

Acta Crystallographica Section E

## Structure Reports

Online

ISSN 1600-5368

Diaquabis[5-(2-pyridyl)-1*H*-tetrazolato- $\kappa^2N^1,N^5$ ]cobalt(II)

Zhen-Hai Sun, Ling-Bo Meng\* and Hua Lin

School of Chemistry and Life Sciences, Harbin University, Harbin 150080, People's Republic of China

Correspondence e-mail: menglb\_hu@sina.com

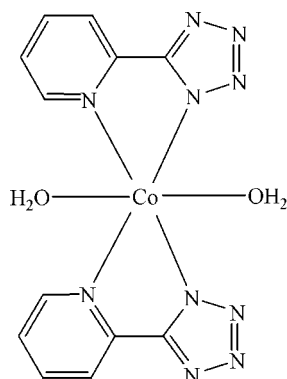
Received 14 January 2009; accepted 9 February 2009

Key indicators: single-crystal X-ray study;  $T = 296$  K; mean  $\sigma(C-C) = 0.003$  Å;  $R$  factor = 0.026;  $wR$  factor = 0.073; data-to-parameter ratio = 11.0.

In the title compound,  $[Co(C_6H_4N_5)_2(H_2O)_2]$ , the Co atom is bonded to two water molecules and two bidentate 5-(2-pyridyl)tetrazolate ligands resulting in a slightly distorted octahedral  $CoN_4O_2$  coordination geometry. The  $Co^{II}$  cation is situated on a crystallographic center of inversion. The asymmetric unit therefore comprises one-half of the molecule. The four N atoms belonging to two bidentate 5-(2-pyridyl)tetrazolate ligands lie in the equatorial plane and the two associated water molecules are observed in the axial coordination sites. The crystal structure exhibits a three-dimensional supramolecular network assembled by intermolecular  $O-H \cdots N$  hydrogen bonds.

## Related literature

For general background, see: Caneschi *et al.* (1989); Tsukuda *et al.* (2002); Vostrikova *et al.* (2000); Kuchar *et al.* (2003)



## Experimental

## Crystal data

$[Co(C_6H_4N_5)_2(H_2O)_2]$   
 $M_r = 387.25$   
 Monoclinic,  $P2_1/c$   
 $a = 7.999$  (2) Å  
 $b = 12.870$  (3) Å  
 $c = 7.168$  (2) Å  
 $\beta = 95.99$  (1)°

$V = 733.8$  (3) Å<sup>3</sup>  
 $Z = 2$   
 Mo  $K\alpha$  radiation  
 $\mu = 1.20$  mm<sup>-1</sup>  
 $T = 296$  K  
 $0.12 \times 0.10 \times 0.08$  mm

## Data collection

Bruker APEXII CCD area-detector diffractometer  
 Absorption correction: multi-scan (SADABS; Bruker, 2001)  
 $T_{min} = 0.869$ ,  $T_{max} = 0.910$

3854 measured reflections  
 1346 independent reflections  
 1270 reflections with  $I > 2\sigma(I)$   
 $R_{int} = 0.012$

## Refinement

$R[F^2 > 2\sigma(F^2)] = 0.026$   
 $wR(F^2) = 0.073$   
 $S = 1.00$   
 1346 reflections  
 122 parameters  
 3 restraints

H atoms treated by a mixture of independent and constrained refinement  
 $\Delta\rho_{max} = 0.29$  e Å<sup>-3</sup>  
 $\Delta\rho_{min} = -0.39$  e Å<sup>-3</sup>

Table 1

Hydrogen-bond geometry (Å, °).

$D-H \cdots A$	$D-H$	$H \cdots A$	$D \cdots A$	$D-H \cdots A$
$O1W-H2W \cdots N2^i$	0.82 (1)	2.00 (1)	2.798 (2)	168 (4)
$O1W-H1W \cdots N1^{ii}$	0.82 (1)	1.92 (1)	2.736 (2)	179 (3)

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

Data collection: APEX2 (Bruker, 2004); cell refinement: SAINT-Plus (Bruker, 2001); data reduction: SAINT-Plus; 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.

The authors are grateful for financial support from the Young Scholar Science Funds of the Science and Technology Bureau of Harbin City (grant No. 2003AFQXJ018).

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: IM2097).

## References

- Bruker (2001). SAINT-Plus and SADABS. Bruker AXS Inc., Madison, Wisconsin, USA.  
 Bruker (2004). APEX2. Bruker AXS Inc., Madison, Wisconsin, USA.  
 Caneschi, A., Gatteschi, D., Renard, J. P., Rey, P. & Sessoli, R. (1989). *J. Am. Chem. Soc.* **111**, 785–786.  
 Kuchar, J., Cernak, J., Zak, Z. & Massa, W. (2003). *Monogr. Ser. Int. Conf. Coord. Chem.* **6**, 127–132.  
 Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.  
 Tsukuda, T., Suzuki, T. & Kaizaki, S. (2002). *J. Chem. Soc. Dalton Trans.* pp. 1721–1726.  
 Vostrikova, K. E., Luneau, D., Wernsdorfer, W., Rey, P. & Verdager, M. (2000). *J. Am. Chem. Soc.* **122**, 718–719.

## supporting information

*Acta Cryst.* (2009). E65, m280 [doi:10.1107/S160053680900470X]

**Diaquabis[5-(2-pyridyl)-1*H*-tetrazolato- $\kappa^2$ N<sup>1</sup>,N<sup>5</sup>]cobalt(II)****Zhen-Hai Sun, Ling-Bo Meng and Hua Lin****S1. Comment**

The design of different kinds of paramagnetic metal coordination architectures with appropriate organic radicals and coligands has been an important subject during the last decade because of its potential usages for molecule-based magnetic materials and optical devices (Caneschi *et al.*, 1989; Tsukuda *et al.*, 2002; Vostrikova *et al.*, 2000; Kuchar *et al.*, 2003). If organic radicals such as the tridentate nitronyl nitroxide radical or the bidentate nitroxide radical are used as an integral part of a ligand system a large number of building blocks with various potential applications may be achieved. In this paper, we report the structure of the title compound, (I).

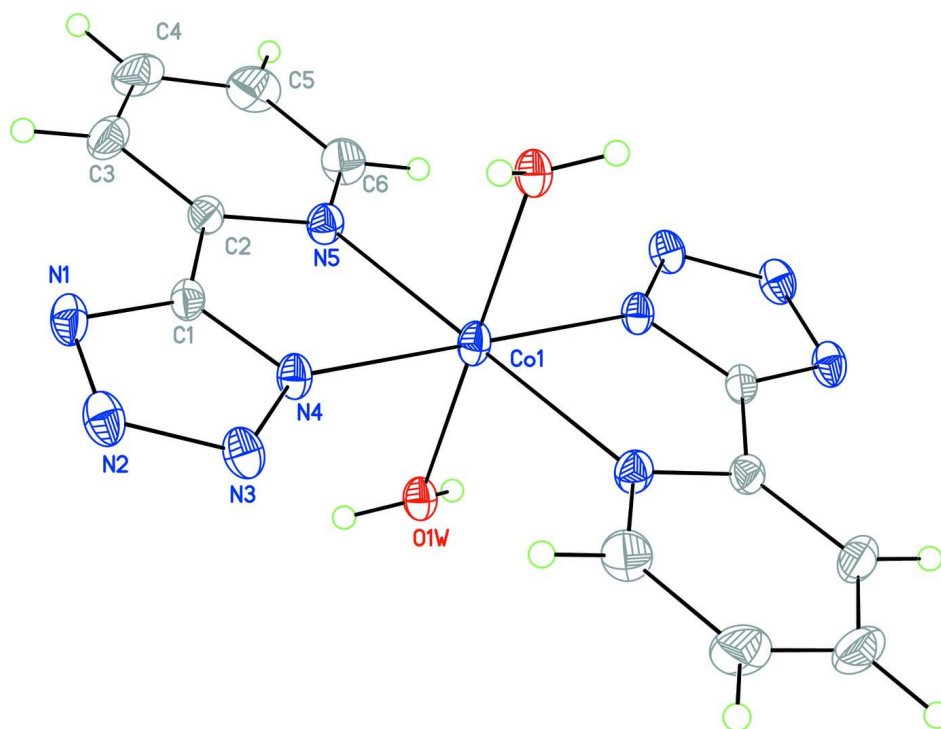
The molecular structure of the title compound is shown in Fig. 1. The Co<sup>II</sup> atom (site symmetry  $\bar{1}$ ) is bonded to two water molecules and two bidentate 5-(2-pyridyl)tetrazolato ligands resulting in a slightly distorted octahedral CoN<sub>4</sub>O<sub>2</sub> coordination geometry. The Co<sup>II</sup> cation is situated on a crystallographic center of inversion. The asymmetric unit therefore comprises one half of the molecule. The four nitrogen atoms belonging to two bidentate 5-(2-pyridyl)tetrazolato ligands lie in the equatorial plane and the two associated water molecules are observed in the axial coordination sites. In the equatorial plane, the Co—N bond lengths are in the range of 2.142 (2)–2.173 (2) Å. The Co—O axial bond length is 2.093 (2) Å. It is also worth noticing that the three-dimensional supramolecular structure is assembled *via* complicated hydrogen bonds, shown in Fig. 2. The hydrogen bonds are listed in Table 1.

**S2. Experimental**

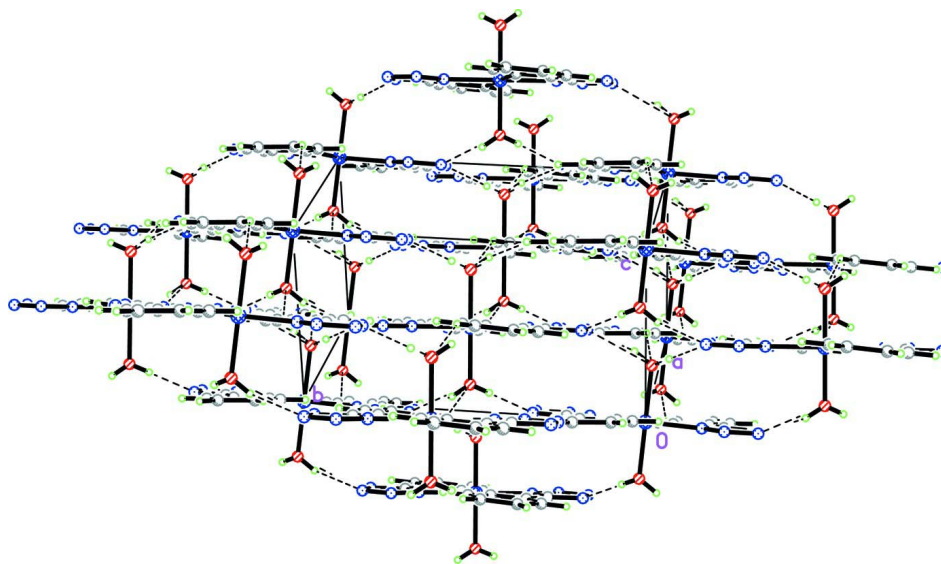
A mixture of cobalt(II) dichloride hexhydrate (1 mmol), 5-(2-pyridyl)tetrazolate (1 mmol) in 20 ml mixed solvate(1:1) of methanol and water was refluxed for several hours. After cooling down the solution was filtered and the filtrate was kept in the ice box. One week later, red blocks of (I) were obtained with a yield of *ca* 56%. Anal. Calc. for C<sub>12</sub>H<sub>12</sub>CoN<sub>10</sub>O<sub>2</sub>: C 37.19, H 3.10, N 36.15%; Found: C 37.22, H 3.08, N 36.11%.

**S3. Refinement**

All H atoms were placed in calculated positions with C—H = 0.93 Å and refined as riding with  $U_{iso}(H) = 1.2U_{eq}(C)$ . The H atoms of the water molecule were located from difference density maps and were refined with distance restraints of  $d(H-H) = 1.38$  (2) Å,  $d(O-H) = 0.82$  (1) Å.

**Figure 1**

The molecular structure of (I), around Co<sup>II</sup>, displacement ellipsoids for the non-hydrogen atoms are drawn at the 50% probability level.

**Figure 2**

Packing diagram of (I) showing the hydrogen bond interaction.

**Diaquabis[5-(2-pyridyl)-1Htetrazolato- $\kappa^2N^1,N^5$ ]cobalt(II)***Crystal data*[Co(C<sub>6</sub>H<sub>4</sub>N<sub>5</sub>)<sub>2</sub>(H<sub>2</sub>O)<sub>2</sub>] $M_r = 387.25$ Monoclinic,  $P2_1/c$ 

Hall symbol: -P 2ybc

 $a = 7.999$  (2) Å $b = 12.870$  (3) Å $c = 7.168$  (2) Å $\beta = 95.99$  (1)° $V = 733.8$  (3) Å<sup>3</sup> $Z = 2$  $F(000) = 394$  $D_x = 1.752$  Mg m<sup>-3</sup>Mo  $K\alpha$  radiation,  $\lambda = 0.71073$  Å

Cell parameters from 1346 reflections

 $\theta = 2.6$ – $25.5$ ° $\mu = 1.20$  mm<sup>-1</sup> $T = 296$  K

Block, red

 $0.12 \times 0.10 \times 0.08$  mm*Data collection*Bruker APEXII CCD area-detector  
diffractometer

Radiation source: fine-focus sealed tube

Graphite monochromator

 $\varphi$  and  $\omega$  scansAbsorption correction: multi-scan  
(*SADABS*; Bruker, 2001) $T_{\min} = 0.869$ ,  $T_{\max} = 0.910$ 

3854 measured reflections

1346 independent reflections

1270 reflections with  $I > 2\sigma(I)$  $R_{\text{int}} = 0.012$  $\theta_{\max} = 25.5$ °,  $\theta_{\min} = 2.6$ ° $h = -9 \rightarrow 7$  $k = -15 \rightarrow 12$  $l = -8 \rightarrow 7$ *Refinement*Refinement on  $F^2$ 

Least-squares matrix: full

 $R[F^2 > 2\sigma(F^2)] = 0.026$  $wR(F^2) = 0.073$  $S = 1.00$ 

1346 reflections

122 parameters

3 restraints

Primary atom site location: structure-invariant  
direct methodsSecondary atom site location: difference Fourier  
mapHydrogen site location: inferred from  
neighbouring sitesH atoms treated by a mixture of independent  
and constrained refinement $w = 1/[\sigma^2(F_o^2) + (0.036P)^2 + 0.7827P]$ where  $P = (F_o^2 + 2F_c^2)/3$  $(\Delta/\sigma)_{\max} < 0.001$  $\Delta\rho_{\max} = 0.29$  e Å<sup>-3</sup> $\Delta\rho_{\min} = -0.39$  e Å<sup>-3</sup>Extinction correction: *SHELXL97* (Sheldrick,  
2008),  $F_c^* = kF_c[1 + 0.001x F_c^2 \lambda^3 / \sin(2\theta)]^{-1/4}$ 

Extinction coefficient: 0.032 (2)

*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 (Å<sup>2</sup>)*

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
Co1	1.0000	0.0000	0.0000	0.02558 (17)
C1	0.9245 (2)	0.22105 (14)	0.0495 (2)	0.0238 (4)
C2	0.7797 (2)	0.17179 (15)	0.1175 (2)	0.0252 (4)

C3	0.6476 (3)	0.22658 (19)	0.1749 (3)	0.0362 (5)
H3	0.6448	0.2988	0.1690	0.043*
C4	0.5198 (3)	0.1717 (2)	0.2411 (3)	0.0459 (6)
H7	0.4276	0.2062	0.2805	0.055*
C5	0.5285 (3)	0.0653 (2)	0.2492 (4)	0.0473 (6)
H6	0.4434	0.0273	0.2963	0.057*
C6	0.6639 (3)	0.01547 (19)	0.1872 (3)	0.0377 (5)
H5	0.6690	-0.0567	0.1921	0.045*
N1	0.9563 (2)	0.32120 (13)	0.0376 (2)	0.0303 (4)
N2	1.1049 (2)	0.32543 (13)	-0.0308 (2)	0.0316 (4)
N3	1.1587 (2)	0.23204 (13)	-0.0591 (2)	0.0290 (4)
N4	1.0465 (2)	0.16372 (12)	-0.0086 (2)	0.0246 (4)
N5	0.7867 (2)	0.06737 (13)	0.1208 (2)	0.0270 (4)
O1W	1.13421 (19)	-0.00907 (10)	0.2663 (2)	0.0275 (3)
H1W	1.108 (5)	-0.0604 (13)	0.324 (4)	0.080*
H2W	1.141 (5)	0.0450 (12)	0.326 (4)	0.080*

*Atomic displacement parameters (Å<sup>2</sup>)*

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
Co1	0.0296 (2)	0.0178 (2)	0.0309 (2)	-0.00067 (13)	0.01065 (16)	-0.00120 (13)
C1	0.0315 (10)	0.0199 (9)	0.0195 (8)	0.0036 (7)	0.0005 (7)	-0.0013 (7)
C2	0.0291 (10)	0.0273 (10)	0.0190 (9)	0.0042 (8)	0.0011 (7)	-0.0026 (7)
C3	0.0361 (12)	0.0399 (12)	0.0325 (11)	0.0140 (9)	0.0033 (9)	-0.0038 (9)
C4	0.0289 (11)	0.0691 (18)	0.0408 (13)	0.0128 (11)	0.0090 (9)	-0.0086 (12)
C5	0.0300 (12)	0.0680 (18)	0.0465 (13)	-0.0078 (11)	0.0160 (10)	-0.0051 (12)
C6	0.0344 (12)	0.0375 (12)	0.0431 (13)	-0.0079 (9)	0.0125 (10)	-0.0014 (9)
N1	0.0448 (10)	0.0194 (8)	0.0263 (9)	0.0029 (7)	0.0020 (7)	0.0005 (7)
N2	0.0447 (10)	0.0207 (8)	0.0295 (9)	-0.0039 (7)	0.0038 (7)	0.0018 (7)
N3	0.0371 (9)	0.0218 (8)	0.0289 (8)	-0.0062 (7)	0.0070 (7)	0.0005 (7)
N4	0.0304 (8)	0.0177 (8)	0.0267 (8)	-0.0016 (7)	0.0081 (6)	-0.0003 (6)
N5	0.0271 (8)	0.0272 (9)	0.0278 (8)	0.0000 (7)	0.0084 (7)	-0.0021 (6)
O1W	0.0340 (8)	0.0203 (7)	0.0289 (7)	-0.0014 (6)	0.0073 (6)	-0.0008 (5)

*Geometric parameters (Å, °)*

Co1—O1W <sup>i</sup>	2.0932 (16)	C3—H3	0.9300
Co1—O1W	2.0932 (16)	C4—C5	1.372 (4)
Co1—N4 <sup>i</sup>	2.1416 (16)	C4—H7	0.9300
Co1—N4	2.1416 (16)	C5—C6	1.371 (3)
Co1—N5 <sup>i</sup>	2.1726 (16)	C5—H6	0.9300
Co1—N5	2.1726 (16)	C6—N5	1.317 (3)
C1—N1	1.318 (3)	C6—H5	0.9300
C1—N4	1.325 (3)	N1—N2	1.333 (3)
C1—C2	1.448 (3)	N2—N3	1.300 (3)
C2—N5	1.345 (3)	N3—N4	1.333 (2)
C2—C3	1.369 (3)	O1W—H1W	0.817 (10)
C3—C4	1.368 (4)	O1W—H2W	0.815 (10)

O1W <sup>i</sup> —Co1—O1W	180.00 (8)	C2—C3—H3	121.1
O1W <sup>i</sup> —Co1—N4 <sup>i</sup>	90.41 (6)	C3—C4—C5	119.6 (2)
O1W—Co1—N4 <sup>i</sup>	89.59 (6)	C3—C4—H7	120.2
O1W <sup>i</sup> —Co1—N4	89.59 (6)	C5—C4—H7	120.2
O1W—Co1—N4	90.41 (6)	C6—C5—C4	119.4 (2)
N4 <sup>i</sup> —Co1—N4	180.000 (15)	C6—C5—H6	120.3
O1W <sup>i</sup> —Co1—N5 <sup>i</sup>	90.47 (6)	C4—C5—H6	120.3
O1W—Co1—N5 <sup>i</sup>	89.53 (6)	N5—C6—C5	121.6 (2)
N4 <sup>i</sup> —Co1—N5 <sup>i</sup>	76.39 (6)	N5—C6—H5	119.2
N4—Co1—N5 <sup>i</sup>	103.61 (6)	C5—C6—H5	119.2
O1W <sup>i</sup> —Co1—N5	89.53 (6)	C1—N1—N2	104.43 (16)
O1W—Co1—N5	90.47 (6)	N3—N2—N1	110.03 (15)
N4 <sup>i</sup> —Co1—N5	103.61 (6)	N2—N3—N4	108.90 (16)
N4—Co1—N5	76.39 (6)	C1—N4—N3	104.89 (16)
N5 <sup>i</sup> —Co1—N5	180.00 (11)	C1—N4—Co1	113.77 (13)
N1—C1—N4	111.76 (18)	N3—N4—Co1	141.31 (13)
N1—C1—C2	128.05 (18)	C6—N5—C2	118.81 (18)
N4—C1—C2	120.19 (18)	C6—N5—Co1	126.01 (15)
N5—C2—C3	122.8 (2)	C2—N5—Co1	115.11 (13)
N5—C2—C1	114.22 (17)	Co1—O1W—H1W	112 (2)
C3—C2—C1	123.0 (2)	Co1—O1W—H2W	115 (2)
C4—C3—C2	117.8 (2)	H1W—O1W—H2W	115.5 (19)
C4—C3—H3	121.1		

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

*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>
O1W—H2W $\cdots$ N2 <sup>ii</sup>	0.82 (1)	2.00 (1)	2.798 (2)	168 (4)
O1W—H1W $\cdots$ N1 <sup>iii</sup>	0.82 (1)	1.92 (1)	2.736 (2)	179 (3)

Symmetry codes: (ii)  $x, -y+1/2, z+1/2$ ; (iii)  $-x+2, y-1/2, -z+1/2$ .