4)	0.0417 (16)
B6	0.9279 (7)	0.3764 (2)	0.9264 (4)	0.0354 (15)
B7	0.6432 (8)	0.3663 (3)	0.8895 (4)	0.0427 (16)
B8	0.8133 (8)	0.3742 (3)	0.7739 (4)	0.0456 (17)
B9	1.1260 (8)	0.4291 (3)	1.0232 (4)	0.0440 (17)
B10	1.1424 (8)	0.3266 (3)	1.0171 (4)	0.0386 (15)
N1	0.4478 (7)	0.5823 (3)	0.8935 (3)	0.0678 (16)
H1A	0.5470	0.5814	0.9176	0.081*
H1B	0.3846	0.5960	0.9337	0.081*
N2	0.4191 (7)	0.5563 (3)	0.7164 (4)	0.0756 (18)
H2A	0.3213	0.5514	0.6915	0.091*
H2B	0.4878	0.5545	0.6741	0.091*
N3	0.1854 (6)	0.6528 (3)	0.7892 (4)	0.0673 (16)
H3A	0.1359	0.6498	0.7357	0.081*
H3B	0.1462	0.6255	0.8237	0.081*
N4	0.4324 (7)	0.7182 (3)	0.8632 (4)	0.084 (2)
H4A	0.4961	0.7131	0.9118	0.100*
H4B	0.4689	0.7485	0.8336	0.100*
N5	0.4420 (6)	0.6870 (3)	0.6575 (4)	0.0741 (18)
H5A	0.4242	0.6628	0.6119	0.089*
H5B	0.3657	0.7140	0.6550	0.089*
N6	0.6878 (6)	0.6488 (3)	0.7685 (4)	0.0733 (18)
H6A	0.7290	0.6692	0.8145	0.088*
H6B	0.7339	0.6137	0.7697	0.088*
O1	0.0701 (4)	0.32294 (14)	0.5030 (2)	0.0375 (9)
O2	-0.1085 (5)	0.37366 (15)	0.4055 (3)	0.0552 (12)
O3	0.0455 (4)	0.42693 (14)	0.5118 (2)	0.0400 (9)
O4	0.3000 (4)	0.38294 (16)	0.5216 (2)	0.0426 (10)
O5	0.4009 (4)	0.3580 (2)	0.6644 (2)	0.0558 (12)
O6	0.1250 (4)	0.37288 (15)	0.6392 (2)	0.0373 (9)
O7	-0.1035 (5)	0.27447 (15)	0.3988 (3)	0.0503 (11)
H7	-0.0574	0.2462	0.4202	0.075*
O8	-0.1303 (6)	0.47363 (17)	0.4077 (3)	0.0774 (17)
H8	-0.0942	0.5022	0.4336	0.116*
O9	0.5727 (5)	0.3794 (2)	0.5539 (3)	0.0638 (13)
H9	0.6359	0.3723	0.5951	0.096*
O10	0.2410 (5)	0.3565 (2)	0.7824 (2)	0.0609 (13)
H10	0.1489	0.3600	0.7944	0.091*
O11	0.7650 (4)	0.37226 (15)	0.9490 (2)	0.0409 (9)
O12	0.6659 (5)	0.3664 (2)	0.8021 (3)	0.0683 (15)
O13	0.9406 (4)	0.37903 (14)	0.8307 (2)	0.0377 (9)
O14	0.9985 (4)	0.42903 (14)	0.9664 (2)	0.0399 (9)
O15	1.2021 (5)	0.37858 (15)	1.0477 (3)	0.0507 (11)
O16	1.0164 (4)	0.32445 (15)	0.9591 (2)	0.0407 (10)

O17	0.4946 (4)	0.36107 (19)	0.9168 (3)	0.0580 (12)
H17	0.4319	0.3579	0.8742	0.087*
O18	0.8250 (5)	0.3745 (2)	0.6850 (2)	0.0691 (15)
H18	0.9178	0.3779	0.6740	0.104*
O19	1.1888 (5)	0.47805 (17)	1.0601 (3)	0.0717 (15)
H19	1.1376	0.5061	1.0422	0.108*
O20	1.2153 (4)	0.27831 (15)	1.0506 (2)	0.0466 (10)
H20	1.1709	0.2495	1.0300	0.070*
O21	0.3273 (11)	0.4825 (3)	0.4013 (6)	0.177 (4)
H1	0.3714	0.4538	0.4274	0.213*
H2	0.2390	0.4810	0.4243	0.213*
O22	0.0595 (11)	0.4556 (4)	0.2344 (6)	0.202 (4)
H3	0.1211	0.4802	0.2134	0.243*
H4	-0.0011	0.4738	0.2670	0.243*
C1	0.3987 (12)	0.5242 (4)	0.8680 (5)	0.097 (3)
H1C	0.2847	0.5215	0.8662	0.117*
H1D	0.4418	0.4966	0.9107	0.117*
C2	0.4543 (13)	0.5106 (4)	0.7813 (6)	0.109 (3)
H2C	0.5673	0.5043	0.7869	0.131*
H2D	0.4054	0.4749	0.7604	0.131*
C3	0.1559 (10)	0.7101 (4)	0.8256 (6)	0.103 (3)
H3C	0.1426	0.7377	0.7780	0.124*
H3D	0.0583	0.7090	0.8552	0.124*
C4	0.2810 (9)	0.7299 (3)	0.8866 (6)	0.083 (2)
H4C	0.2704	0.7713	0.8937	0.100*
H4D	0.2670	0.7122	0.9430	0.100*
C5	0.5921 (9)	0.7141 (4)	0.6522 (5)	0.078 (2)
H5C	0.5925	0.7504	0.6839	0.094*
H5D	0.6086	0.7227	0.5914	0.094*
C6	0.7205 (9)	0.6782 (5)	0.6879 (5)	0.105 (3)
H6C	0.7448	0.6495	0.6445	0.126*
H6D	0.8132	0.7022	0.6986	0.126*

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

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
Co1	0.0375 (5)	0.0835 (7)	0.0385 (5)	-0.0089 (4)	-0.0091 (3)	0.0043 (4)
B1	0.035 (3)	0.035 (4)	0.034 (3)	-0.001 (3)	-0.013 (3)	0.000 (3)
B2	0.039 (3)	0.035 (4)	0.034 (3)	0.001 (3)	-0.008 (3)	0.001 (3)
B3	0.051 (4)	0.035 (4)	0.048 (4)	0.005 (3)	-0.024 (3)	-0.006 (3)
B4	0.035 (4)	0.057 (5)	0.038 (4)	0.000 (3)	-0.005 (3)	-0.004 (3)
B5	0.033 (3)	0.060 (4)	0.031 (3)	0.004 (3)	-0.009 (3)	-0.003 (3)
B6	0.040 (4)	0.031 (4)	0.032 (3)	0.002 (3)	-0.018 (3)	-0.002 (2)
B7	0.043 (4)	0.048 (4)	0.036 (4)	0.002 (3)	-0.008 (3)	0.000 (3)
B8	0.035 (4)	0.063 (5)	0.036 (4)	0.006 (3)	-0.011 (3)	-0.002 (3)
B9	0.043 (4)	0.034 (4)	0.051 (4)	0.003 (3)	-0.023 (3)	-0.006 (3)
B10	0.044 (4)	0.032 (4)	0.038 (3)	0.004 (3)	-0.007 (3)	-0.003 (3)
N1	0.060 (4)	0.088 (5)	0.055 (3)	0.001 (3)	-0.009 (3)	-0.003 (3)

## supplementary materials

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N2	0.079 (4)	0.095 (5)	0.051 (3)	0.008 (4)	-0.007 (3)	-0.015 (3)
N3	0.053 (3)	0.086 (4)	0.062 (4)	-0.006 (3)	0.001 (3)	0.000 (3)
N4	0.069 (4)	0.108 (5)	0.074 (4)	-0.009 (4)	0.005 (3)	-0.029 (4)
N5	0.052 (4)	0.108 (5)	0.061 (4)	0.001 (3)	-0.002 (3)	0.016 (3)
N6	0.046 (3)	0.125 (5)	0.048 (3)	0.002 (3)	-0.007 (3)	-0.002 (3)
O1	0.041 (2)	0.031 (2)	0.039 (2)	0.0017 (16)	-0.0158 (17)	-0.0017 (16)
O2	0.065 (3)	0.036 (2)	0.059 (3)	0.0065 (19)	-0.043 (2)	-0.0046 (19)
O3	0.044 (2)	0.032 (2)	0.041 (2)	0.0039 (17)	-0.0202 (17)	-0.0004 (16)
O4	0.035 (2)	0.057 (3)	0.034 (2)	-0.0018 (18)	-0.0074 (17)	0.0067 (17)
O5	0.031 (2)	0.103 (3)	0.033 (2)	0.011 (2)	-0.0068 (17)	0.008 (2)
O6	0.0293 (19)	0.048 (2)	0.033 (2)	0.0043 (16)	-0.0077 (15)	-0.0029 (16)
O7	0.058 (2)	0.027 (2)	0.061 (3)	0.0002 (18)	-0.033 (2)	-0.0043 (18)
O8	0.103 (4)	0.031 (2)	0.088 (3)	0.012 (2)	-0.072 (3)	-0.006 (2)
O9	0.035 (2)	0.111 (4)	0.045 (3)	0.001 (2)	-0.0018 (19)	0.007 (2)
O10	0.033 (2)	0.121 (4)	0.027 (2)	0.007 (2)	-0.0088 (16)	0.004 (2)
O11	0.041 (2)	0.051 (2)	0.030 (2)	-0.0008 (17)	-0.0092 (17)	0.0005 (16)
O12	0.033 (2)	0.142 (5)	0.029 (2)	-0.002 (2)	-0.0065 (18)	-0.008 (2)
O13	0.035 (2)	0.044 (2)	0.033 (2)	-0.0007 (16)	-0.0104 (16)	-0.0009 (16)
O14	0.045 (2)	0.029 (2)	0.043 (2)	0.0052 (17)	-0.0198 (17)	-0.0065 (16)
O15	0.050 (2)	0.033 (2)	0.064 (3)	0.0054 (18)	-0.034 (2)	-0.0065 (18)
O16	0.044 (2)	0.029 (2)	0.046 (2)	0.0010 (16)	-0.0230 (18)	-0.0024 (16)
O17	0.034 (2)	0.102 (4)	0.038 (2)	-0.013 (2)	-0.0004 (18)	-0.003 (2)
O18	0.031 (2)	0.146 (5)	0.029 (2)	-0.001 (2)	-0.0071 (17)	-0.002 (2)
O19	0.075 (3)	0.033 (2)	0.099 (4)	0.006 (2)	-0.056 (3)	-0.013 (2)
O20	0.046 (2)	0.034 (2)	0.055 (2)	0.0063 (17)	-0.0273 (19)	-0.0023 (18)
O21	0.229 (10)	0.141 (7)	0.173 (8)	0.035 (6)	0.103 (7)	0.032 (6)
O22	0.230 (8)	0.187 (7)	0.200 (7)	-0.038 (6)	0.088 (6)	-0.015 (6)
C1	0.136 (8)	0.084 (7)	0.071 (6)	-0.001 (6)	0.006 (5)	0.011 (5)
C2	0.161 (10)	0.066 (6)	0.099 (7)	0.003 (6)	-0.012 (7)	-0.001 (5)
C3	0.080 (6)	0.143 (9)	0.087 (6)	0.024 (6)	0.007 (5)	-0.025 (6)
C4	0.079 (6)	0.068 (5)	0.103 (6)	0.000 (4)	0.005 (5)	-0.003 (5)
C5	0.077 (5)	0.097 (6)	0.061 (5)	-0.022 (5)	0.003 (4)	0.009 (4)
C6	0.058 (5)	0.184 (11)	0.072 (6)	-0.014 (6)	0.005 (4)	0.011 (6)

### *Geometric parameters (Å, °)*

Co1—N2	2.139 (6)	N2—H2A	0.9000
Co1—N6	2.170 (6)	N2—H2B	0.9000
Co1—N3	2.171 (6)	N3—C3	1.465 (10)
Co1—N1	2.172 (6)	N3—H3A	0.9000
Co1—N5	2.183 (5)	N3—H3B	0.9000
Co1—N4	2.241 (6)	N4—C4	1.384 (9)
B1—O4	1.457 (7)	N4—H4A	0.9000
B1—O6	1.470 (7)	N4—H4B	0.9000
B1—O3	1.471 (7)	N5—C5	1.429 (9)
B1—O1	1.483 (7)	N5—H5A	0.9000
B2—O7	1.347 (7)	N5—H5B	0.9000
B2—O1	1.357 (6)	N6—C6	1.451 (10)
B2—O2	1.370 (7)	N6—H6A	0.9000

B3—O3	1.351 (6)	N6—H6B	0.9000
B3—O8	1.356 (7)	O7—H7	0.8200
B3—O2	1.373 (7)	O8—H8	0.8200
B4—O4	1.350 (7)	O9—H9	0.8200
B4—O5	1.363 (8)	O10—H10	0.8200
B4—O9	1.367 (8)	O17—H17	0.8200
B5—O6	1.352 (7)	O18—H18	0.8200
B5—O10	1.355 (7)	O19—H19	0.8200
B5—O5	1.385 (8)	O20—H20	0.8200
B6—O11	1.451 (8)	O21—H1	0.8502
B6—O14	1.473 (6)	O21—H2	0.8503
B6—O13	1.478 (7)	O22—H3	0.8499
B6—O16	1.488 (7)	O22—H4	0.8501
B7—O11	1.344 (7)	C1—C2	1.470 (10)
B7—O17	1.361 (8)	C1—H1C	0.9700
B7—O12	1.364 (8)	C1—H1D	0.9700
B8—O13	1.350 (7)	C2—H2C	0.9700
B8—O12	1.363 (8)	C2—H2D	0.9700
B8—O18	1.371 (8)	C3—C4	1.445 (10)
B9—O14	1.347 (6)	C3—H3C	0.9700
B9—O19	1.359 (7)	C3—H3D	0.9700
B9—O15	1.377 (7)	C4—H4C	0.9700
B10—O16	1.349 (7)	C4—H4D	0.9700
B10—O20	1.362 (7)	C5—C6	1.452 (10)
B10—O15	1.376 (7)	C5—H5C	0.9700
N1—C1	1.452 (10)	C5—H5D	0.9700
N1—H1A	0.9000	C6—H6C	0.9700
N1—H1B	0.9000	C6—H6D	0.9700
N2—C2	1.470 (10)		
N2—Co1—N6	95.7 (3)	Co1—N4—H4B	109.5
N2—Co1—N3	97.2 (2)	H4A—N4—H4B	108.1
N6—Co1—N3	165.1 (3)	C5—N5—Co1	110.0 (4)
N2—Co1—N1	80.0 (2)	C5—N5—H5A	109.7
N6—Co1—N1	97.6 (2)	Co1—N5—H5A	109.7
N3—Co1—N1	91.9 (2)	C5—N5—H5B	109.7
N2—Co1—N5	94.0 (2)	Co1—N5—H5B	109.7
N6—Co1—N5	78.6 (2)	H5A—N5—H5B	108.2
N3—Co1—N5	93.1 (2)	C6—N6—Co1	111.1 (4)
N1—Co1—N5	172.7 (2)	C6—N6—H6A	109.4
N2—Co1—N4	170.7 (2)	Co1—N6—H6A	109.4
N6—Co1—N4	90.3 (2)	C6—N6—H6B	109.4
N3—Co1—N4	77.9 (2)	Co1—N6—H6B	109.4
N1—Co1—N4	92.2 (2)	H6A—N6—H6B	108.0
N5—Co1—N4	94.1 (3)	B2—O1—B1	123.6 (4)
O4—B1—O6	111.3 (4)	B2—O2—B3	120.0 (4)
O4—B1—O3	109.2 (4)	B3—O3—B1	123.8 (4)
O6—B1—O3	108.0 (4)	B4—O4—B1	122.4 (5)
O4—B1—O1	109.4 (5)	B4—O5—B5	118.7 (5)
O6—B1—O1	109.0 (4)	B5—O6—B1	122.3 (5)

## supplementary materials

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O3—B1—O1	109.9 (4)	B2—O7—H7	109.5
O7—B2—O1	123.7 (5)	B3—O8—H8	109.5
O7—B2—O2	115.4 (4)	B4—O9—H9	109.5
O1—B2—O2	120.8 (5)	B5—O10—H10	109.5
O3—B3—O8	122.7 (5)	B7—O11—B6	123.5 (5)
O3—B3—O2	120.9 (5)	B8—O12—B7	120.0 (5)
O8—B3—O2	116.4 (4)	B8—O13—B6	122.0 (5)
O4—B4—O5	121.7 (6)	B9—O14—B6	124.1 (4)
O4—B4—O9	119.1 (6)	B10—O15—B9	119.4 (4)
O5—B4—O9	119.2 (5)	B10—O16—B6	123.8 (4)
O6—B5—O10	122.9 (5)	B7—O17—H17	109.5
O6—B5—O5	120.8 (5)	B8—O18—H18	109.5
O10—B5—O5	116.3 (5)	B9—O19—H19	109.5
O11—B6—O14	109.0 (5)	B10—O20—H20	109.5
O11—B6—O13	111.6 (4)	H2—O21—H1	98.5
O14—B6—O13	109.0 (4)	H3—O22—H4	107.6
O11—B6—O16	109.7 (5)	N1—C1—C2	109.7 (7)
O14—B6—O16	110.0 (4)	N1—C1—H1C	109.7
O13—B6—O16	107.5 (4)	C2—C1—H1C	109.7
O11—B7—O17	119.5 (5)	N1—C1—H1D	109.7
O11—B7—O12	121.0 (6)	C2—C1—H1D	109.7
O17—B7—O12	119.5 (5)	H1C—C1—H1D	108.2
O13—B8—O12	121.6 (6)	N2—C2—C1	113.1 (7)
O13—B8—O18	122.3 (6)	N2—C2—H2C	109.0
O12—B8—O18	116.1 (5)	C1—C2—H2C	109.0
O14—B9—O19	123.4 (5)	N2—C2—H2D	109.0
O14—B9—O15	121.4 (5)	C1—C2—H2D	109.0
O19—B9—O15	115.3 (4)	H2C—C2—H2D	107.8
O16—B10—O20	122.8 (5)	C4—C3—N3	113.3 (7)
O16—B10—O15	121.1 (5)	C4—C3—H3C	108.9
O20—B10—O15	116.0 (5)	N3—C3—H3C	108.9
C1—N1—Co1	110.0 (4)	C4—C3—H3D	108.9
C1—N1—H1A	109.7	N3—C3—H3D	108.9
Co1—N1—H1A	109.7	H3C—C3—H3D	107.7
C1—N1—H1B	109.7	N4—C4—C3	115.5 (7)
Co1—N1—H1B	109.7	N4—C4—H4C	108.4
H1A—N1—H1B	108.2	C3—C4—H4C	108.4
C2—N2—Co1	109.2 (4)	N4—C4—H4D	108.4
C2—N2—H2A	109.8	C3—C4—H4D	108.4
Co1—N2—H2A	109.8	H4C—C4—H4D	107.5
C2—N2—H2B	109.8	N5—C5—C6	112.4 (7)
Co1—N2—H2B	109.8	N5—C5—H5C	109.1
H2A—N2—H2B	108.3	C6—C5—H5C	109.1
C3—N3—Co1	110.7 (5)	N5—C5—H5D	109.1
C3—N3—H3A	109.5	C6—C5—H5D	109.1
Co1—N3—H3A	109.5	H5C—C5—H5D	107.9
C3—N3—H3B	109.5	N6—C6—C5	114.1 (7)
Co1—N3—H3B	109.5	N6—C6—H6C	108.7
H3A—N3—H3B	108.1	C5—C6—H6C	108.7

C4—N4—Co1	110.7 (5)	N6—C6—H6D	108.7
C4—N4—H4A	109.5	C5—C6—H6D	108.7
Co1—N4—H4A	109.5	H6C—C6—H6D	107.6
C4—N4—H4B	109.5		
N2—Co1—N1—C1	-14.4 (5)	O9—B4—O5—B5	168.5 (6)
N6—Co1—N1—C1	-108.9 (5)	O6—B5—O5—B4	10.5 (9)
N3—Co1—N1—C1	82.5 (5)	O10—B5—O5—B4	-168.4 (6)
N4—Co1—N1—C1	160.5 (5)	O10—B5—O6—B1	-177.1 (5)
N6—Co1—N2—C2	86.2 (6)	O5—B5—O6—B1	4.2 (8)
N3—Co1—N2—C2	-101.2 (6)	O4—B1—O6—B5	-15.5 (7)
N1—Co1—N2—C2	-10.5 (6)	O3—B1—O6—B5	-135.4 (5)
N5—Co1—N2—C2	165.1 (6)	O1—B1—O6—B5	105.3 (6)
N2—Co1—N3—C3	-175.7 (5)	O17—B7—O11—B6	178.1 (5)
N6—Co1—N3—C3	-25.9 (11)	O12—B7—O11—B6	-3.0 (9)
N1—Co1—N3—C3	104.1 (5)	O14—B6—O11—B7	126.0 (5)
N5—Co1—N3—C3	-81.2 (5)	O13—B6—O11—B7	5.6 (7)
N4—Co1—N3—C3	12.2 (5)	O16—B6—O11—B7	-113.4 (5)
N6—Co1—N4—C4	178.9 (6)	O13—B8—O12—B7	3.4 (9)
N3—Co1—N4—C4	8.1 (6)	O18—B8—O12—B7	-179.2 (6)
N1—Co1—N4—C4	-83.4 (6)	O11—B7—O12—B8	-1.8 (9)
N5—Co1—N4—C4	100.4 (6)	O17—B7—O12—B8	177.1 (6)
N2—Co1—N5—C5	-113.7 (5)	O12—B8—O13—B6	-0.3 (9)
N6—Co1—N5—C5	-18.7 (5)	O18—B8—O13—B6	-177.6 (5)
N3—Co1—N5—C5	148.9 (5)	O11—B6—O13—B8	-3.9 (7)
N4—Co1—N5—C5	70.8 (5)	O14—B6—O13—B8	-124.4 (5)
N2—Co1—N6—C6	90.4 (6)	O16—B6—O13—B8	116.4 (5)
N3—Co1—N6—C6	-59.5 (11)	O19—B9—O14—B6	-179.4 (6)
N1—Co1—N6—C6	171.1 (6)	O15—B9—O14—B6	0.6 (10)
N5—Co1—N6—C6	-2.6 (6)	O11—B6—O14—B9	121.2 (6)
N4—Co1—N6—C6	-96.6 (6)	O13—B6—O14—B9	-116.7 (6)
O7—B2—O1—B1	177.7 (5)	O16—B6—O14—B9	0.9 (8)
O2—B2—O1—B1	0.8 (9)	O16—B10—O15—B9	4.1 (9)
O4—B1—O1—B2	-112.9 (5)	O20—B10—O15—B9	-174.0 (6)
O6—B1—O1—B2	125.2 (5)	O14—B9—O15—B10	-3.2 (10)
O3—B1—O1—B2	7.0 (7)	O19—B9—O15—B10	176.8 (6)
O7—B2—O2—B3	177.7 (6)	O20—B10—O16—B6	175.5 (5)
O1—B2—O2—B3	-5.1 (9)	O15—B10—O16—B6	-2.6 (9)
O3—B3—O2—B2	0.5 (10)	O11—B6—O16—B10	-119.9 (6)
O8—B3—O2—B2	-179.3 (6)	O14—B6—O16—B10	0.1 (8)
O8—B3—O3—B1	-171.5 (6)	O13—B6—O16—B10	118.6 (5)
O2—B3—O3—B1	8.8 (10)	Co1—N1—C1—C2	36.8 (9)
O4—B1—O3—B3	108.3 (6)	Co1—N2—C2—C1	34.8 (9)
O6—B1—O3—B3	-130.6 (6)	N1—C1—C2—N2	-48.5 (11)
O1—B1—O3—B3	-11.8 (8)	Co1—N3—C3—C4	-31.1 (9)
O5—B4—O4—B1	-0.7 (9)	Co1—N4—C4—C3	-28.2 (10)
O9—B4—O4—B1	178.5 (5)	N3—C3—C4—N4	40.7 (11)
O6—B1—O4—B4	13.8 (7)	Co1—N5—C5—C6	37.6 (8)
O3—B1—O4—B4	132.9 (5)	Co1—N6—C6—C5	23.9 (9)
O1—B1—O4—B4	-106.7 (6)	N5—C5—C6—N6	-41.8 (10)

## supplementary materials

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O4—B4—O5—B5

-12.3 (9)

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

<i>D</i> —H $\cdots$ <i>A</i>	<i>D</i> —H	H $\cdots$ <i>A</i>	<i>D</i> $\cdots$ <i>A</i>	<i>D</i> —H $\cdots$ <i>A</i>
N1—H1A $\cdots$ O15 <sup>i</sup>	0.90	2.36	3.188 (7)	154
N1—H1A $\cdots$ O19 <sup>i</sup>	0.90	2.64	3.425 (7)	147
N1—H1B $\cdots$ O11 <sup>ii</sup>	0.90	2.38	3.276 (7)	174
N2—H2A $\cdots$ O8 <sup>iii</sup>	0.90	2.23	3.089 (7)	159
N2—H2B $\cdots$ O21 <sup>iv</sup>	0.90	2.18	3.030 (10)	157
N3—H3A $\cdots$ O2 <sup>iii</sup>	0.90	2.23	3.074 (7)	157
N4—H4A $\cdots$ O20 <sup>i</sup>	0.90	2.49	3.199 (7)	136
N5—H5B $\cdots$ O7 <sup>iii</sup>	0.90	2.34	3.085 (7)	140
N6—H6A $\cdots$ O20 <sup>i</sup>	0.90	2.42	3.302 (7)	168
N6—H6B $\cdots$ O22 <sup>iv</sup>	0.90	2.38	3.235 (12)	158
O7—H7 $\cdots$ O16 <sup>v</sup>	0.82	1.84	2.647 (5)	170
O8—H8 $\cdots$ O3 <sup>iii</sup>	0.82	1.87	2.687 (5)	170
O10—H10 $\cdots$ O13 <sup>vi</sup>	0.82	1.94	2.753 (6)	172
O18—H18 $\cdots$ O6 <sup>vii</sup>	0.82	1.88	2.687 (6)	170
O19—H19 $\cdots$ O14 <sup>i</sup>	0.82	1.89	2.691 (5)	164
O20—H20 $\cdots$ O1 <sup>viii</sup>	0.82	1.91	2.725 (5)	170
O22—H3 $\cdots$ O19 <sup>ix</sup>	0.85	2.45	2.993 (11)	122

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

Fig. 1

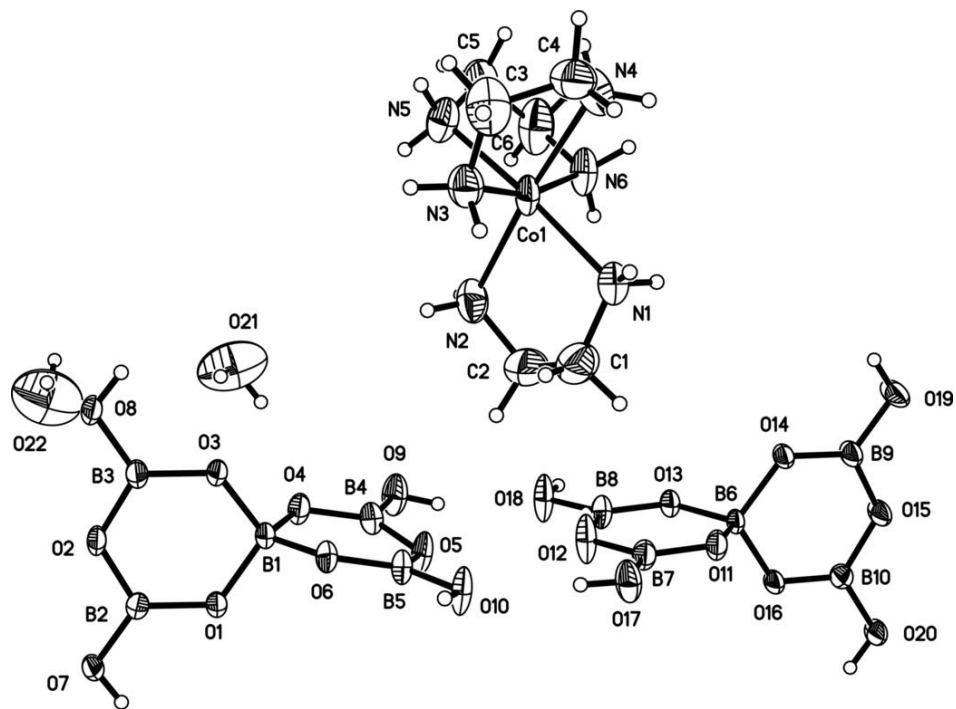


Fig. 2

