

Acetato(*N*-phenylpyridine-2-carboxamido- κ^2 N,N)(*N*-phenylpyridine-2-carboxamide- κ^2 N¹,O)copper(II)

Ligia Gomes,^{a,*} John Nicolson Low,^b Mário A. D. C. Valente,^c Cristina Freire^c and Baltazar Castro^c

^aCIAGEB—Faculdade de Ciências de Saúde, Escola Superior de Saúde da UFP, Universidade Fernando Pessoa, Rua Carlos da Maia 296, P-4200-150 Porto, Portugal, ^bDepartment of Chemistry, University of Aberdeen, Meston Walk, Old Aberdeen AB24 3UE, Scotland, and ^cREQUIMTE, Departamento de Química, Faculdade de Ciências, Universidade do Porto, Rua do Campo Alegre, 4169-007 Porto, Portugal

Correspondence e-mail: lrgomes@ufp.pt

Received 19 April 2007

Accepted 12 May 2007

Online 14 June 2007

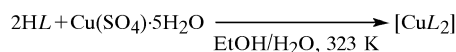
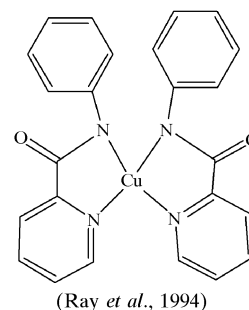
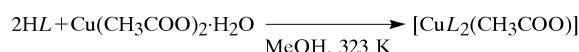
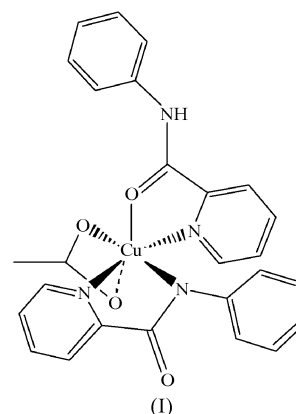
The title complex, [Cu(C₁₂H₉N₂O)(C₂H₃O₂)(C₁₂H₁₀N₂O)], is a neutral Cu^{II} complex with a primary N₃O₂ coordination sphere. The Cu centre coordinates to both a deprotonated and a neutral molecule of *N*-phenylpyridine-2-carboxamide and also to an acetate anion. The coordination around the metal centre is asymmetric, the deprotonated ligand providing two N donor atoms [Cu—N = 1.995 (2) and 2.013 (2) Å] and the neutral ligand providing one N and one O donor atom to the coordination environment [Cu—N = 2.042 (2) Å and Cu—O = 2.2557 (19) Å], the fifth donor being an O atom of the acetate ion [Cu—O = 1.9534 (19) Å]. The remaining O atom from the acetate ion can be considered as a weak donor atom [Cu—O = 2.789 (2) Å], conferring to the Cu complex an asymmetric octahedral geometry. The crystal structure is stabilized by intermolecular N—H...O, C—H...O and C—H... π interactions.

Comment

The title complex, (I), assumes a different geometry to previously reported complexes in the literature with identical and similar ligands. In the Cu^{II} complex with the same ligand (Ray *et al.*, 1994), the structure determination showed that the Cu complex is four-coordinate with a symmetric N₄ coordination environment, with the ligand assuming a *cis* conformation. A Cu complex with a similar ligand [*N*-(2-chloro-6-methylphenyl)pyridine-2-carboxamide] has also been reported (Patra *et al.*, 1999). In this case, the molecular structure determination showed that the Cu centre is five-coordinate in a distorted trigonal-bipyramidal geometry, having an N₄O coordination environment, with the pyridine and the amide N atoms of each organic ligand occupying an axial and an

equatorial position and the fifth coordination position being occupied by a water molecule.

The *N*-phenylpyridine-2-carboxamide ligand (*L*) was obtained by a condensation reaction between pyridine-2-carboxylic acid and phenylamide in a basic reductive reaction medium following a modification of the procedure described by Barnes *et al.* (1978) and a similar procedure described by Ray *et al.* (1994). The ligand, potentially bidentate, reacted with copper(II) acetate forming a five-coordinate complex, (I). The synthesis of the complex was performed in a fashion similar to that reported previously (Ray *et al.*, 1994) but using different reaction conditions. In the previous synthesis, the ligand (dissolved in ethanol) was allowed to react with an aqueous solution of CuSO₄·5H₂O, while in the synthesis reported here, the ligand was dissolved in methanol and added to a methanol solution of Cu(CH₃COO)₂·H₂O.



A view of the structure of the title complex and the coordination environment around the Cu atom, together with the atomic numbering scheme, is shown in Fig. 1. The coordination environment around copper is of the N₃O₂-type and is asymmetric. One of the *N*-phenylpyridine-2-carboxamide molecules (ligand *A*) provides a pyridine N and an amide O donor atom. The second molecule (ligand *B*, labelled X4#, where *X* is the atom label and # is an integer) provides a pyridine and a deprotonated amide N donor atom. The remaining donor O atom, O3, is from the acetate anion. Atom O31 of the acetate residue can be considered to interact weakly with the Cu^{II} ion [Cu1—O31 = 2.789 (2) Å]. In this

case, the primary N_3O_2 five-coordination geometry gives place to an effective asymmetric octahedral elongated geometry (Kiani *et al.*, 2002; Burčák *et al.*, 2005). The primary Cu-atom geometry is a distorted square-based pyramid with a τ value of 0.10 [the structure index is defined as $\tau = (\beta - \alpha)/60$, where β

and α are the largest coordination angles; $\tau = 0$ for square-pyramidal geometry and $\tau = 1$ for trigonal-bipyramidal geometry (Addison *et al.*, 1984)]. Ligand *B* (providing two N donor atoms), an acetate O atom and the pyridine N atom of ligand *A* encompass the basal plane of the square pyramid [amide $Cu1-N47 = 1.995(2)$ Å, pyridine $Cu1-N41$ and $Cu1-N1 = 2.013(5)$ and $2.042(2)$ Å, respectively, and acetate $Cu1-O3 = 1.9534(19)$ Å], from which the Cu atom is displaced by $0.1253(11)$ Å towards an apical amide O donor atom [$Cu1-O2 = 2.2557(19)$ Å]. The apical $Cu1-O2$ bond length is 0.26 Å longer than the mean distance adopted by the basal atoms. The bond angles involving the coordinated metal centre and the donor atoms are given in Table 1. The largest distortions from square-pyramidal geometry are indicated by the $N41-Cu1-N1$ and $O3-Cu1-N47$ angles. These deviations can be attributed to steric effects imposed by the conformations assumed by the ligands.

The presence of the H atom on atom N27 in ligand *A* precludes this atom being coordinated to the Cu atom; instead, ligand *A* is rotated by approximately 180° and carbonyl atom O2 is the donor to the Cu atom, so that ligands *A* and *B* assume different conformations around the $C2-C27$ and $C42-C47$ bonds, the $N1-C2-C27-N27$ torsion angle in ligand *A* being $171.8(2)^\circ$, and $N41-C42-C47-N47$, the corresponding torsion angle in ligand *B*, being $0.1(3)^\circ$. In ligand *A*, the $C27-N27-C21-C22$ torsion angle is $-174.7(3)^\circ$, while the corresponding angle $C47-N47-$

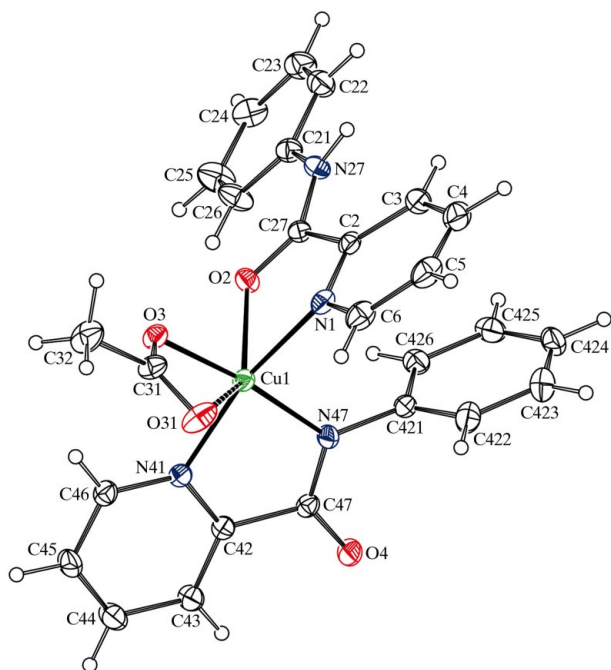


Figure 1
A view of (I), with our numbering scheme. Displacement ellipsoids are drawn at the 30% probability level.

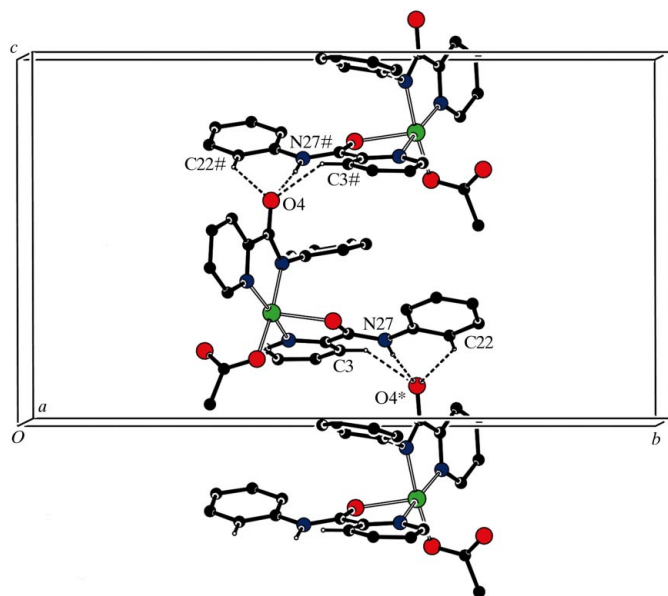


Figure 2
A view of the chain parallel to the *c* axis formed by the action of one $N-H \cdots O$ hydrogen bond augmented by two $C-H \cdots O$ hydrogen bonds, all involving atom O4 as the acceptor. Atoms labelled with an asterisk (*) or a hash (#) are at the symmetry positions $(1-x, 1-y, -\frac{1}{2}+z)$ and $(1-x, 1-y, \frac{1}{2}-z)$, respectively. H atoms not involved in the hydrogen bonding have been omitted for the sake of clarity.

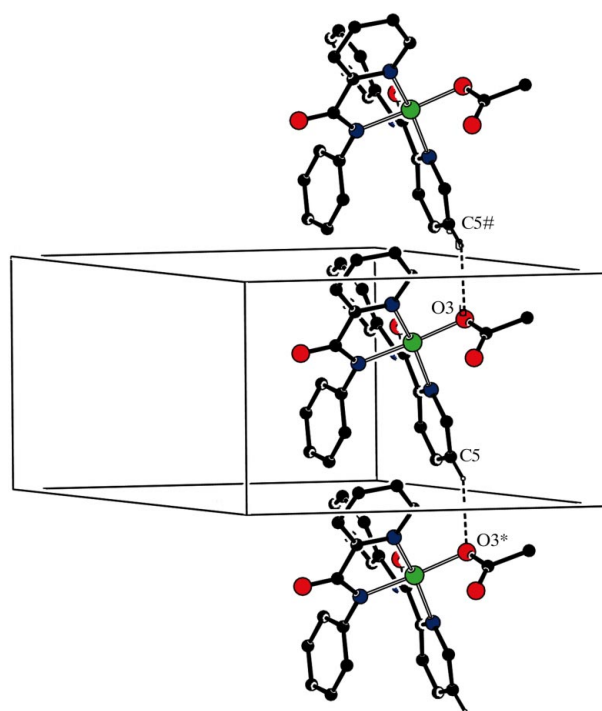


Figure 3
A view of the chain parallel to the *a* axis formed by a $C-H \cdots O$ hydrogen bond. Atoms labelled with an asterisk (*) or a hash (#) are at the symmetry positions $(-1+x, y, z)$ and $(1+x, y, z)$, respectively. H atoms not involved in the hydrogen bonding have been omitted for the sake of clarity.

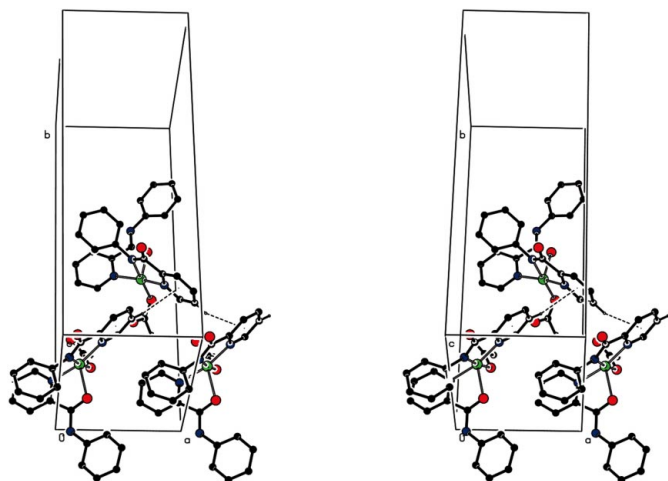


Figure 4

A stereoview of the chain formed by a C—H... π interaction. H atoms not involved in the hydrogen bonding have been omitted for the sake of clarity.

C421—C422 in ligand *B* is $-96.9(3)^\circ$. The C27—N27 bond [$1.346(3) \text{ \AA}$] is significantly longer than the C47—N47 bond [$1.323(3) \text{ \AA}$] at the 3σ level. Atom H27 is thus available for hydrogen bonding.

The supramolecular structure is defined by an N—H...O, three C—H...O and one C—H... π hydrogen bond, which combine to form a three-dimensional network. Atom N27 acts as a hydrogen-bond donor, *via* H27, to O4ⁱ (all symmetry codes are given in Table 2). This is augmented by the C3—H3...O4ⁱ and C22—H22...O4ⁱ hydrogen bonds. These three hydrogen bonds link the molecules into a chain that runs parallel to the *c* axis (Table 2 and Fig. 2). Atom C5 acts as a hydrogen-bond donor, *via* H5, to O3ⁱⁱ, thus linking the molecules into a chain that runs parallel to the *a* axis (Table 2 and Fig. 3). Finally, atom C45 is involved in a C—H... π contact with the pyridine ring containing atom N41ⁱⁱⁱ (Table 2 and Fig. 4).

Experimental

N-Phenylpyridine-2-carboxamide was prepared following a modification of the procedure described by Barnes *et al.* (1978). A solution consisting of a mixture of pyridine-2-carboxylic acid (picolinic acid, 40 mmol), phenylamide (aniline, 40 mmol) and triphenyl phosphite (40 mmol) in 50 ml of pyridine was kept for 3 h in a boiling water bath. The resulting solution was cooled and maintained at room temperature for 48 h. The resulting white fibrous crystals were filtered off and washed with a small amount of a 1:1 mixture of acetone and diethyl ether (78% yield). Analysis found: C 72.9, H 5.10, N 14.01%; $\text{C}_{12}\text{H}_{10}\text{N}_2\text{O}$ requires: C 72.7, H 5.08, N 14.14%. For the synthesis of (I), a solution of copper(II) acetate monohydrate in methanol (2.5 mmol) was added to a solution of *N*-phenylpyridine-2-carboxamide (5.0 mmol) in methanol at 323 K. The resulting solution was left to cool for 24 h, allowing partial evaporation of the solvent. Single crystals were obtained by slow evaporation of the resulting solution at room temperature. These were collected and washed with a 1:1 mixture of acetone and diethyl ether, and dried under low pressure. Analysis found: C 60.23, H 4.45, N 10.78%; $\text{C}_{26}\text{H}_{22}\text{CuN}_4\text{O}_4$ requires: C 60.28, H 4.28, N 10.82%.

Crystal data

$[\text{Cu}(\text{C}_{12}\text{H}_9\text{N}_2\text{O})(\text{C}_2\text{H}_3\text{O}_2)-(\text{C}_{12}\text{H}_{10}\text{N}_2\text{O})]$
 $M_r = 518.02$
 Orthorhombic, $Pna2_1$
 $a = 7.9604(1) \text{ \AA}$
 $b = 23.057(3) \text{ \AA}$
 $c = 13.227(2) \text{ \AA}$

$V = 2427.7(5) \text{ \AA}^3$
 $Z = 4$
 Mo $K\alpha$ radiation
 $\mu = 0.94 \text{ mm}^{-1}$
 $T = 120(2) \text{ K}$
 $0.25 \times 0.10 \times 0.10 \text{ mm}$

Data collection

Stoe Stadi-4 diffractometer
 Absorption correction: multi-scan (North *et al.*, 1968)
 $T_{\min} = 0.799$, $T_{\max} = 0.912$
 6079 measured reflections
 5831 independent reflections

4590 reflections with $I > 2\sigma(I)$
 $R_{\text{int}} = 0.022$
 10 standard reflections
 frequency: 120 min
 intensity decay: none

Refinement

$R[F^2 > 2\sigma(F^2)] = 0.035$
 $wR(F^2) = 0.088$
 $S = 1.03$
 5831 reflections
 317 parameters
 1 restraint

H-atom parameters constrained
 $\Delta\rho_{\text{max}} = 0.21 \text{ e \AA}^{-3}$
 $\Delta\rho_{\text{min}} = -0.26 \text{ e \AA}^{-3}$
 Absolute structure: Flack (1983),
 2827 Friedel pairs
 Flack parameter: 0.003 (11)

Table 1

Selected bond and torsion angles ($^\circ$).

O3—Cu1—N47	173.55 (9)	N41—Cu1—N1	167.38 (8)
O3—Cu1—N41	93.02 (9)	O3—Cu1—O2	95.35 (7)
N47—Cu1—N41	81.05 (9)	N47—Cu1—O2	89.43 (8)
O3—Cu1—N1	92.53 (9)	N41—Cu1—O2	114.30 (8)
N47—Cu1—N1	92.81 (9)	N1—Cu1—O2	76.41 (8)
N1—C2—C27—N27	171.8 (2)	N41—C42—C47—N47	0.1 (3)
C27—N27—C21—C22	$-174.7(3)$	C47—N47—C421—C422	$-96.9(3)$

Table 2

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

Cg5 is the centroid of the pyridine ring containing atom N41.

$D\cdots H\cdots A$	$D\cdots H$	$H\cdots A$	$D\cdots A$	$D\cdots H\cdots A$
N27—H27...O4 ⁱ	0.89	1.92	2.805 (3)	170
C3—H3...O4 ⁱ	0.95	2.32	3.095 (4)	138
C5—H5...O3 ⁱⁱ	0.95	2.55	3.401 (4)	150
C22—H22...O4 ⁱ	0.95	2.52	3.279 (4)	137
C45—H45...Cg5 ⁱⁱⁱ	0.95	2.78	3.582 (3)	142

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

Compound (I) crystallized in the orthorhombic system; space groups $Pna2_1$ and $Pnma$ were permitted from the systematic absences, and $Pna2_1$ was confirmed by the analysis. H atoms were treated as riding atoms, with C—H distances of 0.95 (aromatic) and 0.98 $\text{\AA}$ (methyl), an N—H distance of 0.89 $\text{\AA}$, and $U_{\text{iso}}(\text{H})$ values of 1.5 (methyl) or 1.2 times $U_{\text{eq}}(\text{C,N})$. The correct orientation of the structure with respect to the polar-axis direction was established by means of the Flack (1983) parameter.

Data collection: *STADI4* (Stoe & Cie, 1996); cell refinement: *X-RED* (Stoe & Cie, 1996); data reduction: *X-RED*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *OSCAIL* (McArdle, 2003) and *SHELXL97* (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 2003); software used to prepare material for publication: *SHELXL97* and *PRPKAPPA* (Ferguson, 1999).

X-ray data were collected at the Institut für Anorganische Chemie, Universität Karlsruhe. LG thanks Fundação Para a Ciência e Tecnologia (POCI/QUI/61873/2004) for financial support.

Supplementary data for this paper are available from the IUCr electronic archives (Reference: GG3093). Services for accessing these data are described at the back of the journal.

References

- Addison, A. W., Rao, T. N. & Verschoor, G. C. (1984). *J. Chem. Soc. Dalton Trans.* pp. 1349–1356.
- Barnes, P. J., Chapman, R. L., Vagg, R. S. & Watton, E. C. (1978). *J. Chem. Eng. Data*, **23**, 349–350.
- Burčák, M., Potočník, I., Massa, W. & Jäger, L. (2005). *Acta Cryst.* **C61**, m353–m355.
- Ferguson, G. (1999). *PRPKAPPA*. University of Guelph, Canada.
- Flack, H. D. (1983). *Acta Cryst.* **A39**, 876–881.
- Kiani, S., Staples, R. J. & Packard, A. B. (2002). *Acta Cryst.* **C58**, m593–m595.
- McArdle, P. (2003). *OSCAIL for Windows*. Version 10. Crystallography Centre, Chemistry Department, NUI Galway, Ireland.
- North, A. C. T., Phillips, D. C. & Mathews, F. S. (1968). *Acta Cryst.* **A24**, 351–359.
- Patra, A. K., Ray, M. & Mukherjee, R. (1999). *J. Chem. Soc. Dalton Trans.* pp. 2461–2466.
- Ray, M., Mukherjee, R., Richardson, J. F., Mashuta, M. S. & Buchanan, R. M. (1994). *J. Chem. Soc. Dalton Trans.* pp. 965–969.
- Sheldrick, G. M. (1997). *SHELXS97* and *SHELXL97*. University of Göttingen, Germany.
- Spek, A. L. (2003). *J. Appl. Cryst.* **36**, 7–13.
- Stoe & Cie (1996). *STADI4* and *X-RED*. Stoe & Cie GmbH, Darmstadt, Germany.