

Acta Crystallographica Section E

## Structure Reports

Online

ISSN 1600-5368

# catena-Poly[[diaquacobalt(II)]-bis( $\mu$ -4-fluorobenzoato- $\kappa^2$ O:O')]

Fu-Fu Zhou and Bi-Song Zhang\*

 College of Materials Science and Chemical Engineering, Jinhua College of Profession and Technology, Jinhua, Zhejiang 321017, People's Republic of China  
 Correspondence e-mail: zbs\_jy@163.com

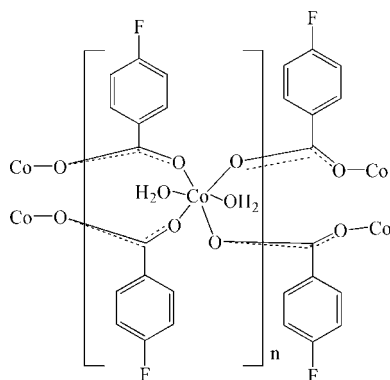
Received 13 March 2009; accepted 22 April 2009

 Key indicators: single-crystal X-ray study;  $T = 290$  K; mean  $\sigma(\text{C}-\text{C}) = 0.004$  Å;  $R$  factor = 0.032;  $wR$  factor = 0.087; data-to-parameter ratio = 15.2.

The hydrothermal reaction of  $\text{CoCO}_3$  and 4-fluorobenzoic acid afforded the title  $\text{Co}^{\text{II}}$  complex,  $[\text{Co}(\text{C}_7\text{H}_4\text{FO}_2)_2(\text{H}_2\text{O})_2]_n$ . The  $\text{Co}^{\text{II}}$  atom is located on an inversion center and is coordinated by six O atoms from two water molecules and four  $\mu_2$ -carboxylate groups of 4-fluorobenzoate anions, forming a distorted  $\text{CoO}_6$  octahedron, with  $\text{Co}-\text{O}$  bond lengths in the range 2.071 (2)–2.130 (2) Å. All adjacent  $\text{O}-\text{Co}-\text{O}$  angles are in the range 84.78 (6)–95.22 (6)° and opposite angles are 180.0°. Each  $\mu$ -carboxylate group of the 4-fluorobenzoate anions bridges two symmetry-related  $\text{Co}^{\text{II}}$  atoms. Hydrogen-bonding interactions of the coordinated water molecules further connect the cobalt–carboxylate units, forming layers perpendicular to the  $a$  axis. The cobalt–oxygen layers are encased in a sandwich-like fashion by layers of  $\pi$ -stacked 4-fluorobenzoate anions. Within these layers the benzene rings of the 4-fluorobenzoate anions are  $\pi$ -stacked, with centroid–centroid distances of 3.432 (4) Å.

## Related literature

For other complexes of the 2(or 4)-fluorobenzoato ligand, see: Zhang (2006c); Zhang *et al.* (2005a,b). For related structures, see: Zhang (2004, 2005, 2006a,b,c); Zhang *et al.* (2008); Majumder *et al.* (2006); Shi *et al.* (1996).



## Experimental

## Crystal data

 $[\text{Co}(\text{C}_7\text{H}_4\text{FO}_2)_2(\text{H}_2\text{O})_2]$   
 $M_r = 373.17$   
 Monoclinic,  $P2_1/c$   
 $a = 14.866$  (3) Å  
 $b = 6.6043$  (13) Å  
 $c = 7.3081$  (15) Å  
 $\beta = 100.94$  (3)°

 $V = 704.5$  (3) Å<sup>3</sup>  
 $Z = 2$   
 Mo  $K\alpha$  radiation  
 $\mu = 1.27$  mm<sup>-1</sup>  
 $T = 290$  K  
 $0.54 \times 0.35 \times 0.10$  mm

## Data collection

 Rigaku R-Axis RAPID diffractometer  
 Absorption correction: multi-scan (ABSCOR; Higashi, 1995)  
 $T_{\text{min}} = 0.590$ ,  $T_{\text{max}} = 0.879$ 

 6437 measured reflections  
 1616 independent reflections  
 1432 reflections with  $I > 2\sigma(I)$   
 $R_{\text{int}} = 0.038$ 

## Refinement

 $R[F^2 > 2\sigma(F^2)] = 0.032$   
 $wR(F^2) = 0.087$   
 $S = 1.15$   
 1616 reflections

 106 parameters  
 H-atom parameters constrained  
 $\Delta\rho_{\text{max}} = 0.44$  e Å<sup>-3</sup>  
 $\Delta\rho_{\text{min}} = -0.34$  e Å<sup>-3</sup>

Table 1

Hydrogen-bond geometry (Å, °).

$D-H\cdots A$	$D-H$	$H\cdots A$	$D\cdots A$	$D-H\cdots A$
$\text{O2}-\text{H2B}\cdots\text{O3}^{\text{i}}$	0.85	2.00	2.833 (2)	167
$\text{O2}-\text{H2A}\cdots\text{O3}^{\text{ii}}$	0.85	2.11	2.835 (2)	143
$\text{O2}-\text{H2A}\cdots\text{O1}^{\text{iii}}$	0.85	2.42	3.115 (1)	140

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

Data collection: *RAPID-AUTO* (Rigaku, 1998); cell refinement: *RAPID-AUTO*; data reduction: *CrystalStructure* (Rigaku/MS, 2002); 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 gratefully acknowledge financial support by the Education Office of Zhejiang Province (grant No. 20051316).

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: ZL2189).

## References

- Higashi, T. (1995). *ABSCOR*. Rigaku Corporation, Tokyo, Japan.  
 Majumder, A., Gramlich, V., Rosair, G. M., Batten, S. R., Masuda, J. D., Fallah, M. S. E., Ribas, J., Sutter, J.-P., Desplanches, C. & Mitra, S. (2006). *Cryst. Growth Des.* **6**, 2355–2368.  
 Rigaku (1998). *RAPID-AUTO*. Rigaku Corporation, Tokyo, Japan.  
 Rigaku/MS (2002). *CrystalStructure*. Rigaku/MS, The Woodlands, Texas, USA.  
 Sheldrick, G. M. (2008). *Acta Cryst.* **A64**, 112–122.  
 Shi, J. M., Cheng, P., Miao, M. M., Jiang, Z. H., Liu, Y. J. & Wang, G. L. (1996). *J. Inorg. Chem.* **12**, 372–376.  
 Zhang, B.-S. (2004). *Z. Kristallogr. New Cryst. Struct.* **219**, 141–142.  
 Zhang, B.-S. (2005). *Z. Kristallogr. New Cryst. Struct.* **220**, 73–74.  
 Zhang, B.-S. (2006a). *Acta Cryst.* **E62**, m2645–m2647.  
 Zhang, B.-S. (2006b). *Z. Kristallogr. New Cryst. Struct.* **221**, 191–194.  
 Zhang, B. S. (2006c). *Z. Kristallogr. New Cryst. Struct.* **221**, 355–356.

## metal-organic compounds

---

Zhang, B.-S., Wu, C. S. & Wang, Y. H. (2008). *Chin. J. Struct. Chem.* **27**, 1360–1364.

Zhang, B.-S., Zeng, X.-R., Yu, Y.-Y., Fang, X.-N. & Huang, C.-F. (2005a). *Z. Kristallogr. New Cryst. Struct.* **220**, 75–76.

Zhang, B.-S., Zhu, X.-C., Yu, Y.-Y., Chen, L., Chen, Z.-B. & Hu, Y.-M. (2005b). *Z. Kristallogr. New Cryst. Struct.* **220**, 211–212.

**supplementary materials**

*Acta Cryst.* (2009). E65, m587-m588 [ doi:10.1107/S1600536809014913 ]

***catena*-Poly[[diaquacobalt(II)]-bis( $\mu$ -4-fluorobenzoato- $\kappa^2$ O:O')]**

**F.-F. Zhou and B.-S. Zhang**

**Comment**

Cobalt(II) ions can form, among others, mononuclear and one-dimensional network complexes (Majumder *et al.*, 2006). In this context we have studied and reported the crystal structures of complexes with halobenzoate ligands, X—C<sub>6</sub>H<sub>4</sub>COO<sup>-</sup>, where X is F, Cl, Br or I, (Zhang, 2004, 2005, 2006a,b,c; Zhang *et al.*, 2005, 2008). In this report we would like to report the synthesis and crystal structure of the title complex,  ${}^2\infty[\text{Co}(\text{H}_2\text{O})_2(\text{FC}_6\text{H}_4\text{COO})_{4/2}]$ . Within the title compound, each Co<sup>II</sup> atom is located on a crystallographic inversion center and is coordinated by six O atoms from two water molecules and four  $\mu_2$ -carboxyl groups of 4-fluorobenzoic acid anions, to form a distorted CoO<sub>6</sub> octahedron, with Co—O bond lengths in the range of 2.071 (2) to 2.130 (2) Å. All adjacent O—Co—O bond angles are in the range of 84.78 (6)–95.22 (6)° and opposite angles are 180.0 (1)°.

Each  $\mu_2$ -carboxyl group of the 4-fluorobenzoic anions bridges two symmetry related cobalt atoms, Co(1) and Co(1)<sup>vi</sup> (vi:  $-x + 1, -y, -z + 1$ ). Hydrogen bonding interactions of the coordinated water molecules further connect the cobalt-carboxylate units with each other to form layers perpendicular to the *a* axis (Fig.2). The O—H...O bond lengths are in the range of 2.83 (2) to 3.12 (1) Å, the O—H...O bond angles are in the range of 139.7 (1) —167.0 (1)°, Table 2. The cobalt-oxygen layers are encased in a sandwich like fashion by layers of  $\pi$ -stacked 4-fluorobenzoate anions. Within these layers the benzene rings of the 4-fluorobenzoate anions are  $\pi$  stacked with centroid to centroid<sup>iii</sup> (iii =  $x, 0.5-y, -0.5+z$ ) distances of 3.432 (4)Å.

**Experimental**

CoCO<sub>3</sub> (0.132 g, 1.110 mmol), 4-fluorobenzoic acid (0.085 g, 0.607 mmol) and 15 ml CH<sub>3</sub>OH/H<sub>2</sub>O (1:2, *v/v*) were mixed and stirred for *ca* 5.0 h, and the resulting suspension was heated in a 23 ml Teflon-lined stainless steel autoclave at 433 K for 6 days. After the autoclave cooled to room temperature, the solid was filtered off. The resulting purple filtrate was allowed to stand at room temperature and slow evaporation over three months gave red block crystals suitable for X-ray analysis. Yield: 76%.

**Refinement**

C-bound H atoms were placed in calculated positions, with C—H = 0.93 Å and  $U_{\text{iso}}(\text{H}) = 1.2U_{\text{eq}}(\text{C})$ , and were refined using the riding-model approximation. The H atoms of the water molecule were located in a difference Fourier map and refined with an O—H distance restraint of 0.85 (1) Å and  $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{O})$ .

## Figures

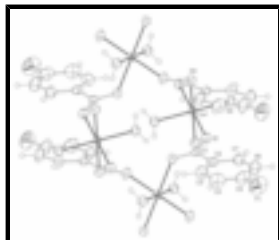


Fig. 1. The structure unit of the title compound, showing the atom-labelling scheme. Displacement ellipsoids are drawn at the 50% probability level.

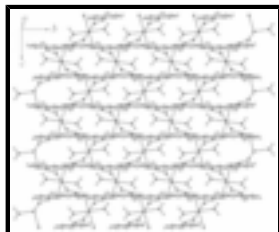


Fig. 2. View of the title complex along the [100] direction showing the two-dimensional layering.

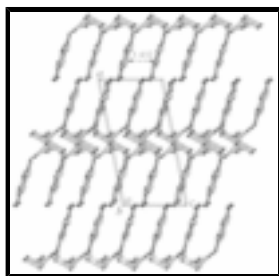


Fig. 3. A packing diagram of the title complex, viewed along the *b* axis.  $\pi$ - $\pi$  Stacking interactions are indicated as dashed double arrows.

## *catena*-Poly[[diaquacobalt(II)]-bis( $\mu$ -4-fluorobenzoato- $\kappa^2$ O:O')]

### Crystal data

[Co(C<sub>7</sub>H<sub>4</sub>FO<sub>2</sub>)<sub>2</sub>(H<sub>2</sub>O)<sub>2</sub>]

*M<sub>r</sub>* = 373.17

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

Hall symbol: -*P* 2ybc

*a* = 14.866 (3) Å

*b* = 6.6043 (13) Å

*c* = 7.3081 (15) Å

$\beta$  = 100.94 (3)°

*V* = 704.5 (3) Å<sup>3</sup>

*Z* = 2

*F*<sub>000</sub> = 378

*D<sub>x</sub>* = 1.759 Mg m<sup>-3</sup>

Mo *K*α radiation

$\lambda$  = 0.71073 Å

Cell parameters from 5552 reflections

$\theta$  = 3.4–27.5°

$\mu$  = 1.27 mm<sup>-1</sup>

*T* = 290 K

Block, red

0.54 × 0.35 × 0.10 mm

### Data collection

Rigaku R-Axis RAPID  
diffractometer

Radiation source: fine-focus sealed tube

Monochromator: graphite

1616 independent reflections

1432 reflections with *I* > 2σ(*I*)

*R*<sub>int</sub> = 0.038

Detector resolution: 10 pixels mm<sup>-1</sup>  
 $T = 290$  K  
 $\omega$  scans  
 Absorption correction: multi-scan  
 (ABSCOR; Higashi, 1995)  
 $T_{\min} = 0.590$ ,  $T_{\max} = 0.879$   
 6437 measured reflections

$\theta_{\max} = 27.5^\circ$   
 $\theta_{\min} = 3.4^\circ$   
 $h = -19 \rightarrow 19$   
 $k = -7 \rightarrow 8$   
 $l = -9 \rightarrow 9$

### Refinement

Refinement on  $F^2$   
 Least-squares matrix: full  
 $R[F^2 > 2\sigma(F^2)] = 0.032$   
 $wR(F^2) = 0.087$   
 $S = 1.15$   
 1616 reflections  
 106 parameters  
 Primary atom site location: structure-invariant direct methods

Secondary atom site location: difference Fourier map  
 Hydrogen site location: inferred from neighbouring sites  
 H-atom parameters constrained  
 $w = 1/[\sigma^2(F_o^2) + (0.0337P)^2 + 0.6464P]$   
 where  $P = (F_o^2 + 2F_c^2)/3$   
 $(\Delta/\sigma)_{\max} < 0.001$   
 $\Delta\rho_{\max} = 0.44 \text{ e } \text{\AA}^{-3}$   
 $\Delta\rho_{\min} = -0.34 \text{ e } \text{\AA}^{-3}$   
 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 ( $\text{\AA}^2$ )

	$x$	$y$	$z$	$U_{\text{iso}}^*/U_{\text{eq}}$
Co1	0.5000	0.0000	0.5000	0.01947 (14)
O1	0.60194 (11)	0.0944 (2)	0.7171 (2)	0.0278 (3)
O2	0.56707 (11)	-0.2799 (2)	0.5136 (2)	0.0285 (3)
H2B	0.5729	-0.3586	0.6071	0.043*
H2A	0.5482	-0.3444	0.4130	0.043*
O3	0.57083 (10)	0.0875 (2)	0.2851 (2)	0.0260 (3)
F1	0.98672 (12)	0.3394 (4)	1.1685 (3)	0.0776 (7)
C1	0.62472 (14)	0.2606 (3)	0.7934 (3)	0.0202 (4)
C2	0.72091 (14)	0.2833 (4)	0.8984 (3)	0.0255 (4)
C3	0.75685 (19)	0.4727 (4)	0.9486 (4)	0.0378 (6)
H3	0.7203	0.5873	0.9217	0.045*

## supplementary materials

---

C4	0.8473 (2)	0.4922 (5)	1.0391 (5)	0.0504 (8)
H4	0.8725	0.6190	1.0720	0.060*
C5	0.89849 (18)	0.3206 (5)	1.0786 (4)	0.0487 (7)
C6	0.86542 (18)	0.1311 (5)	1.0332 (4)	0.0476 (7)
H6	0.9021	0.0173	1.0633	0.057*
C7	0.77507 (17)	0.1134 (4)	0.9404 (4)	0.0358 (5)
H7	0.7509	-0.0139	0.9063	0.043*

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

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{12}$	$U^{13}$	$U^{23}$
Co1	0.0219 (2)	0.0161 (2)	0.0191 (2)	-0.00099 (14)	0.00055 (14)	0.00070 (13)
O1	0.0262 (8)	0.0231 (8)	0.0306 (8)	-0.0007 (6)	-0.0034 (6)	-0.0042 (6)
O2	0.0390 (9)	0.0198 (8)	0.0254 (8)	0.0022 (6)	0.0027 (6)	0.0007 (6)
O3	0.0287 (8)	0.0240 (8)	0.0249 (7)	-0.0049 (6)	0.0041 (6)	0.0012 (6)
F1	0.0302 (9)	0.1146 (19)	0.0775 (14)	-0.0175 (11)	-0.0163 (9)	-0.0037 (13)
C1	0.0217 (9)	0.0223 (10)	0.0169 (9)	-0.0031 (8)	0.0045 (7)	0.0005 (7)
C2	0.0237 (10)	0.0312 (12)	0.0212 (10)	-0.0044 (9)	0.0026 (8)	-0.0023 (8)
C3	0.0354 (13)	0.0341 (14)	0.0425 (15)	-0.0079 (10)	0.0036 (11)	-0.0060 (11)
C4	0.0389 (15)	0.055 (2)	0.0544 (18)	-0.0201 (14)	0.0005 (13)	-0.0115 (13)
C5	0.0241 (12)	0.079 (2)	0.0398 (15)	-0.0120 (13)	-0.0031 (10)	-0.0034 (14)
C6	0.0291 (13)	0.0597 (19)	0.0491 (16)	0.0079 (12)	-0.0049 (11)	0.0031 (14)
C7	0.0300 (12)	0.0362 (14)	0.0378 (13)	0.0008 (10)	-0.0024 (9)	-0.0020 (10)

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

Co1—O1 <sup>i</sup>	2.0712 (16)	C1—C2	1.497 (3)
Co1—O1	2.0712 (16)	C2—C7	1.381 (3)
Co1—O2 <sup>i</sup>	2.0938 (16)	C2—C3	1.382 (3)
Co1—O2	2.0938 (16)	C3—C4	1.387 (4)
Co1—O3	2.1301 (15)	C3—H3	0.9300
Co1—O3 <sup>i</sup>	2.1301 (15)	C4—C5	1.365 (5)
O1—C1	1.248 (3)	C4—H4	0.9300
O2—H2B	0.8500	C5—C6	1.362 (5)
O2—H2A	0.8500	C6—C7	1.390 (4)
O3—C1 <sup>ii</sup>	1.278 (3)	C6—H6	0.9300
F1—C5	1.357 (3)	C7—H7	0.9300
C1—O3 <sup>iii</sup>	1.278 (3)		
O1 <sup>i</sup> —Co1—O1	180.00 (10)	O1—C1—C2	117.95 (19)
O1 <sup>i</sup> —Co1—O2 <sup>i</sup>	87.54 (6)	O3 <sup>iii</sup> —C1—C2	118.37 (18)
O1—Co1—O2 <sup>i</sup>	92.46 (6)	C7—C2—C3	119.8 (2)
O1 <sup>i</sup> —Co1—O2	92.46 (6)	C7—C2—C1	119.5 (2)
O1—Co1—O2	87.54 (6)	C3—C2—C1	120.7 (2)
O2 <sup>i</sup> —Co1—O2	180.00 (9)	C2—C3—C4	120.1 (3)
O1 <sup>i</sup> —Co1—O3	84.78 (6)	C2—C3—H3	120.0
O1—Co1—O3	95.22 (6)	C4—C3—H3	120.0

O2 <sup>i</sup> —Co1—O3	91.33 (6)	C5—C4—C3	118.4 (3)
O2—Co1—O3	88.67 (6)	C5—C4—H4	120.8
O1 <sup>i</sup> —Co1—O3 <sup>i</sup>	95.22 (6)	C3—C4—H4	120.8
O1—Co1—O3 <sup>i</sup>	84.78 (6)	F1—C5—C6	118.3 (3)
O2 <sup>i</sup> —Co1—O3 <sup>i</sup>	88.67 (6)	F1—C5—C4	118.4 (3)
O2—Co1—O3 <sup>i</sup>	91.33 (6)	C6—C5—C4	123.4 (2)
O3—Co1—O3 <sup>i</sup>	180.00 (6)	C5—C6—C7	117.8 (3)
C1—O1—Co1	134.73 (14)	C5—C6—H6	121.1
Co1—O2—H2B	123.6	C7—C6—H6	121.1
Co1—O2—H2A	109.0	C2—C7—C6	120.6 (3)
H2B—O2—H2A	110.8	C2—C7—H7	119.7
C1 <sup>ii</sup> —O3—Co1	124.82 (13)	C6—C7—H7	119.7
O1—C1—O3 <sup>iii</sup>	123.68 (19)		

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

*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>
O2—H2B $\cdots$ O3 <sup>iv</sup>	0.85	2.00	2.833 (2)	167
O2—H2A $\cdots$ O3 <sup>v</sup>	0.85	2.11	2.835 (2)	143
O2—H2A $\cdots$ O1 <sup>vi</sup>	0.85	2.42	3.115 (1)	140

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

Fig. 1

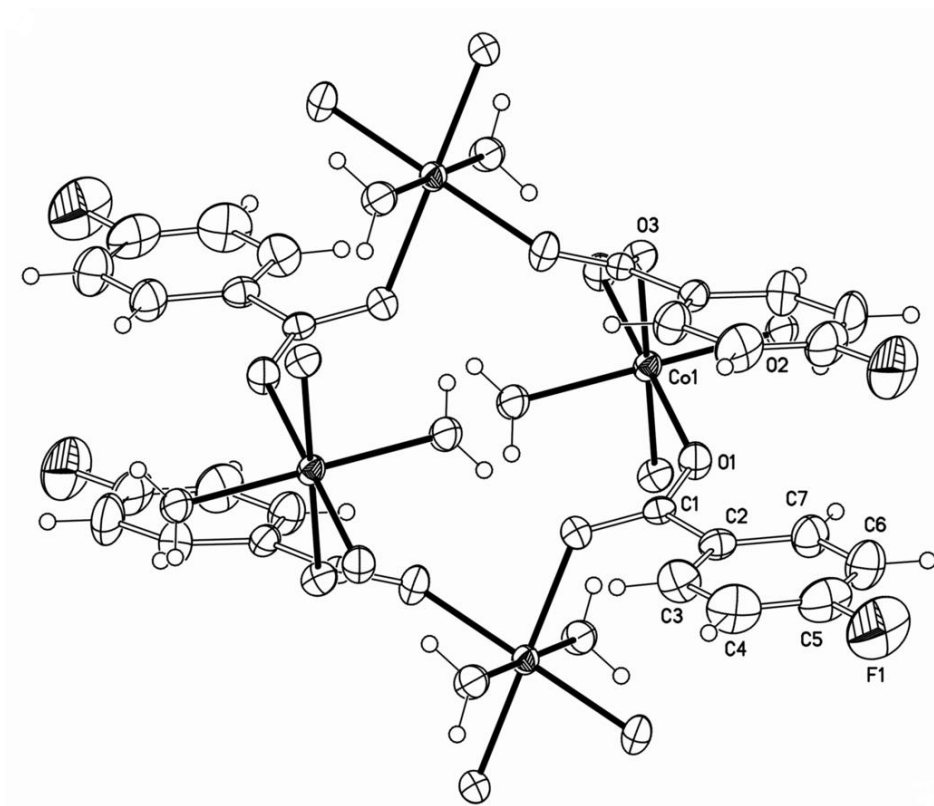


Fig. 2

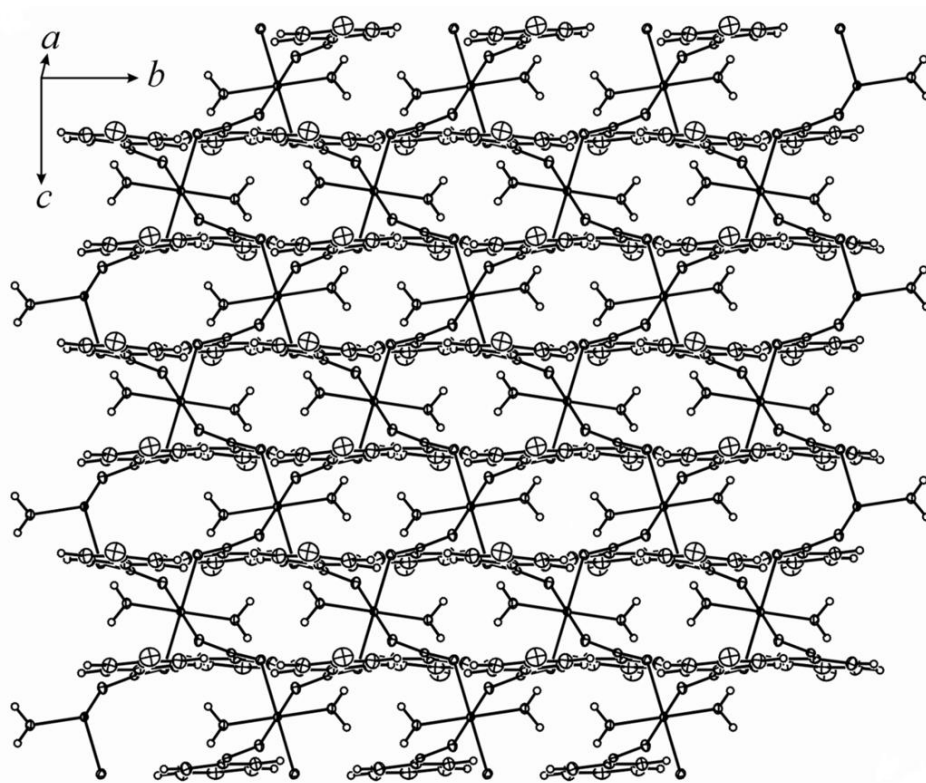


Fig. 3

