

Acta Crystallographica Section E

Structure Reports

Online

ISSN 1600-5368

trans-Bis(1,1,1,5,5,5-hexafluoropentane-2,4-dionato- $\kappa^2 O, O'$)bis(4-methyl-1,2,3-selenadiazole- κN^3)copper(II)

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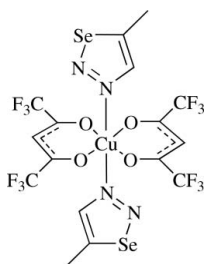
Received 18 November 2009; accepted 11 January 2010

Key indicators: single-crystal X-ray study; $T = 293$ K; mean $\sigma(C-C) = 0.009$ Å; disorder in main residue; R factor = 0.055; wR factor = 0.126; data-to-parameter ratio = 14.0.

In the title compound, $[Cu(C_5HF_6O_2)_2(C_3H_4N_2Se)_2]$, the Cu^{II} atom (site symmetry $\bar{1}$) is coordinated by two O, O' -bidentate 1,1,1,5,5,5-hexafluoro-2,4-pentanedione (hp) ligands and two 4-methyl-1,2,3-selenadiazole molecules, resulting in a slightly distorted *trans*- CuN_2O_4 octahedral geometry in which the *cis* angles deviate by less than 3° from 90° . The selenadiazole plane is canted at $73.13(17)^\circ$ to the square plane defined by the pentanedionate O atoms. The F atoms of one of the hp ligands are disordered over two sets of sites in a 0.66(3):0.34(3) ratio. There are no significant intermolecular interactions in the crystal.

Related literature

Similar structures are exhibited by bis(hexafluoropentanedionato) copper complexes of imidazole (Colacio *et al.*, 2000), pyrazole (Kogane *et al.*, 1990; Fokin *et al.*, 2002) and substituted pyridines (De Panthou *et al.*, 1996; Iwahori *et al.*, 2001; Sano *et al.*, 1997).



Experimental

Crystal data

$[Cu(C_5HF_6O_2)_2(C_3H_4N_2Se)_2]$
 $M_r = 771.74$
Monoclinic, $P2_1/c$
 $a = 8.191(2)$ Å
 $b = 14.390(4)$ Å
 $c = 11.429(4)$ Å
 $\beta = 104.86(3)^\circ$

$V = 1302.1(7)$ Å³
 $Z = 2$
Mo $K\alpha$ radiation
 $\mu = 3.75$ mm⁻¹
 $T = 293$ K
 $0.25 \times 0.25 \times 0.25$ mm

Data collection

Nicolet R3m/V diffractometer
Absorption correction: ψ scan
(*SHELXTL*; Sheldrick, 2008)
 $T_{min} = 0.755$, $T_{max} = 0.793$
3218 measured reflections
3014 independent reflections

1894 reflections with $I > 2\sigma(I)$
 $R_{int} = 0.048$
3 standard reflections every 97 reflections
intensity decay: none

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.055$
 $wR(F^2) = 0.126$
 $S = 1.03$
3014 reflections
215 parameters

H atoms treated by a mixture of independent and constrained refinement
 $\Delta\rho_{max} = 0.44$ e Å⁻³
 $\Delta\rho_{min} = -0.42$ e Å⁻³

Table 1

Selected bond lengths (Å).

| | | | |
|-------|-----------|-------|-----------|
| Cu—O1 | 1.967 (3) | Cu—N1 | 2.391 (4) |
| Cu—O2 | 1.981 (3) | | |

Data collection: *XSCANS* (Siemens, 1996); cell refinement: *XSCANS*; data reduction: *XSCANS*; program(s) used to solve structure: *SHELXL97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *SHELXTL* (Sheldrick, 2008); software used to prepare material for publication: *SHELXL97* (Sheldrick, 2008).

We wish to thank Dr D. Shah, Imperial College, for experimental assistance.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: HB5239).

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supplementary materials

Acta Cryst. (2010). E66, m241 [doi:10.1107/S1600536810001297]

***trans*-Bis(1,1,1,5,5,5-hexafluoropentane-2,4-dionato- κ^2O,O')bis(4-methyl-1,2,3-selenadiazole- κN^3)copper(II)**

N. M. Boag, A. D. Jackson, P. D. Lickiss, R. D. Pilkington and A. D. Redhouse

Comment

The title molecule, [Cu(C₃HF₆O₂)₂(C₃H₄N₂Se)₂], (I) was prepared as a potential precursor to CuInSe₂. The molecule (Fig. 1) is centrosymmetric resulting in pairs of equivalent ligands lying *trans* to each other in a slightly distorted octahedral coordination geometry in which the *cis* angles deviate less than 3° from right angles. The Cu is bound to N1 of the selenadiazole whose plane is canted at 73.13 (0.17)° to the square plane defined by the pentanedionato oxygen atoms. The Cu—N bond is elongated. There are no intermolecular interactions.

Experimental

A solution of 4-methyl-1,2,3-selenadiazole (4.65 g, 0.032 mol) in dichloromethane was added dropwise to a solution of Cu(hfac)₂.xH₂O (7.84 g, 0.016 mol) in dichloromethane/toluene (50 ml) at 273 K in the absence of light. The mixture was stirred for 12 h, the solvent removed *in vacuo* and the residue dissolved in warm toluene. Slow cooling afforded olive-green parallelepipeds of (I). Yield 8.13 g (65%), mpt. 354–356 K. Found: C, 24.86; H, 1.24; N, 7.31%. Calc. for C₁₆H₁₂CuF₁₂N₄O₄Se₂: C, 24.90; H, 1.31; N, 7.26%. μ 2.15 BM.

Refinement

All H atoms were placed in calculated positions and refined using a riding model. All other hydrogen atoms were located and fully refined.

Figures

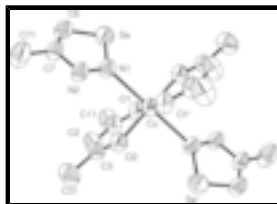


Fig. 1. The molecular structure of (I), with 50% probability displacement ellipsoids. Hydrogen atoms and the fluorine atoms have been excluded for clarity.

***trans*-Bis(1,1,1,5,5,5-hexafluoropentane-2,4-dionato- κ^2O,O')bis(4-methyl-1,2,3-selenadiazole- κN^3)copper(II)**

Crystal data

[Cu(C₃HF₆O₂)₂(C₃H₄N₂Se)₂]

$M_r = 771.74$

$D_x = 1.968 \text{ Mg m}^{-3}$

Melting point: 355 K

supplementary materials

Monoclinic, $P2_1/c$

$a = 8.191$ (2) Å

$b = 14.390$ (4) Å

$c = 11.429$ (4) Å

$\beta = 104.86$ (3)°

$V = 1302.1$ (7) Å³

$Z = 2$

$F(000) = 742$

Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å

Cell parameters from 20 reflections

$\theta = 7.9$ – 14.5 °

$\mu = 3.75$ mm⁻¹

$T = 293$ K

Parallelepiped, green

$0.25 \times 0.25 \times 0.25$ mm

Data collection

Nicolet R3m/V
diffractometer

graphite

profile data from $\theta/2\theta$ scans

Absorption correction: ψ scan
(SHELXTL; Sheldrick, 2008)

$T_{\min} = 0.755$, $T_{\max} = 0.793$

3218 measured reflections

3014 independent reflections

1894 reflections with $I > 2\sigma(I)$

$R_{\text{int}} = 0.048$

$\theta_{\max} = 27.6$ °, $\theta_{\min} = 2.3$ °

$h = -2 \rightarrow 10$

$k = -6 \rightarrow 18$

$l = -14 \rightarrow 14$

3 standard reflections every 97 reflections

intensity decay: none

Refinement

Refinement on F^2

Least-squares matrix: full

$R[F^2 > 2\sigma(F^2)] = 0.055$

$wR(F^2) = 0.126$

$S = 1.03$

3014 reflections

215 parameters

0 restraints

Primary atom site location: structure-invariant direct methods

Secondary atom site location: difference Fourier map

Hydrogen site location: inferred from neighbouring sites

H atoms treated by a mixture of independent and constrained refinement

$w = 1/[\sigma^2(F_o^2) + (0.0459P)^2 + 1.964P]$

where $P = (F_o^2 + 2F_c^2)/3$

$(\Delta/\sigma)_{\max} < 0.001$

$\Delta\rho_{\max} = 0.44$ e Å⁻³

$\Delta\rho_{\min} = -0.42$ e Å⁻³

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.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å²)

| | <i>x</i> | <i>y</i> | <i>z</i> | $U_{\text{iso}}^*/U_{\text{eq}}$ | Occ. (<1) |
|----|----------|----------|----------|----------------------------------|-----------|
| Cu | 0.0000 | 0.0000 | 0.5000 | 0.0467 (2) | |

| | | | | | |
|------|--------------|-------------|-------------|-------------|----------|
| Se | 0.11516 (8) | 0.14840 (4) | 0.26686 (5) | 0.0667 (2) | |
| N1 | 0.0700 (6) | 0.1433 (3) | 0.4188 (4) | 0.0564 (11) | |
| N2 | 0.0391 (6) | 0.2234 (3) | 0.4541 (4) | 0.0572 (11) | |
| C6 | 0.0853 (8) | 0.2732 (4) | 0.2739 (5) | 0.0628 (15) | |
| C7 | 0.0470 (7) | 0.2966 (4) | 0.3777 (5) | 0.0577 (13) | |
| C71 | 0.0087 (11) | 0.3911 (4) | 0.4164 (6) | 0.093 (2) | |
| H71A | -0.0143 | 0.4322 | 0.3479 | 0.140* | |
| H71B | 0.1040 | 0.4139 | 0.4772 | 0.140* | |
| H71C | -0.0881 | 0.3882 | 0.4489 | 0.140* | |
| O1 | -0.1707 (5) | -0.0178 (2) | 0.3457 (3) | 0.0546 (9) | |
| O2 | -0.1614 (5) | 0.0692 (2) | 0.5702 (3) | 0.0520 (8) | |
| C1 | -0.3071 (7) | 0.0274 (4) | 0.3148 (5) | 0.0582 (14) | |
| C11 | -0.4037 (9) | 0.0109 (5) | 0.1836 (6) | 0.0771 (19) | |
| F11 | -0.5552 (6) | 0.0472 (5) | 0.1545 (4) | 0.157 (3) | |
| F12 | -0.3218 (6) | 0.0490 (3) | 0.1084 (3) | 0.1142 (15) | |
| F13 | -0.4170 (6) | -0.0780 (3) | 0.1545 (4) | 0.1076 (14) | |
| C2 | -0.3728 (8) | 0.0879 (4) | 0.3859 (5) | 0.0674 (16) | |
| C3 | -0.2960 (7) | 0.1034 (4) | 0.5075 (5) | 0.0541 (13) | |
| C31 | -0.3885 (10) | 0.1722 (5) | 0.5750 (7) | 0.0782 (19) | |
| F311 | -0.318 (2) | 0.2515 (8) | 0.581 (3) | 0.145 (9) | 0.66 (3) |
| F312 | -0.5418 (12) | 0.1700 (18) | 0.5425 (19) | 0.161 (10) | 0.66 (3) |
| F313 | -0.349 (2) | 0.1452 (18) | 0.6957 (10) | 0.137 (6) | 0.66 (3) |
| F321 | -0.300 (2) | 0.210 (2) | 0.663 (3) | 0.105 (10) | 0.34 (3) |
| F322 | -0.520 (6) | 0.141 (2) | 0.591 (5) | 0.18 (2) | 0.34 (3) |
| F323 | -0.457 (6) | 0.2452 (19) | 0.4941 (19) | 0.138 (14) | 0.34 (3) |
| H2 | -0.475 (7) | 0.118 (4) | 0.347 (5) | 0.065 (17)* | |
| H6 | 0.085 (9) | 0.314 (5) | 0.207 (7) | 0.12 (3)* | |

Atomic displacement parameters (\AA^2)

| | U^{11} | U^{22} | U^{33} | U^{12} | U^{13} | U^{23} |
|-----|------------|------------|-------------|-------------|-------------|--------------|
| Cu | 0.0603 (5) | 0.0401 (4) | 0.0375 (4) | 0.0048 (4) | 0.0085 (4) | -0.0043 (4) |
| Se | 0.0834 (5) | 0.0652 (4) | 0.0568 (4) | 0.0044 (3) | 0.0276 (3) | -0.0066 (3) |
| N1 | 0.072 (3) | 0.051 (3) | 0.051 (2) | 0.001 (2) | 0.023 (2) | 0.004 (2) |
| N2 | 0.081 (3) | 0.047 (3) | 0.047 (2) | 0.002 (2) | 0.023 (2) | 0.005 (2) |
| C6 | 0.080 (4) | 0.063 (4) | 0.049 (3) | -0.001 (3) | 0.022 (3) | 0.012 (3) |
| C7 | 0.080 (4) | 0.047 (3) | 0.046 (3) | 0.002 (3) | 0.014 (3) | 0.009 (2) |
| C71 | 0.152 (7) | 0.059 (4) | 0.076 (4) | 0.002 (4) | 0.044 (5) | 0.001 (3) |
| O1 | 0.065 (2) | 0.051 (2) | 0.0436 (18) | 0.0042 (18) | 0.0060 (17) | -0.0060 (16) |
| O2 | 0.064 (2) | 0.047 (2) | 0.0444 (18) | 0.0014 (17) | 0.0132 (17) | -0.0044 (15) |
| C1 | 0.067 (4) | 0.058 (3) | 0.045 (3) | 0.003 (3) | 0.007 (3) | -0.002 (2) |
| C11 | 0.077 (4) | 0.092 (5) | 0.052 (4) | 0.012 (4) | -0.003 (3) | -0.016 (3) |
| F11 | 0.098 (3) | 0.260 (7) | 0.081 (3) | 0.080 (4) | -0.033 (2) | -0.062 (4) |
| F12 | 0.149 (4) | 0.133 (4) | 0.052 (2) | -0.001 (3) | 0.011 (2) | 0.013 (2) |
| F13 | 0.130 (4) | 0.102 (3) | 0.072 (2) | -0.014 (3) | -0.008 (2) | -0.024 (2) |
| C2 | 0.061 (4) | 0.074 (4) | 0.060 (3) | 0.013 (3) | 0.003 (3) | -0.014 (3) |
| C3 | 0.056 (3) | 0.048 (3) | 0.061 (3) | -0.001 (3) | 0.019 (3) | -0.010 (3) |
| C31 | 0.081 (5) | 0.070 (5) | 0.089 (5) | -0.002 (4) | 0.032 (4) | -0.030 (4) |

supplementary materials

| | | | | | | |
|------|------------|------------|------------|------------|-------------|-------------|
| F311 | 0.164 (16) | 0.064 (6) | 0.23 (2) | 0.004 (7) | 0.095 (18) | -0.043 (9) |
| F312 | 0.045 (6) | 0.27 (2) | 0.158 (13) | 0.041 (8) | -0.001 (6) | -0.123 (14) |
| F313 | 0.147 (12) | 0.188 (15) | 0.088 (6) | 0.053 (10) | 0.052 (7) | -0.030 (8) |
| F321 | 0.067 (11) | 0.12 (2) | 0.104 (17) | 0.027 (14) | -0.015 (11) | -0.071 (14) |
| F322 | 0.23 (4) | 0.132 (17) | 0.27 (5) | -0.10 (2) | 0.22 (4) | -0.10 (2) |
| F323 | 0.21 (3) | 0.101 (14) | 0.094 (12) | 0.105 (18) | 0.034 (16) | 0.019 (10) |

Geometric parameters (Å, °)

| | | | |
|------------------------|------------|---------------|------------|
| Cu—O1 | 1.967 (3) | C1—C2 | 1.390 (8) |
| Cu—O2 | 1.981 (3) | C1—C11 | 1.524 (8) |
| Cu—N1 | 2.391 (4) | C11—F11 | 1.308 (7) |
| Se—C6 | 1.817 (6) | C11—F13 | 1.318 (8) |
| Se—N1 | 1.867 (4) | C11—F12 | 1.336 (8) |
| N1—N2 | 1.268 (6) | C2—C3 | 1.389 (8) |
| N2—C7 | 1.380 (6) | C2—H2 | 0.95 (6) |
| C6—C7 | 1.345 (7) | C3—C31 | 1.565 (8) |
| C6—H6 | 0.97 (8) | C31—F312 | 1.214 (12) |
| C7—C71 | 1.488 (8) | C31—F311 | 1.273 (12) |
| C71—H71A | 0.96 | C31—F313 | 1.389 (15) |
| C71—H71B | 0.96 | C31—F321 | 1.204 (17) |
| C71—H71C | 0.96 | C31—F322 | 1.23 (2) |
| O1—C1 | 1.262 (6) | C31—F323 | 1.418 (17) |
| O2—C3 | 1.252 (6) | | |
| O1—Cu—O2 ⁱ | 88.06 (14) | O1—C1—C11 | 113.2 (5) |
| O1—Cu—O2 | 91.94 (14) | C2—C1—C11 | 119.5 (5) |
| O1—Cu—N1 | 87.15 (15) | F11—C11—F13 | 108.2 (6) |
| O1 ⁱ —Cu—N1 | 92.85 (15) | F11—C11—F12 | 105.9 (6) |
| O2 ⁱ —Cu—N1 | 91.44 (15) | F13—C11—F12 | 105.0 (6) |
| O2—Cu—N1 | 88.57 (15) | F11—C11—C1 | 114.0 (5) |
| C6—Se—N1 | 86.4 (2) | F13—C11—C1 | 112.8 (6) |
| N2—N1—Se | 111.3 (3) | F12—C11—C1 | 110.4 (6) |
| N2—N1—Cu | 125.0 (3) | C3—C2—C1 | 122.8 (6) |
| Se—N1—Cu | 121.3 (2) | C3—C2—H2 | 121 (3) |
| N1—N2—C7 | 116.6 (4) | C1—C2—H2 | 116 (3) |
| C7—C6—Se | 110.6 (4) | O2—C3—C2 | 128.1 (5) |
| C7—C6—H6 | 126 (4) | O2—C3—C31 | 115.7 (5) |
| Se—C6—H6 | 123 (4) | C2—C3—C31 | 116.3 (6) |
| C6—C7—N2 | 115.2 (5) | F312—C31—F311 | 117.2 (13) |
| C6—C7—C71 | 127.2 (5) | F312—C31—F313 | 104.9 (12) |
| N2—C7—C71 | 117.5 (5) | F311—C31—F313 | 102.0 (11) |
| C7—C71—H71A | 109.5 | F312—C31—C3 | 115.2 (8) |
| C7—C71—H71B | 109.5 | F311—C31—C3 | 109.0 (8) |
| H71A—C71—H71B | 109.5 | F313—C31—C3 | 107.1 (8) |
| C7—C71—H71C | 109.5 | F321—C31—F322 | 114 (2) |
| H71A—C71—H71C | 109.5 | F321—C31—F323 | 105.4 (16) |
| H71B—C71—H71C | 109.5 | F322—C31—F323 | 99 (2) |
| C1—O1—Cu | 123.9 (3) | F321—C31—C3 | 115.3 (10) |

| | | | |
|---------------------------|------------|----------------|-------------|
| C3—O2—Cu | 123.2 (3) | F322—C31—C3 | 113.4 (14) |
| O1—C1—C2 | 127.4 (5) | F323—C31—C3 | 107.9 (9) |
| C6—Se—N1—N2 | 0.8 (4) | Cu—O1—C1—C11 | 171.1 (4) |
| C6—Se—N1—Cu | 164.0 (3) | O1—C1—C11—F11 | 171.4 (6) |
| O1—Cu—N1—N2 | 109.9 (4) | C2—C1—C11—F11 | -8.8 (10) |
| O1 ⁱ —Cu—N1—N2 | -70.1 (4) | O1—C1—C11—F13 | 47.5 (8) |
| O2 ⁱ —Cu—N1—N2 | -162.1 (4) | C2—C1—C11—F13 | -132.7 (6) |
| O2—Cu—N1—N2 | 17.9 (4) | O1—C1—C11—F12 | -69.6 (7) |
| O1—Cu—N1—Se | -50.9 (3) | C2—C1—C11—F12 | 110.2 (7) |
| O1 ⁱ —Cu—N1—Se | 129.1 (3) | O1—C1—C2—C3 | -3.2 (11) |
| O2 ⁱ —Cu—N1—Se | 37.1 (3) | C11—C1—C2—C3 | 177.1 (6) |
| O2—Cu—N1—Se | -142.9 (3) | Cu—O2—C3—C2 | 11.9 (8) |
| Se—N1—N2—C7 | -1.0 (6) | Cu—O2—C3—C31 | -168.1 (4) |
| Cu—N1—N2—C7 | -163.4 (4) | C1—C2—C3—O2 | 1.3 (10) |
| N1—Se—C6—C7 | -0.5 (5) | C1—C2—C3—C31 | -178.8 (6) |
| Se—C6—C7—N2 | 0.1 (7) | O2—C3—C31—F312 | -145.3 (18) |
| Se—C6—C7—C71 | -178.2 (6) | C2—C3—C31—F312 | 34.8 (19) |
| N1—N2—C7—C6 | 0.6 (8) | O2—C3—C31—F311 | 80.6 (17) |
| N1—N2—C7—C71 | 179.1 (6) | C2—C3—C31—F311 | -99.4 (16) |
| O2 ⁱ —Cu—O1—C1 | -164.5 (4) | O2—C3—C31—F313 | -29.0 (14) |
| O2—Cu—O1—C1 | 15.5 (4) | C2—C3—C31—F313 | 151.0 (13) |
| N1 ⁱ —Cu—O1—C1 | 107.0 (4) | O2—C3—C31—F321 | 24 (3) |
| N1—Cu—O1—C1 | -73.0 (4) | C2—C3—C31—F321 | -156 (3) |
| O1—Cu—O2—C3 | -16.9 (4) | O2—C3—C31—F322 | -110 (3) |
| O1 ⁱ —Cu—O2—C3 | 163.1 (4) | C2—C3—C31—F322 | 71 (3) |
| N1 ⁱ —Cu—O2—C3 | -109.8 (4) | O2—C3—C31—F323 | 142 (2) |
| N1—Cu—O2—C3 | 70.2 (4) | C2—C3—C31—F323 | -38 (3) |
| Cu—O1—C1—C2 | -8.6 (8) | | |

Symmetry codes: (i) $-x, -y, -z+1$.

Fig. 1

