

**catena-Poly[[[triacquacopper(II)]- $\mu_2$ -pyrazine-2,3-dicarboxylato] monohydrate]**Wei-Ping Wu,<sup>a\*</sup> Feng-Chun Zeng,<sup>a</sup> Yu Wu<sup>a</sup> and Jian Peng<sup>b</sup><sup>a</sup>Department of Chemistry, Sichuan University of Science and Engineering, Zigong, 643000, People's Republic of China, and <sup>b</sup>Department of Materials and Chemical Engineering, Sichuan University of Science and Engineering, Zigong

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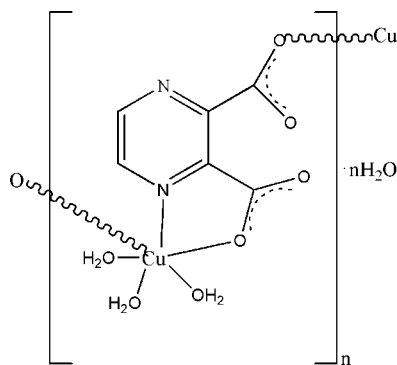
Received 16 November 2007; accepted 24 November 2007

Key indicators: single-crystal X-ray study;  $T = 298$  K; mean  $\sigma(\text{C}-\text{C}) = 0.007$  Å;  $R$  factor = 0.036;  $wR$  factor = 0.089; data-to-parameter ratio = 10.8.

The Cu atom in the title complex,  $\{[\text{Cu}(\text{C}_6\text{H}_2\text{N}_2\text{O}_4)(\text{H}_2\text{O})_3] \cdot \text{H}_2\text{O}\}_n$  or  $\{[\text{Cu}(L)(\text{H}_2\text{O})_3] \cdot \text{H}_2\text{O}\}_n$  ( $L$  is pyrazine-2,3-dicarboxylate), displays octahedral coordination formed by the ligand  $L$  and three coordinated water molecules. The ligand  $L$  is tridentate, with one N atom of the pyrazine ring and one O atom of one carboxylate group forming a chelate ring, whereas one O atom from the second carboxylate group is coordinated to another Cu atom. The ligand  $L$  links molecules to form an infinite chain parallel to the  $[101]$  direction. The chains are further linked through  $\text{O}-\text{H} \cdots \text{O}$  and  $\text{O}-\text{H} \cdots \text{N}$  hydrogen bonds involving the water molecules to build up a three-dimensional network.

**Related literature**

For related literature, see: Gokel *et al.* (2004); Shan *et al.* (2001); Starosta & Leciejewicz (2005); Takusagawa & Shimada (1973); Tombul *et al.* (2007); Ptasiwicz-Bak & Leciejewicz (1997*a,b*).

**Experimental***Crystal data*

$[\text{Cu}(\text{C}_6\text{H}_2\text{N}_2\text{O}_4)(\text{H}_2\text{O})_3] \cdot \text{H}_2\text{O}$   
 $M_r = 301.70$   
 Monoclinic,  $Cc$

$a = 8.4254$  (4) Å  
 $b = 18.0692$  (8) Å  
 $c = 7.4187$  (3) Å

$\beta = 114.4120$  (10)°  
 $V = 1028.45$  (8) Å<sup>3</sup>  
 $Z = 4$   
 Mo  $K\alpha$  radiation

$\mu = 2.16$  mm<sup>-1</sup>  
 $T = 298$  (2) K  
 $0.28 \times 0.25 \times 0.17$  mm

*Data collection*

Bruker APEXII area-detector diffractometer  
 Absorption correction: multi-scan (SADABS; Sheldrick, 2004)  
 $T_{\min} = 0.519$ ,  $T_{\max} = 0.660$

3079 measured reflections  
 1683 independent reflections  
 1654 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.067$

*Refinement*

$R[F^2 > 2\sigma(F^2)] = 0.036$   
 $wR(F^2) = 0.089$   
 $S = 1.11$   
 1683 reflections  
 156 parameters  
 2 restraints

H-atom parameters constrained  
 $\Delta\rho_{\text{max}} = 0.67$  e Å<sup>-3</sup>  
 $\Delta\rho_{\text{min}} = -1.08$  e Å<sup>-3</sup>  
 Absolute structure: Flack (1983),  
 758 Friedel pairs  
 Flack parameter:  $-0.04$  (2)

**Table 1**

Hydrogen-bond geometry (Å, °).

$D-\text{H} \cdots A$	$D-\text{H}$	$\text{H} \cdots A$	$D \cdots A$	$D-\text{H} \cdots A$
$\text{O5}-\text{H5A} \cdots \text{O7}^{\text{i}}$	0.84	2.30	2.953 (4)	134
$\text{O5}-\text{H5B} \cdots \text{O8}$	0.86	1.79	2.630 (6)	168
$\text{O6}-\text{H6A} \cdots \text{O4}^{\text{ii}}$	0.85	1.98	2.837 (4)	176
$\text{O6}-\text{H6A} \cdots \text{O3}^{\text{iii}}$	0.85	2.57	3.170 (5)	128
$\text{O6}-\text{H6B} \cdots \text{O4}^{\text{iii}}$	0.84	1.87	2.691 (4)	167
$\text{O7}-\text{H7A} \cdots \text{N2}^{\text{iii}}$	0.83	1.98	2.817 (5)	177
$\text{O7}-\text{H7B} \cdots \text{O1}^{\text{iv}}$	0.83	1.90	2.719 (6)	166
$\text{O8}-\text{H8A} \cdots \text{O4}^{\text{iv}}$	0.85	2.02	2.864 (6)	176
$\text{O8}-\text{H8B} \cdots \text{O1}^{\text{v}}$	0.85	2.11	2.898 (6)	155

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

Data collection: APEX2 (Bruker, 2004); cell refinement: SAINT (Bruker, 2004); data reduction: SAINT; program(s) used to solve structure: SHELXS97 (Sheldrick, 1997); program(s) used to refine structure: SHELXL97 (Sheldrick, 1997); molecular graphics: ORTEPIII (Burnett & Johnson, 1996) and PLATON (Spek, 2003); software used to prepare material for publication: SHELXL97.

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Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: DN2285).

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**supplementary materials**

*Acta Cryst.* (2008). E64, m61 [ doi:10.1107/S1600536807062800 ]

***catena*-Poly[[[triaquacopper(II)]- $\mu_2$ -pyrazine-2,3-dicarboxylato] monohydrate]**

**W.-P. Wu, F.-C. Zeng, Y. Wu and J. Peng**

**Comment**

Transition metal complexes with bipyridine derivatives are suitable models for the study of excited state dynamics. In addition, they are of interest for the development of light-energy conversion devices and optical sensors (Gokel *et al.*, 2004; Shan *et al.*, 2001). Since the single-crystal X-ray analysis of pyrazine-2,3 dicarboxylic acid was first determined (Takusagawa & Shimada, 1973), a variety of metal-organic compounds of pyrazine-2,3-dicarboxylic acid have been characterized crystallographically, due to growing interest in supramolecular chemistry (Tombul *et al.*, 2007). These include the calcium (Ptasiewicz-Bak & Leciejewicz, 1997*a*; Starosta & Leciejewicz, 2005) and magnesium (Ptasiewicz-Bak & Leciejewicz, 1997*b*) complexes. In this paper, we report the synthesis and crystal structure of the title complex.(I).

The Cu<sup>II</sup> ion displays octahedral coordination formed by the one *L* ligand and three coordinated water molecules. The ligand *L* is tridentate with the N atom of the pyridine ring and one O atom of one carboxylate forming a chelate ring whereas one O atom from the second carboxylate is coordinated to another Cu atom (Fig. 1). Then the ligand *L* links molecules to form an infinite chain parallel to the [1 0 1] direction. The chains are further linked through O—H $\cdots$ O and O—H $\cdots$ N involving the water molecules to build up a three dimensional network (Table 1).

**Experimental**

*L* (0.031 g, 0.018 mmol), CuSO<sub>4</sub> (0.018 g, 0.016 mmol) and NaOH(0.048 mmol,0.12 mmol), were added in a mixed solvent of ethanol, the mixture was heated for three hours under reflux. during the process stirring and influx were required. The resultant was then filtered to give a pure solution which was infiltrated by diethyl ether freely in a closed vessel, two weeks later some single crystals of the size suitable for X-Ray diffraction analysis.

**Refinement**

All H atoms attached to C atoms were fixed geometrically and treated as riding with C—H = 0.93 Å and  $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ . H atoms of water molecule were located in difference Fourier maps and included in the subsequent refinement using restraints (O—H = 0.85 (1)Å and H $\cdots$ H = 1.39 (2) Å) with  $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{O})$ . In the last stage of refinement, they were treated as riding on their parent O atoms.

**Figures**

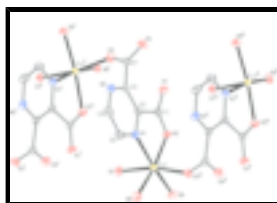


Fig. 1. View of compound (I) with the atom-labelling scheme. Displacement ellipsoids are drawn at the 30% probability level. H atoms have been omitted for clarity. [Symmetry codes: (i)  $x - 1/2, 1/2 - y, z - 1/2$ ; (ii)  $1/2 + x, 1/2 - y, 1/2 + z$ ]

## **catena-Poly[[[triaquacopper(II)]- $\mu_2$ -pyrazine-2,3-dicarboxylato] monohydrate]**

### *Crystal data*

$[\text{Cu}(\text{C}_6\text{H}_2\text{N}_2\text{O}_4)(\text{H}_2\text{O})_3]\cdot\text{H}_2\text{O}$	$F_{000} = 612$
$M_r = 301.70$	$D_x = 1.949 \text{ Mg m}^{-3}$
Monoclinic, $Cc$	Mo $K\alpha$ radiation
Hall symbol: $C -2yc$	$\lambda = 0.71073 \text{ \AA}$
$a = 8.4254 (4) \text{ \AA}$	Cell parameters from 1683 reflections
$b = 18.0692 (8) \text{ \AA}$	$\theta = 2.3\text{--}25.2^\circ$
$c = 7.4187 (3) \text{ \AA}$	$\mu = 2.16 \text{ mm}^{-1}$
$\beta = 114.4120 (10)^\circ$	$T = 298 (2) \text{ K}$
$V = 1028.45 (8) \text{ \AA}^3$	Block, blue
$Z = 4$	$0.28 \times 0.25 \times 0.17 \text{ mm}$

### *Data collection*

Bruker APEXII area-detector diffractometer	1683 independent reflections
Radiation source: fine-focus sealed tube	1654 reflections with $I > 2\sigma(I)$
Monochromator: graphite	$R_{\text{int}} = 0.067$
$T = 298(2) \text{ K}$	$\theta_{\text{max}} = 25.2^\circ$
$\varphi$ and $\omega$ scan	$\theta_{\text{min}} = 2.3^\circ$
Absorption correction: multi-scan (SADABS; Sheldrick, 2004)	$h = -10 \rightarrow 9$
$T_{\text{min}} = 0.519$ , $T_{\text{max}} = 0.660$	$k = -21 \rightarrow 20$
3079 measured reflections	$l = -8 \rightarrow 8$

### *Refinement*

Refinement on $F^2$	Hydrogen site location: inferred from neighbouring sites
Least-squares matrix: full	H-atom parameters constrained
$R[F^2 > 2\sigma(F^2)] = 0.036$	$w = 1/[\sigma^2(F_o^2) + (0.0632P)^2]$
$wR(F^2) = 0.089$	where $P = (F_o^2 + 2F_c^2)/3$
$S = 1.11$	$(\Delta/\sigma)_{\text{max}} < 0.001$
1683 reflections	$\Delta\rho_{\text{max}} = 0.67 \text{ e \AA}^{-3}$
156 parameters	$\Delta\rho_{\text{min}} = -1.08 \text{ e \AA}^{-3}$
2 restraints	Extinction correction: none
Primary atom site location: structure-invariant direct methods	Absolute structure: Flack (1983), 758 Friedel pairs
Secondary atom site location: difference Fourier map	Flack parameter: $-0.04 (2)$

*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 ( $\text{\AA}^2$ )*

	<i>x</i>	<i>y</i>	<i>z</i>	$U_{\text{iso}}^*/U_{\text{eq}}$
Cu1	0.89418 (3)	0.118643 (19)	0.89933 (3)	0.02206 (17)
N1	0.6873 (5)	0.18186 (18)	0.9306 (5)	0.0277 (8)
N2	0.4368 (5)	0.2821 (2)	0.9255 (5)	0.0289 (10)
O1	0.9124 (6)	0.34477 (15)	0.9145 (8)	0.0380 (8)
O2	0.9816 (4)	0.22606 (16)	0.9101 (5)	0.0311 (7)
O3	0.5382 (5)	0.40933 (18)	0.6974 (4)	0.0347 (8)
O4	0.6390 (5)	0.42851 (17)	1.0176 (4)	0.0346 (7)
O5	0.7715 (5)	0.01798 (16)	0.8841 (6)	0.0428 (8)
H5A	0.8168	-0.0080	0.9872	0.064*
H5B	0.6618	0.0110	0.8202	0.064*
O6	1.1011 (4)	0.07381 (17)	0.8605 (4)	0.0314 (7)
H6A	1.1120	0.0292	0.9021	0.047*
H6B	1.1000	0.0780	0.7471	0.047*
O7	0.7584 (5)	0.12285 (15)	0.5794 (5)	0.0302 (8)
H7A	0.8141	0.1510	0.5379	0.039 (15)*
H7B	0.6501	0.1250	0.5249	0.033 (16)*
C1	0.8817 (8)	0.2773 (2)	0.9095 (8)	0.0247 (9)
C2	0.7074 (6)	0.2543 (2)	0.9108 (6)	0.0229 (9)
C3	0.5804 (6)	0.3047 (2)	0.9043 (6)	0.0232 (9)
C4	0.4209 (6)	0.2097 (3)	0.9474 (6)	0.0328 (10)
H4	0.3237	0.1927	0.9642	0.039*
C5	0.5417 (6)	0.1592 (2)	0.9461 (6)	0.0322 (10)
H5	0.5227	0.1089	0.9561	0.039*
C7	0.5890 (6)	0.3869 (2)	0.8690 (7)	0.0226 (9)
O8	0.4396 (6)	-0.0183 (3)	0.7257 (8)	0.0755 (15)
H8A	0.3537	0.0099	0.6642	0.113*
H8B	0.4043	-0.0601	0.7463	0.113*

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

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
Cu1	0.0207 (2)	0.0188 (2)	0.0264 (2)	0.0014 (2)	0.00942 (17)	-0.00095 (19)

## supplementary materials

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N1	0.028 (2)	0.0247 (17)	0.0301 (16)	-0.0003 (15)	0.0116 (15)	0.0023 (14)
N2	0.023 (3)	0.0329 (18)	0.031 (2)	-0.0011 (14)	0.0125 (18)	-0.0029 (15)
O1	0.0243 (17)	0.0237 (14)	0.065 (2)	-0.0024 (14)	0.0179 (14)	0.0017 (17)
O2	0.0231 (17)	0.0236 (14)	0.0479 (16)	0.0006 (13)	0.0160 (14)	-0.0014 (13)
O3	0.0441 (19)	0.0313 (16)	0.0264 (15)	-0.0016 (15)	0.0122 (13)	0.0034 (12)
O4	0.049 (2)	0.0275 (14)	0.0286 (14)	-0.0017 (14)	0.0175 (14)	-0.0071 (12)
O5	0.0312 (17)	0.0303 (16)	0.0567 (19)	-0.0052 (14)	0.0080 (14)	0.0110 (15)
O6	0.0317 (16)	0.0314 (14)	0.0324 (13)	0.0075 (14)	0.0145 (12)	0.0045 (13)
O7	0.0225 (18)	0.0338 (18)	0.0320 (19)	-0.0006 (11)	0.0088 (15)	0.0049 (11)
C1	0.020 (2)	0.0256 (18)	0.0268 (16)	-0.004 (2)	0.0080 (14)	-0.0001 (18)
C2	0.022 (2)	0.0225 (19)	0.0215 (17)	-0.0037 (16)	0.0063 (15)	-0.0012 (14)
C3	0.019 (2)	0.027 (2)	0.0194 (16)	-0.0031 (16)	0.0039 (14)	-0.0017 (15)
C4	0.029 (3)	0.035 (2)	0.042 (3)	-0.009 (2)	0.023 (2)	-0.0048 (16)
C5	0.034 (3)	0.0257 (19)	0.039 (2)	-0.0028 (19)	0.0162 (18)	-0.0010 (17)
C7	0.020 (2)	0.025 (2)	0.024 (2)	0.0004 (15)	0.0112 (17)	-0.0018 (14)
O8	0.031 (2)	0.062 (3)	0.102 (3)	-0.0071 (18)	-0.004 (2)	0.021 (2)

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

Cu1—O6	2.048 (3)	O5—H5A	0.8422
Cu1—O2	2.066 (3)	O5—H5B	0.8559
Cu1—O5	2.072 (3)	O6—H6A	0.8539
Cu1—O3 <sup>i</sup>	2.098 (3)	O6—H6B	0.8410
Cu1—O7	2.169 (4)	O7—H7A	0.8328
Cu1—N1	2.175 (4)	O7—H7B	0.8323
N1—C2	1.335 (5)	C1—C2	1.530 (7)
N1—C5	1.343 (7)	C2—C3	1.391 (6)
N2—C4	1.332 (6)	C3—C7	1.515 (5)
N2—C3	1.347 (6)	C4—C5	1.369 (7)
O1—C1	1.244 (5)	C4—H4	0.9300
O2—C1	1.249 (6)	C5—H5	0.9300
O3—C7	1.232 (6)	O8—H8A	0.8483
O3—Cu1 <sup>ii</sup>	2.098 (3)	O8—H8B	0.8472
O4—C7	1.255 (5)		
O6—Cu1—O2	93.81 (13)	Cu1—O6—H6B	116.5
O6—Cu1—O5	94.56 (15)	H6A—O6—H6B	113.7
O2—Cu1—O5	171.41 (14)	Cu1—O7—H7A	107.6
O6—Cu1—O3 <sup>i</sup>	84.14 (13)	Cu1—O7—H7B	120.6
O2—Cu1—O3 <sup>i</sup>	98.28 (13)	H7A—O7—H7B	117.6
O5—Cu1—O3 <sup>i</sup>	84.50 (14)	O1—C1—O2	126.5 (6)
O6—Cu1—O7	87.38 (13)	O1—C1—C2	117.0 (5)
O2—Cu1—O7	91.59 (12)	O2—C1—C2	116.5 (4)
O5—Cu1—O7	86.87 (14)	N1—C2—C3	121.0 (4)
O3 <sup>i</sup> —Cu1—O7	167.38 (13)	N1—C2—C1	115.6 (4)
O6—Cu1—N1	171.52 (13)	C3—C2—C1	123.2 (4)
O2—Cu1—N1	77.94 (13)	N2—C3—C2	120.8 (4)
O5—Cu1—N1	93.62 (15)	N2—C3—C7	115.3 (4)

O3 <sup>i</sup> —Cu1—N1	98.85 (14)	C2—C3—C7	123.9 (4)
O7—Cu1—N1	90.86 (14)	N2—C4—C5	122.8 (5)
C2—N1—C5	118.1 (4)	N2—C4—H4	118.6
C2—N1—Cu1	111.0 (3)	C5—C4—H4	118.6
C5—N1—Cu1	130.5 (3)	N1—C5—C4	120.3 (4)
C4—N2—C3	116.9 (4)	N1—C5—H5	119.8
C1—O2—Cu1	117.8 (3)	C4—C5—H5	119.8
C7—O3—Cu1 <sup>ii</sup>	144.4 (3)	O3—C7—O4	123.9 (4)
Cu1—O5—H5A	114.2	O3—C7—C3	118.7 (4)
Cu1—O5—H5B	124.0	O4—C7—C3	117.3 (4)
H5A—O5—H5B	113.7	H8A—O8—H8B	110.3
Cu1—O6—H6A	107.0		

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

*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>
O5—H5A $\cdots$ O7 <sup>iii</sup>	0.84	2.30	2.953 (4)	134
O5—H5B $\cdots$ O8	0.86	1.79	2.630 (6)	168
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O6—H6A $\cdots$ O3 <sup>iv</sup>	0.85	2.57	3.170 (5)	128
O6—H6B $\cdots$ O4 <sup>v</sup>	0.84	1.87	2.691 (4)	167
O7—H7A $\cdots$ N2 <sup>v</sup>	0.83	1.98	2.817 (5)	177
O7—H7B $\cdots$ O1 <sup>ii</sup>	0.83	1.90	2.719 (6)	166
O8—H8A $\cdots$ O4 <sup>ii</sup>	0.85	2.02	2.864 (6)	176
O8—H8B $\cdots$ O1 <sup>vi</sup>	0.85	2.11	2.898 (6)	155

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

Fig. 1

