Acta Crystallographica Section E
Structure Reports Online
ISSN 1600-5368

Bis(2-phenylethylammonium) tetrachloridocobaltate(II)

In-Hwan Oh,[a] Dahye Kim,[b] Young-Duk Huh,[b] Younbong Park,[c] J. M. Sungil Park[a] and Seong-Hun Park[d]*

[a]Neutron Science Division, Korea Atomic Energy Research Institute, Daejeon, 305-353, Republic of Korea, [b]Department of Chemistry, Dankook University, Gyeonggi-Do, 448-701, Republic of Korea, [c]Department of Chemistry, Chungnam National University, Daejeon, 305-764, Republic of Korea, and [d]Department of Chemistry, Faculty of Liberal Art & Teacher Education, University of Seoul, Seoul, 130-743, Republic of Korea
Correspondence e-mail: parksh@uos.ac.kr

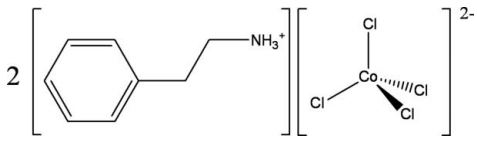
Received 22 March 2011; accepted 29 March 2011

Key indicators: single-crystal X-ray study; T = 296 K; mean σ(C–C) = 0.011 Å; R factor = 0.055; wR factor = 0.161; data-to-parameter ratio = 17.0.

Crystals of the title compound, $(C_6H_5CH_2CH_2NH_3)_2[CoCl_4]$, were grown by the solvent-evaporation method. This inorganic–organic hybrid compound exhibits a layered structure in which isolated $CoCl_4$ inorganic layers alternate with bilayers of phenylethylammonium cations. Although the inorganic anion is zero-dimensional, the layered structure is stabilized *via* N—H···Cl hydrogen bonds. The $CoCl_4$ tetrahedra connect to the cations through N—H···Cl hydrogen bonds, building a two-dimensional network extending parallel to (010).

Related literature

For inorganic–organic hybrids containing tetrahedral anions, see: Abdi *et al.* (2005); Huh *et al.* (2006); Zouari & Ben Salah, (2004). For low-dimensional magnetism in inorganic–organic perovskite systems, see: de Jongh (1986); Park & Lee (2005, 2006); Depmeier (2009); Mitzi (1999). For classification of hydrogen bonds depending on bond lengths, see: Steiner (1998, 2002).



Experimental

Crystal data

$(C_8H_{12}N)_2[CoCl_4]$
M_r = 445.10
Monoclinic, $P2_1/c$
a = 7.4623 (13) Å
b = 24.664 (3) Å
c = 11.1997 (16) Å
β = 91.769 (13)°
V = 2060.3 (5) Å^3
Z = 4
Mo $K\alpha$ radiation
μ = 1.35 mm^{-1}
T = 296 K
0.50 × 0.40 × 0.35 mm

Data collection

Bruker P4 diffractometer
Absorption correction: multi-scan (*SADABS*; Sheldrick, 1996)
T_{min} = 0.237, T_{max} = 0.265
4692 measured reflections
3595 independent reflections
1566 reflections with $I > 2\sigma(I)$
R_{int} = 0.041
3 standard reflections every 97 reflections
intensity decay: none

Refinement

$R[F^2 > 2\sigma(F^2)]$ = 0.055
$wR(F^2)$ = 0.161
S = 1.03
3595 reflections
211 parameters
2 restraints
H-atom parameters constrained
$\Delta\rho_{max}$ = 0.43 e Å^{-3}
$\Delta\rho_{min}$ = −0.30 e Å^{-3}

Table 1
Selected bond lengths (Å).

Co1—Cl4	2.229 (2)	Co1—Cl1	2.272 (2)
Co1—Cl2	2.251 (2)	Co1—Cl3	2.276 (2)

Table 2
Hydrogen-bond geometry (Å, °).

D—H···A	D—H	H···A	D···A	D—H···A
N2—H2C···Cl1^{i}	0.89	2.62	3.445 (6)	156
N2—H2A···Cl4^{ii}	0.89	2.51	3.321 (6)	152
N1—H1C···Cl3^{iii}	0.89	2.42	3.291 (8)	167
N1—H1B···Cl1	0.89	2.55	3.382 (7)	156

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

Data collection: *XSCANS* (Bruker, 1996); cell refinement: *XSCANS*; data reduction: *XSCANS*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *PLATON* (Spek, 2009) and *DIAMOND* (Brandenburg, 1999); software used to prepare material for publication: *SHELXL97*.

IHO thanks Professor G. Heger for discussion of the results and for suggestions.

Supplementary data and figures for this paper are available from the IUCr electronic archives (Reference: SI2347).

References

Abdi, M., Zouari, F., Chniba-Boudjada, N., Bordet, P. & Salah, A. B. (2005). *Acta Cryst.* E**61**, m240–m241.
Brandenburg, K. (1999). *DIAMOND*. Crystal Impact GbR, Bonn, Germany.
Bruker (1996). *XSCANS*. Bruker AXS Inc., Madison, Wisconsin, USA.
Depmeier, W. (2009). *Z. Kristallogr.* **224**, 287–294.
Huh, Y. D., Kim, J. H., Kweon, S. S., Kuk, W. K., Hwang, C. S., Hyun, J. W., Kim, Y. J. & Park, Y. (2006). *Curr. Appl. Phys.* **6**, 219–223.
Jongh, L. J. de (1986). In *Magnetic Properties of Layered Transition Metal Compounds*. Dordrecht: Kluwer.
Mitzi, D. B. (1999). *Prog. Inorg. Chem.* **48**, 1–121.
Park, S.-H. & Lee, C. E. (2005). *J. Phys. Chem. B*, **109**, 1118–1124.

Park, S.-H. & Lee, C. E. (2006). *Bull. Kor. Chem. Soc.* **27**, 1587–1591.
Sheldrick, G. M. (1996). *SADABS*. University of Göttingen, Germany.
Sheldrick, G. M. (2008). *Acta Cryst.* A**64**, 112–122.
Spek, A. L. (2009). *Acta Cryst*. D**65**, 148–155.
Steiner, T. (1998). *Acta Cryst.* B**54**, 456–463.
Steiner, T. (2002). *Angew. Chem. Int. Ed.* **41**, 48–76.
Zouari, F. & Ben Salah, A. (2004). *Solid State Sci.* **6**, 847–851.

supporting information

Acta Cryst. (2011). E**67**, m522–m523 [doi:10.1107/S1600536811011603]

Bis(2-phenylethylammonium) tetrachloridocobaltate(II)

In-Hwan Oh, Dahye Kim, Young-Duk Huh, Younbong Park, J. M. Sungil Park and Seong-Hun Park

S1. Comment

The title compound, $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$, belongs to the layered inorganic-organic hybrid systems of general formula A_2MX_4 (where A = organic cation, *M* = divalent metal, *X* = halides). These systems are of special interest because of typical low-dimensional magnetic systems (de Jongh, 1986; Mitzi, 1999). To investigate the role of interlayer spacing on the magnetic properties, a variety of hybrid systems using long-chain alkylamine have been developed. However, their crystallographic studies are limited because their insolubility make it difficult to obtain a good single-crystal. As a part of our research interest in the low-dimensional magnetism (Park & Lee 2005, 2006), we synthesized a series of the layered inorganic-organic perovskite materials using phenethylamine and present the crystal structure of $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$. Among the phenethylammonium-based compounds, several examples with tetrahedral anions are known to literature, for example, $(C_6H_5C_2H_4NH_3)_2ZnBr_4$ (Huh *et al.*, 2006), $(C_6H_5(CH_2)_2NH_3)_2Cd_{0.75}Hg_{0.25}Br_4$ (Zouari & Ben Salah, 2004), $(C_8H_{12}N)TlBr_4$ (Abdi *et al.*, 2005). Except for $(C_8H_{12}N)TlBr_4$, in which the heavy atom has trivalent, the other bivalent compounds have tetrahedral MBr_4 anions with non-magnetic ions in common. The present paper is the first report of the tetrahedral MCl_4 with magnetic ion using phenethylamine.

Fig. 1 shows the molecular structure of $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$. The asymmetric unit of the title compound consists of two phenethylammonium cations and one isolated $CoCl_4$ anion; the latter is arranged as an distorted tetrahedron, whose bond lengths ranging from 2.229 (2) to 2.276 (2) Å (Table 1). Interestingly, the crystal structure exhibits a layered inorganic-organic structure although the dimension of inorganic backbone is 0-dimensional or isolated $CoCl_4$ tetrahedra, as shown in Fig. 2. The $CoCl_4$ tetrahedral groups are isolated and are connected to the organic cations by N—H···Cl hydrogen bonds *via* the NH_3-groups. Tab. 2 and Fig. 2 display also the N—H···Cl hydrogen bonds of $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$. Between the $CoCl_4$ layers, —CNH_3^+ ions are located in the space between $CoCl_4$ tetrahedra, which is formed by Cl atoms. N—H···Cl hydrogen bonds connect the two groups. The $CoCl_4$ tetrahedra connect the $C_6H_5CH_2CH_2NH_3^+$ ions through hydrogen bonds to build a two-dimensional hydrogen-bonded NH_3—$CoCl_4$ network. Due to the hydrogen bonds, the Co—Cl bond lengths increase, resulting in slightly deformed $CoCl_4$ tetrahedra. The obtained bond lengths suggest that the strength of the N—H···Cl hydrogen bonds in the structure can be classified as weak (Steiner, 1998; Steiner, 2002).

S2. Experimental

$CoCl_2{\cdot}6H_2O$ (99%, Aldrich), phenethylamine ($C_6H_5CH_2CH_2NH_2$, 99.5%, Aldrich), HCl (37 wt % in water, Aldrich), and methanol (anhydrous, 99.8%, Aldrich) are used as received. For the preparation of single-crystal $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$, 10 ml of a 0.25*M* $CoCl_2{\cdot}6H_2O$ methanol solution were mixed with 10 ml of a 0.5*M* phenethylamine methanol solution. 1 mL of an HCl solution was added to the mixed solution. Blue crystals of $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$ were obtained after 7 days at room temperature. Elemental analysis of C, H, and N was carried

out by CHNS analysis (CE Instrument EA 1112 series). The expected formula of $C_{16}H_{24}N_2Cl_4Co$ was confirmed. The relative weights calculated for $C_{16}H_{24}N_2Cl_4Co$ were: C, 43.17%, H, 5.43%, N, 6.29%; found: C, 43.14%, H, 5.44%, N, 6.23%.

S3. Refinement

H atoms bonded to C were positioned geometrically and refined based on a riding model (C—H = 0.95Å in aromatic ring and 0.99 Å for CH_2) with U_{iso}(H) = 1.2 of their parent atoms. H atoms at N atoms were located in a difference map and refined with distance constrained of N—H = 0.89 Å, and with U_{iso}(H) = 1.2U_{eq}(N). C7—C8 and C15—C16 bond lengths were refined with restrained distances 1.545 (2) Å.

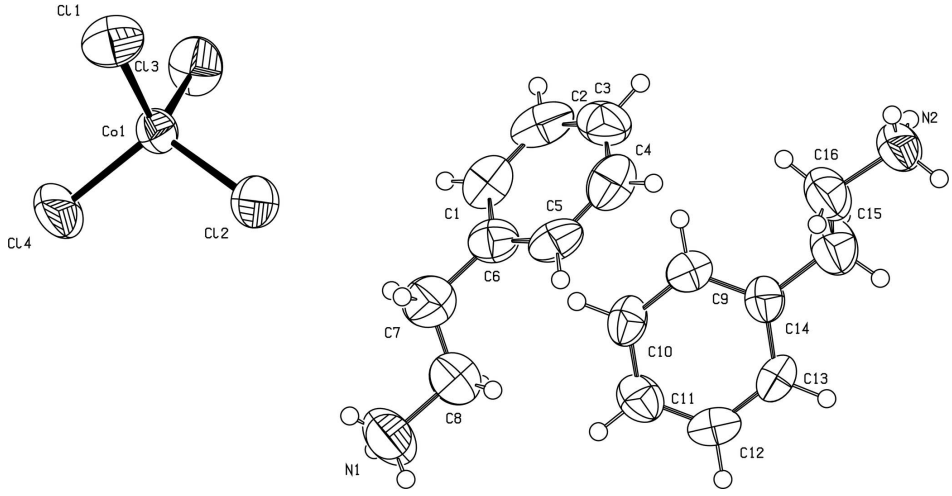


Figure 1

Molecular structure of $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$, showing the atomic labeling and 50% probability displacement elllisoids for non-H atoms.

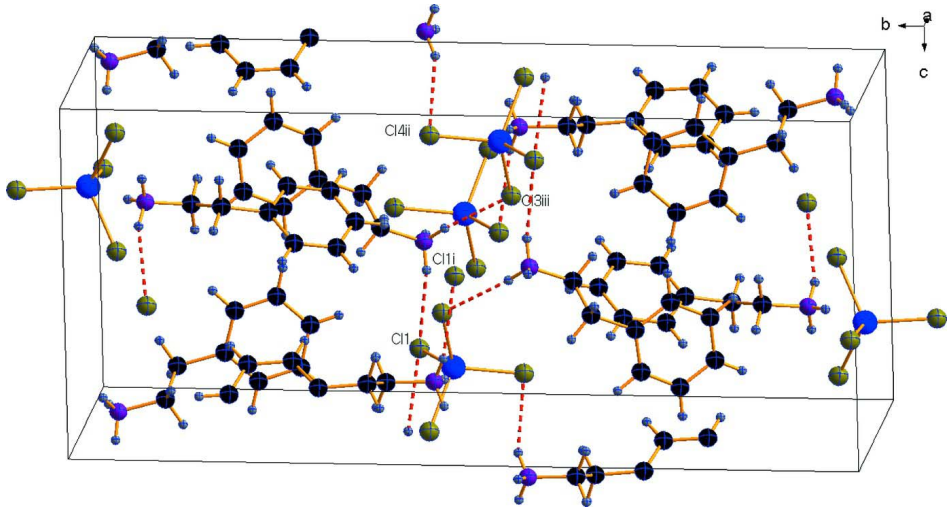


Figure 2

Crystal structure of $(C_6H_5CH_2CH_2NH_3)_2CoCl_4$ viewed along the *a* axis, showing the N—H···Cl hydrogen bonds as dashed lines.

Bis(2-phenylethylammonium) tetrachloridocobaltate(II)

Crystal data

$(C_8H_{12}N)_2[CoCl_4]$
$M_r = 445.10$
Monoclinic, $P2_1/c$
Hall symbol: -P 2ybc
$a = 7.4623$ (13) Å
$b = 24.664$ (3) Å
$c = 11.1997$ (16) Å
$\beta = 91.769$ (13)°
$V = 2060.3$ (5) Å^3
$Z = 4$
$F(000) = 916$
$D_x = 1.435$ Mg m^{-3}
Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
Cell parameters from 38 reflections
$\theta = 3.3$–12.3°
$\mu = 1.35$ mm^{-1}
$T = 296$ K
Rectangle, blue
0.5 × 0.4 × 0.35 mm

Data collection

Bruker P4 diffractometer
Radiation source: fine-focus sealed tube
Graphite monochromator
$2\theta/\omega$ scans
Absorption correction: multi-scan (*SADABS*; Sheldrick, 1996)
$T_{min} = 0.237$, $T_{max} = 0.265$
4692 measured reflections
3595 independent reflections
1566 reflections with $I > 2\sigma(I)$
$R_{int} = 0.041$
$\theta_{max} = 25.0°$, $\theta_{min} = 2.0°$
$h = -1 \rightarrow 8$
$k = -1 \rightarrow 29$
$l = -13 \rightarrow 13$
3 standard reflections every 97 reflections
intensity decay: none

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.055$
$wR(F^2) = 0.161$
$S = 1.03$
3595 reflections
211 parameters
2 restraints
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
$w = 1/[\sigma^2(F_o^2) + (0.0502P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 0.43$ e Å^{-3}
$\Delta\rho_{min} = -0.30$ e Å^{-3}
Extinction correction: *SHELXL*, $Fc^* = kFc[1+0.001xFc^2\lambda^3/\sin(2\theta)]^{-1/4}$
Extinction coefficient: 0.0018 (7)

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

	x	*y*	*z*	U_{iso}*/U_{eq}
Co1	0.25951 (13)	0.52176 (4)	0.77334 (8)	0.0581 (3)
Cl1	0.0134 (3)	0.55281 (9)	0.67021 (18)	0.0911 (7)
Cl2	0.2717 (3)	0.55493 (8)	0.96063 (16)	0.0901 (7)
Cl3	0.5051 (3)	0.54580 (9)	0.67008 (18)	0.0895 (7)
Cl4	0.2382 (4)	0.43175 (8)	0.78339 (19)	0.1218 (11)
C1	0.3714 (10)	0.6982 (4)	0.1447 (7)	0.075 (2)
H1	0.3974	0.6694	0.0946	0.090*
C2	0.4215 (10)	0.7492 (4)	0.1131 (6)	0.081 (3)
H31	0.4849	0.7546	0.0439	0.097*
C3	0.3783 (11)	0.7927 (3)	0.1835 (8)	0.083 (2)
H3	0.4077	0.8278	0.1608	0.099*

C4	0.2910 (10)	0.7836 (4)	0.2879 (7)	0.081 (2)
H4	0.2642	0.8125	0.3376	0.097*
C5	0.2433 (9)	0.7316 (4)	0.3188 (6)	0.068 (2)
H5	0.1823	0.7258	0.3888	0.082*
C6	0.2847 (10)	0.6882 (3)	0.2473 (6)	0.066 (2)
C7	0.2286 (12)	0.6304 (4)	0.2746 (7)	0.099 (3)
H7A	0.0987	0.6285	0.2720	0.118*
H7B	0.2717	0.6067	0.2126	0.118*
C8	0.2921 (13)	0.6110 (3)	0.3860 (7)	0.106 (3)
H8A	0.2501	0.6346	0.4484	0.127*
H8B	0.4221	0.6121	0.3886	0.127*
C9	0.2308 (9)	0.2503 (3)	0.1306 (5)	0.0560 (17)
H9	0.2728	0.2687	0.1983	0.067*
C10	0.2513 (9)	0.1950 (3)	0.1235 (6)	0.0627 (19)
H10	0.3066	0.1762	0.1866	0.075*
C11	0.1908 (10)	0.1675 (3)	0.0243 (7)	0.069 (2)
H11	0.2044	0.1301	0.0198	0.083*
C12	0.1107 (10)	0.1951 (3)	−0.0676 (6)	0.067 (2)
H12	0.0702	0.1763	−0.1353	0.080*
C13	0.0887 (9)	0.2501 (3)	−0.0622 (5)	0.0608 (18)
H13	0.0334	0.2684	−0.1260	0.073*
C14	0.1485 (9)	0.2788 (3)	0.0380 (6)	0.0562 (17)
C15	0.1166 (11)	0.3392 (3)	0.0449 (7)	0.086 (2)
H15A	0.0752	0.3519	−0.0331	0.103*
H15B	0.0215	0.3458	0.1002	0.103*
C16	0.2724 (11)	0.3707 (3)	0.0826 (7)	0.085 (2)
H16A	0.3704	0.3625	0.0307	0.102*
H16B	0.3088	0.3602	0.1632	0.102*
N1	0.2316 (11)	0.5540 (3)	0.4099 (6)	0.115 (3)
H1A	0.1329	0.5469	0.3661	0.172*
H1B	0.2083	0.5505	0.4870	0.172*
H1C	0.3177	0.5309	0.3909	0.172*
N2	0.2383 (8)	0.4300 (2)	0.0799 (5)	0.0758 (18)
H2A	0.2107	0.4403	0.0053	0.114*
H2B	0.3362	0.4475	0.1059	0.114*
H2C	0.1476	0.4378	0.1267	0.114*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Co1	0.0607 (6)	0.0511 (5)	0.0628 (6)	0.0000 (5)	0.0052 (4)	−0.0041 (5)
Cl1	0.0673 (13)	0.1124 (17)	0.0931 (14)	0.0206 (13)	−0.0035 (11)	0.0131 (12)
Cl2	0.135 (2)	0.0655 (12)	0.0702 (12)	0.0041 (13)	0.0055 (13)	−0.0163 (10)
Cl3	0.0707 (13)	0.1058 (16)	0.0931 (14)	−0.0135 (13)	0.0222 (11)	−0.0084 (12)
Cl4	0.225 (3)	0.0497 (11)	0.0914 (15)	−0.0165 (16)	0.0130 (18)	−0.0131 (10)
C1	0.060 (5)	0.098 (6)	0.066 (5)	0.007 (5)	0.001 (4)	−0.013 (4)
C2	0.048 (5)	0.140 (8)	0.055 (4)	0.009 (6)	0.004 (4)	0.020 (5)
C3	0.068 (6)	0.082 (6)	0.097 (6)	−0.007 (5)	−0.017 (5)	0.030 (5)

C4	0.068 (6)	0.099 (7)	0.076 (5)	0.006 (5)	−0.005 (4)	−0.017 (5)
C5	0.059 (5)	0.104 (6)	0.043 (4)	0.009 (5)	0.007 (3)	0.006 (4)
C6	0.057 (5)	0.077 (5)	0.065 (5)	0.006 (4)	0.000 (4)	0.009 (4)
C7	0.101 (7)	0.099 (7)	0.095 (6)	−0.012 (6)	−0.019 (6)	0.013 (5)
C8	0.130 (9)	0.090 (7)	0.097 (6)	−0.034 (6)	−0.008 (6)	0.013 (5)
C9	0.056 (4)	0.063 (4)	0.049 (4)	−0.012 (4)	0.003 (3)	0.000 (3)
C10	0.062 (5)	0.060 (5)	0.065 (4)	−0.007 (4)	−0.007 (4)	0.019 (4)
C11	0.071 (5)	0.052 (4)	0.085 (5)	−0.007 (4)	0.002 (4)	−0.002 (4)
C12	0.066 (5)	0.083 (6)	0.050 (4)	−0.009 (4)	0.001 (4)	−0.016 (4)
C13	0.061 (5)	0.072 (5)	0.049 (4)	0.000 (4)	−0.009 (3)	0.014 (4)
C14	0.053 (4)	0.051 (4)	0.064 (4)	0.000 (4)	0.001 (4)	0.008 (3)
C15	0.077 (6)	0.066 (5)	0.115 (6)	−0.001 (5)	−0.010 (5)	0.007 (5)
C16	0.089 (6)	0.054 (5)	0.112 (6)	0.003 (5)	−0.011 (5)	−0.003 (4)
N1	0.177 (8)	0.066 (4)	0.103 (5)	−0.025 (5)	0.033 (5)	−0.003 (4)
N2	0.099 (5)	0.050 (4)	0.079 (4)	0.002 (3)	0.005 (4)	0.003 (3)

Geometric parameters (Å, º)

Co1—Cl4	2.229 (2)	C15—C16	1.451 (9)
Co1—Cl2	2.251 (2)	C16—N2	1.485 (8)
Co1—Cl1	2.272 (2)	C1—H1	0.931
Co1—Cl3	2.276 (2)	C2—H31	0.931
C1—C6	1.358 (9)	C3—H3	0.931
C1—C2	1.363 (10)	C4—H4	0.929
C2—C3	1.376 (10)	C5—H5	0.929
C3—C4	1.374 (10)	C7—H7A	0.970
C4—C5	1.377 (10)	C7—H7B	0.970
C5—C6	1.379 (10)	C8—H8A	0.968
C6—C7	1.519 (10)	C8—H8B	0.969
C7—C8	1.405 (9)	C9—H9	0.930
C8—N1	1.502 (9)	C10—H10	0.930
C9—C10	1.376 (8)	C11—H11	0.929
C9—C14	1.380 (8)	C12—H12	0.929
C10—C11	1.367 (9)	C13—H13	0.930
C11—C12	1.358 (9)	C15—H15A	0.970
C12—C13	1.368 (9)	C15—H15B	0.970
C13—C14	1.389 (8)	C16—H16A	0.970
C14—C15	1.510 (9)	C16—H16B	0.970
Cl4—Co1—Cl2	108.41 (8)	C16—C15—C14	114.6 (6)
Cl4—Co1—Cl1	107.67 (11)	C15—C16—N2	112.8 (7)
Cl2—Co1—Cl1	111.10 (9)	H5—C5—C4	119.6
Cl4—Co1—Cl3	110.19 (10)	H2A—N2—H2C	109.5
Cl2—Co1—Cl3	111.65 (9)	H2C—N2—H2B	109.4
Cl1—Co1—Cl3	107.75 (9)	H2A—N2—H2B	109.4
C6—C1—C2	122.0 (7)	C16—N2—H2A	109.4
C1—C2—C3	120.0 (7)	C16—N2—H2A	109.4
C4—C3—C2	119.1 (8)	C16—N2—H2B	109.5

C3—C4—C5	119.9 (8)	H1A—N1—C8	109.3
C4—C5—C6	120.9 (7)	H1B—N1—C8	109.4
C1—C6—C5	118.1 (7)	H1C—N1—C8	109.4
C1—C6—C7	118.9 (7)	H1A—N1—H1B	109.5
C5—C6—C7	123.0 (7)	H1B—N1—H1C	109.5
C8—C7—C6	114.3 (7)	H1A—N1—H1C	109.6
C7—C8—N1	112.5 (7)	C3—C4—H4	119.9
C10—C9—C14	120.6 (6)	C2—C3—H3	120.5
C11—C10—C9	120.3 (6)	C2—C1—H1	119.0
C12—C11—C10	119.6 (7)	H1—C1—C6	118.8
C11—C12—C13	121.0 (6)	C6—C7—H7B	108.5
C12—C13—C14	120.3 (6)	C6—C7—H7A	108.4
C9—C14—C13	118.2 (6)	C7—C8—H8B	108.9
C9—C14—C15	122.0 (6)	C7—C8—H8A	109.0
C13—C14—C15	119.7 (6)		

C6—C1—C2—C3	−2.5 (12)	C14—C9—C10—C11	0.2 (11)
C1—C2—C3—C4	2.6 (12)	C9—C10—C11—C12	0.2 (11)
C2—C3—C4—C5	−2.0 (11)	C10—C11—C12—C13	−0.4 (11)
C3—C4—C5—C6	1.1 (11)	C11—C12—C13—C14	0.1 (11)
C2—C1—C6—C5	1.7 (11)	C10—C9—C14—C13	−0.5 (10)
C2—C1—C6—C7	178.3 (7)	C10—C9—C14—C15	177.3 (6)
C4—C5—C6—C1	−0.9 (11)	C12—C13—C14—C9	0.4 (10)
C4—C5—C6—C7	−177.4 (7)	C12—C13—C14—C15	−177.5 (7)
C1—C6—C7—C8	125.0 (9)	C9—C14—C15—C16	49.4 (10)
C5—C6—C7—C8	−58.6 (11)	C13—C14—C15—C16	−132.8 (8)
C6—C7—C8—N1	179.3 (7)	C14—C15—C16—N2	176.0 (6)

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N2—H2*C*···Cl1^{i}	0.89	2.62	3.445 (6)	156
N2—H2*A*···Cl4^{ii}	0.89	2.51	3.321 (6)	152
N1—H1*C*···Cl3^{iii}	0.89	2.42	3.291 (8)	167
N1—H1*B*···Cl1	0.89	2.55	3.382 (7)	156

Symmetry codes: (i) −*x*, −*y*+1, −*z*+1; (ii) *x*, *y*, *z*−1; (iii) −*x*+1, −*y*+1, −*z*+1.