Acta Crystallographica Section E
Structure Reports Online
ISSN 1600-5368

Hydrogen-bonding patterns in trimethoprim tetrafluoroborate

Madhukar Hemamalini,[a] Packianathan Thomas Muthiah[a]* and Daniel E. Lynch[b]

[a]School of Chemistry, Bharathidasan University, Tiruchirappalli 620 024, Tamil Nadu, India, and [b]Faculty of Health and Life Sciences, Coventry University, Coventry CV1 5FB, England

Correspondence e-mail: tommtrichy@yahoo.co.in

Key indicators

Single-crystal X-ray study
T = 120 K
Mean σ(C–C) = 0.002 Å
Disorder in solvent or counterion
R factor = 0.049
wR factor = 0.132
Data-to-parameter ratio = 14.9

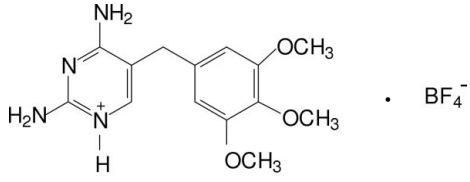
For details of how these key indicators were automatically derived from the article, see http://journals.iucr.org/e.

Received 3 October 2005
Accepted 8 November 2005
Online 16 November 2005

In the title compound [systematic name: 2,4-diamino-5-(3,4,5-trimethoxybenzyl)pyrimidinium tetrafluoroborate], $C_{14}H_{19}N_4O_3^+\cdot BF_4^-$, the trimethoprim (TMP) molecule is protonated at one of the pyrimidine N atoms. The protonated N atom and 2-amine group of the TMP cation interact with the tetrafluoroborate anion through a pair of N—H···F hydrogen bonds [graph set $R_2^2(8)$]. The inversion-related TMP cations are linked through a pair of N—H···N hydrogen bonds. The 2-amine group of one TMP cation and the 4-amine group of another cation are bridged by a methoxy O atom, *via* N—H···O hydrogen bonds.

Comment

Trimethoprim [2,4-diamino-5-(3′,4′,5′-trimethoxybenzyl)-pyrimidine or TMP] is a well known antifolate drug. It is a potent inhibitor of bacterial dihydrofolate reductase (DHFR) but is less effective against human DHFR. The drug (TMP) in its N1-protonated form inhibits DHFR. The crystal structure of trimethoprim (Koetzle & Williams, 1976) and its complexes, for example, trimethoprim monobenzoate benzoic acid (Bettinetti *et al.*, 1985) and trimethoprim acetate (Bryan *et al.*, 1987), have been reported in the literature. The present study has been undertaken to explore the hydrogen-bonding patterns involving the TMP cation in a variety of environments. The crystal structures of TMP sulfate trihydrate (Muthiah *et al.*, 2001), TMP nitrate (Murugesan & Muthiah, 1997) and TMP carboxylates (Stanley *et al.*, 2005) have also been reported from our laboratory.



(I)

The asymmetric unit of (I) contains a protonated trimethoprim (TMP) cation and a tetrafluoroborate anion (FLUB) (Fig. 1). The trimethoprim molecule is protonated at atom N1 of the pyrimidine moiety, which is evident from the increase in the internal angle at protonated N1 [C2—N1—C6 = 120.15 (13)°] compared with that at unprotonated atom N3 [C2—N3—C4 = 118.36 (14)°]. The dihedral angle between the pyrimidine and benzene planes is 84.27 (7)°; the corresponding angle in trimethoprim perchlorate is 83.7 (2)° (Muthiah *et al.*, 2002). The conformation of the trimethoprim cation is described by the two torsion angles C4—C5—C7—C8 and C5—C7—C8—C9, which are 77.84 (19) and

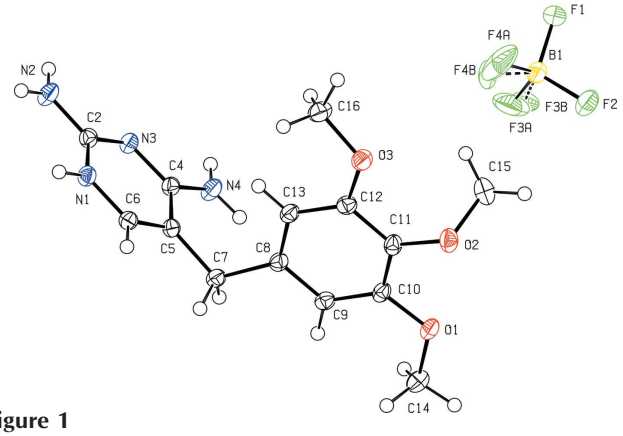


Figure 1
A view of (I), with the atom-labelling scheme and 50% probability displacement ellipsoids.

−158.03 (14)°, respectively. The distorted tetrahedral BF_4 ion has typical B—F distances.

Atoms F2 and F1 act as acceptors in N—H···F interactions (Table 2) with the protonated pyrimidine N1 and 2-amine group of the TMP cation, leading to the formation of a fork-like hydrogen-bonding pattern with graph-set notation $R_2^2(8)$ (Etter, 1990; Bernstein *et al.*, 1995). The $R_2^2(8)$ motif is frequently observed in aminopyrimidine carboxylate salts (Lynch & Jones, 2004). Here the tetrafluoroborate anion mimics the role of the carboxylate group. The TMP cations are paired centrosymmetrically through N4—H4*A*···N3^{iii} and N3···H4*A*^{iii}—N4^{iii} hydrogen bonds (symmetry codes are given in Table 2). The 2-amine group of one TMP cation and the 4-amine group of another cation (both of these cations being members of a base pair) are bridged by methoxy atom O1, using a pair of N—H···O hydrogen bonds, leading to a complementary *DADA* (*D* = donor in hydrogen bonds, *A* = acceptor in hydrogen bonds) array of quadruple hydrogen bonds (Fig. 2). This pattern is similar to that reported in TMP nitrate (Murugesan & Muthiah, 1997), TMP trifluoroacetate (Francis *et al.*, 2002), and TMP salicylate methanol solvate (Panneerselvam *et al.*, 2002). The hydrogen-bonding parameters are listed in Table 2.

Experimental

Hot aqueous solutions of trimethoprim (145 mg; obtained as a gift sample from Shilpa Antibiotics Ltd) and tetrafluoroboric acid (220 mg of 40% solution; Aldrich) were mixed in a 1:2 molar ratio. The resulting solution was warmed over a water bath for a few minutes and then kept at room temperature for crystallization. After a few days, block-shaped colourless crystals of (I) were obtained.

Crystal data

$C_{14}H_{19}N_4O_3^+\cdot BF_4^-$
M_r = 378.14
Triclinic, $P\overline{1}$
a = 9.4105 (3) Å
b = 9.5397 (2) Å
c = 10.1276 (4) Å
α = 88.564 (2)°
β = 73.253 (2)°
γ = 72.304 (2)°
V = 827.48 (5) Å^3
Z = 2
D_x = 1.518 Mg m^{-3}
Mo $K\alpha$ radiation
Cell parameters from 3811 reflections
θ = 3.0–27.6°
μ = 0.14 mm^{-1}
T = 120 (2) K
Block, colourless
0.18 × 0.16 × 0.09 mm

Data collection

Bruker–Nonius KappaCCD area-detector diffractometer
φ and ω scans
Absorption correction: none
18185 measured reflections
3811 independent reflections
3193 reflections with $I > 2\sigma(I)$
R_{int} = 0.041
θ_{max} = 27.6°
$h = -12 \rightarrow 12$
$k = -12 \rightarrow 12$
$l = -13 \rightarrow 13$

Refinement

Refinement on F^2
$R[F^2 > 2\sigma(F^2)]$ = 0.049
$wR(F^2)$ = 0.132
S = 1.15
3811 reflections
255 parameters
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0644P)^2 + 0.2497P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max}$ = 0.001
$\Delta\rho_{max}$ = 0.61 e Å^{-3}
$\Delta\rho_{min}$ = −0.52 e Å^{-3}
Extinction correction: *SHELXL97*
Extinction coefficient: 0.133 (9)

Table 1
Selected geometric parameters (Å, °).

O1—C10	1.377 (2)	N1—C2	1.356 (2)
O1—C14	1.443 (2)	N1—C6	1.364 (2)
O2—C11	1.3802 (19)	N2—C2	1.330 (2)
O2—C15	1.435 (2)	N3—C2	1.331 (2)
O3—C16	1.435 (2)	N3—C4	1.347 (2)
O3—C12	1.368 (2)	N4—C4	1.322 (2)
C10—O1—C14	116.47 (12)	N4—C4—C5	120.69 (15)
C11—O2—C15	114.69 (13)	N3—C4—N4	117.24 (15)
C12—O3—C16	116.53 (12)	N1—C6—C5	121.27 (15)
C2—N1—C6	120.15 (13)	O1—C10—C9	123.88 (15)
C2—N3—C4	118.36 (14)	O1—C10—C11	115.49 (14)
N2—C2—N3	119.35 (15)	O2—C11—C12	121.87 (15)
N1—C2—N2	118.59 (14)	O2—C11—C10	118.96 (15)
N1—C2—N3	122.06 (15)	O3—C12—C11	115.08 (14)
N3—C4—C5	122.06 (14)	O3—C12—C13	124.55 (15)

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

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N1—H1···F2^{i}	0.88	1.97	2.8445 (17)	177
N2—H2*A*···O1^{ii}	0.88	2.10	2.9345 (18)	158
N2—H2*B*···F1^{i}	0.88	2.01	2.8851 (17)	174
N4—H4*A*···N3^{iii}	0.88	2.29	3.121 (2)	158
N4—H4*B*···O1^{iv}	0.88	2.36	2.9210 (18)	122
C6—H6···O2^{v}	0.95	2.50	3.171 (2)	128
C9—H9···F3*A*^{iv}	0.95	2.38	2.995 (9)	122
C14—H14*B*···F4*A*^{vi}	0.98	2.50	3.414 (10)	155
C15—H15*C*···O3	0.98	2.46	3.022 (2)	116

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

All H atoms were placed in idealized locations and were refined using a riding model, with C—H = 0.95–0.99 Å, N—H = 0.88 Å and U_{iso}(H) = 1.2U_{eq}(C,N). Two of the F atoms in the BF_4 group are disordered over two positions, and the occupancy factors for the disordered positions F3*A*/F3*B* and F4*A*/F4*B* were refined to 0.60 (2)/0.40 (2). Similarity restraints were applied to distances involving disordered atoms.

Data collection: *COLLECT* (Hooft, 1998); cell refinement: *DENZO* (Otwinowski & Minor, 1997) and *COLLECT*; data reduction: *DENZO* and *COLLECT*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure:

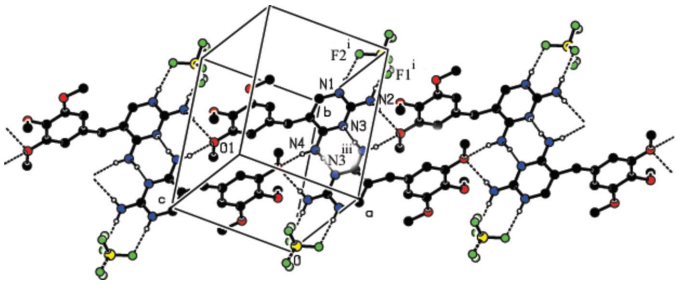


Figure 2
The hydrogen-bonding (dashed lines) patterns of (I). [Symmetry codes: (i) $x, 1 + y, z - 1$; (iii) $1 - x, 1 - y, -z$.]

SHELXL97 (Sheldrick, 1997); molecular graphics: *PLATON* (Spek, 2003); software used to prepare material for publication: *PLATON*.

MH thanks the Council of Scientific and Industrial Research (CSIR), India, for the award of a Senior Research Fellowship (SRF) [reference No. 9/475(123)/2004-EMR-I]. DL thanks the EPSRC National Crystallography Service (Southampton, England) for X-ray data collection.

References

Bernstein, J., Davis, R. E., Shimoni, L. & Chang, N.-L. (1995). *Angew. Chem. Int. Ed. Engl.* **34**, 1555–1573.
Bettinetti, G. P., Giordano, F., La Manna, A., Giuseppetti, G. & Tadini, C. (1985). *Acta Cryst.* C**41**, 1249–1253.
Bryan, R. F., Haltiwanger, R. C. & Woods, M. K. (1987). *Acta Cryst.* C**43**, 2412–2415.
Etter, M. C. (1990). *Acc. Chem. Res.* **23**, 120–126.
Francis, S., Muthiah, P. T., Bocelli, G. & Righi, L. (2002). *Acta Cryst.* E**58**, o717–o719.
Hooft, R. (1998). *COLLECT*. Nonius BV, Delft, The Netherlands.
Koetzle, T. F. & Williams, G. J. B. (1976). *J. Am. Chem. Soc.* **98**, 2074–2078.
Lynch, D. E. & Jones, G. D. (2004). *Acta Cryst.* B**60**, 748–754.
Murugesan, S. & Muthiah, P. T. (1997). *Acta Cryst.* C**53**, 763–764.
Muthiah, P. T., Umadevi, B., Stanley, N., Bocelli, G. & Cantoni, A. (2002). *Acta Cryst.* E**58**, o59–o61.
Muthiah, P. T., Umadevi, B., Stanley, N., Shui, X. & Eggleston, D. S. (2001). *Acta Cryst.* E**57**, o1179–o1182.
Otwinowski, Z. & Minor, W. (1997). *Methods in Enzymology*. Vol. 276, *Macromolecular Crystallography*, Part A, edited by C. W. Carter Jr & R. M. Sweet, pp. 307–326. New York: Academic Press.
Panneerselvam, P., Stanley, N. & Muthiah, P. T. (2002). *Acta Cryst.* E**58**, o180–o182.
Sheldrick, G. M. (1997). *SHELXS97* and *SHELXL97*. University of Göttingen, Germany.
Spek, A. L. (2003). *J. Appl. Cryst.* **36**, 7–13.
Stanley, N., Muthiah, P. T., Geib, S. J., Luger, P., Weber, M. & Messerschmidt, M. (2005). *Tetrahedron*, **61**, 7201–7210.

supporting information

Acta Cryst. (2005). E**61**, o4107–o4109 [https://doi.org/10.1107/S1600536805036615]

Hydrogen-bonding patterns in trimethoprim tetrafluoroborate

Madhukar Hemamalini, Packianathan Thomas Muthiah and Daniel E. Lynch

2,4-diamino-5-(3,4,5-trimethoxybenzyl)pyrimidinium fluoroborate

Crystal data

$C_{14}H_{19}N_4O_3^+\cdot BF_4^-$
$M_r = 378.14$
Triclinic, $P\overline{1}$
Hall symbol: -P 1
$a = 9.4105$ (3) Å
$b = 9.5397$ (2) Å
$c = 10.1276$ (4) Å
$\alpha = 88.564$ (2)°
$\beta = 73.253$ (2)°
$\gamma = 72.304$ (2)°
$V = 827.48$ (5) Å^3
$Z = 2$
$F(000) = 392$
$D_x = 1.518$ Mg m^{-3}
Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
Cell parameters from 3811 reflections
$\theta = 3.0$–27.6°
$\mu = 0.14$ mm^{-1}
$T = 120$ K
Block, colourless
0.18 × 0.16 × 0.09 mm

Data collection

Bruker–Nonius KappaCCD area-detector diffractometer
Radiation source: Bruker–Nonius FR591 rotating anode
Graphite monochromator
φ and ω scans
18185 measured reflections
3811 independent reflections
3193 reflections with $I > 2\sigma(I)$
$R_{int} = 0.041$
$\theta_{max} = 27.6°$, $\theta_{min} = 3.0°$
$h = -12\rightarrow12$
$k = -12\rightarrow12$
$l = -13\rightarrow13$

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)] = 0.049$
$wR(F^2) = 0.132$
$S = 1.15$
3811 reflections
255 parameters
6 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
$w = 1/[\sigma^2(F_o^2) + (0.0644P)^2 + 0.2497P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 0.61$ e Å^{-3}
$\Delta\rho_{min} = -0.52$ e Å^{-3}
Extinction correction: SHELXL97, $FC^*=KFC[1+0.001XFC^2\Lambda^3/SIN(2\Theta)]^{-1/4}$
Extinction coefficient: 0.133 (9)

Special details

Geometry. Bond distances, angles *etc*. have been calculated using the rounded fractional coordinates. All e.s.d.'s are estimated from the variances of the (full) variance-covariance matrix. The cell e.s.d.'s are taken into account in the estimation of distances, angles and torsion angles

Refinement. Refinement on F^2 for ALL reflections except those flagged by the user for potential systematic errors. Weighted *R*-factors *wR* and all goodnesses 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 observed criterion of $F^2 > \sigma(F^2)$ is used only for calculating -*R*-factor-obs *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 (Å²)

	x	*y*	*z*	U_{iso}*/U_{eq}	Occ. (<1)
O1	−0.22859 (13)	0.61645 (12)	0.66705 (11)	0.0221 (3)	
O2	−0.06715 (14)	0.72735 (13)	0.78897 (11)	0.0248 (3)	
O3	0.15105 (13)	0.84755 (12)	0.64102 (11)	0.0235 (3)	
N1	0.28278 (15)	0.96385 (14)	−0.00878 (13)	0.0199 (4)	
N2	0.53520 (16)	0.86442 (15)	−0.15031 (14)	0.0246 (4)	
N3	0.40722 (15)	0.70767 (14)	−0.03325 (13)	0.0195 (4)	
N4	0.28298 (16)	0.55383 (14)	0.09004 (15)	0.0238 (4)	
C2	0.40794 (18)	0.84404 (17)	−0.06383 (15)	0.0190 (4)	
C4	0.27950 (18)	0.68998 (17)	0.05895 (15)	0.0186 (4)	
C5	0.14285 (18)	0.81297 (17)	0.12055 (15)	0.0182 (4)	
C6	0.15165 (18)	0.94728 (17)	0.08297 (16)	0.0192 (4)	
C7	−0.00296 (17)	0.79327 (17)	0.21807 (16)	0.0199 (4)	
C8	−0.00211 (17)	0.76276 (16)	0.36594 (15)	0.0185 (4)	
C9	−0.10785 (17)	0.69467 (16)	0.44282 (16)	0.0190 (4)	
C10	−0.12541 (17)	0.68018 (16)	0.58268 (16)	0.0188 (4)	
C11	−0.03807 (18)	0.73361 (16)	0.64772 (16)	0.0196 (4)	
C12	0.07051 (18)	0.79892 (16)	0.56898 (16)	0.0196 (4)	
C13	0.08929 (18)	0.81245 (17)	0.42804 (16)	0.0194 (4)	
C14	−0.3298 (2)	0.57224 (19)	0.60493 (18)	0.0266 (5)	
C15	0.0542 (2)	0.62255 (19)	0.83157 (18)	0.0298 (5)	
C16	0.28441 (19)	0.8868 (2)	0.56058 (18)	0.0266 (5)	
F1	0.56011 (11)	0.15397 (11)	0.78546 (10)	0.0272 (3)	
F2	0.30228 (12)	0.24550 (11)	0.90592 (11)	0.0322 (3)	
F3A	0.3745 (7)	0.1814 (13)	0.6750 (7)	0.083 (2)	0.60 (2)
F4A	0.4213 (9)	0.3796 (4)	0.7583 (15)	0.083 (2)	0.60 (2)
B1	0.4133 (2)	0.23827 (19)	0.7771 (2)	0.0276 (6)	
F3B	0.3813 (8)	0.1471 (6)	0.6919 (6)	0.0282 (16)	0.40 (2)
F4B	0.4046 (11)	0.3723 (5)	0.7221 (6)	0.0322 (16)	0.40 (2)
H1	0.28620	1.05250	−0.03210	0.0240*	
H2A	0.61790	0.78820	−0.18670	0.0300*	
H2B	0.53670	0.95420	−0.17110	0.0300*	
H4A	0.36650	0.47940	0.05090	0.0290*	
H4B	0.20180	0.53760	0.14980	0.0290*	
H6	0.06490	1.03210	0.12110	0.0230*	
H7A	−0.02500	0.71090	0.17900	0.0240*	
H7B	−0.09060	0.88360	0.22080	0.0240*	
H9	−0.16780	0.65820	0.39950	0.0230*	
H13	0.16410	0.85550	0.37460	0.0230*	
H14A	−0.39000	0.65770	0.56720	0.0320*	

H14B	−0.40140	0.53330	0.67510	0.0320*
H14C	−0.26680	0.49570	0.53040	0.0320*
H15A	0.07690	0.52510	0.78690	0.0360*
H15B	0.02010	0.61800	0.93220	0.0360*
H15C	0.14860	0.65310	0.80480	0.0360*
H16A	0.35430	0.80460	0.49390	0.0320*
H16B	0.34000	0.90840	0.62190	0.0320*
H16C	0.25000	0.97420	0.51100	0.0320*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
O1	0.0211 (6)	0.0236 (6)	0.0208 (6)	−0.0100 (5)	−0.0018 (5)	0.0043 (4)
O2	0.0277 (6)	0.0273 (6)	0.0159 (6)	−0.0064 (5)	−0.0036 (5)	0.0030 (4)
O3	0.0241 (6)	0.0297 (6)	0.0193 (6)	−0.0123 (5)	−0.0059 (5)	0.0008 (4)
N1	0.0206 (7)	0.0182 (6)	0.0204 (7)	−0.0069 (5)	−0.0045 (5)	0.0037 (5)
N2	0.0212 (7)	0.0191 (7)	0.0281 (7)	−0.0068 (5)	0.0014 (6)	0.0036 (5)
N3	0.0195 (7)	0.0190 (6)	0.0183 (6)	−0.0064 (5)	−0.0026 (5)	0.0019 (5)
N4	0.0194 (7)	0.0195 (7)	0.0271 (7)	−0.0058 (5)	0.0008 (6)	0.0036 (5)
C2	0.0205 (8)	0.0214 (8)	0.0162 (7)	−0.0079 (6)	−0.0054 (6)	0.0016 (6)
C4	0.0189 (7)	0.0219 (8)	0.0163 (7)	−0.0081 (6)	−0.0054 (6)	0.0024 (6)
C5	0.0178 (7)	0.0233 (8)	0.0142 (7)	−0.0071 (6)	−0.0048 (6)	0.0016 (6)
C6	0.0173 (7)	0.0224 (8)	0.0168 (7)	−0.0051 (6)	−0.0043 (6)	0.0008 (6)
C7	0.0162 (7)	0.0239 (8)	0.0185 (7)	−0.0066 (6)	−0.0032 (6)	0.0010 (6)
C8	0.0158 (7)	0.0184 (7)	0.0174 (7)	−0.0027 (6)	−0.0017 (6)	0.0007 (5)
C9	0.0161 (7)	0.0175 (7)	0.0218 (8)	−0.0046 (6)	−0.0039 (6)	0.0005 (6)
C10	0.0166 (7)	0.0152 (7)	0.0202 (8)	−0.0035 (6)	−0.0003 (6)	0.0023 (6)
C11	0.0196 (7)	0.0187 (7)	0.0162 (7)	−0.0032 (6)	−0.0016 (6)	0.0011 (5)
C12	0.0170 (7)	0.0188 (7)	0.0208 (8)	−0.0038 (6)	−0.0042 (6)	0.0000 (6)
C13	0.0162 (7)	0.0210 (7)	0.0189 (7)	−0.0058 (6)	−0.0018 (6)	0.0012 (6)
C14	0.0245 (8)	0.0283 (9)	0.0282 (9)	−0.0136 (7)	−0.0040 (7)	0.0029 (7)
C15	0.0392 (10)	0.0273 (9)	0.0239 (9)	−0.0084 (7)	−0.0132 (8)	0.0054 (7)
C16	0.0216 (8)	0.0341 (9)	0.0254 (8)	−0.0124 (7)	−0.0045 (7)	−0.0010 (7)
F1	0.0221 (5)	0.0325 (5)	0.0288 (5)	−0.0086 (4)	−0.0101 (4)	0.0049 (4)
F2	0.0281 (6)	0.0300 (5)	0.0319 (6)	−0.0094 (4)	0.0015 (4)	0.0051 (4)
F3A	0.0294 (18)	0.177 (6)	0.0344 (18)	−0.012 (3)	−0.0181 (14)	0.006 (3)
F4A	0.036 (2)	0.041 (2)	0.137 (6)	−0.0033 (16)	0.015 (4)	0.052 (3)
B1	0.0211 (9)	0.0302 (10)	0.0292 (10)	−0.0077 (8)	−0.0052 (8)	0.0113 (8)
F3B	0.027 (2)	0.028 (3)	0.037 (3)	−0.0106 (13)	−0.0177 (18)	−0.0065 (15)
F4B	0.038 (3)	0.025 (2)	0.027 (3)	−0.0061 (16)	−0.0042 (15)	0.0111 (15)

Geometric parameters (Å, º)

F1—B1	1.397 (2)	C5—C7	1.503 (2)
F2—B1	1.405 (2)	C5—C6	1.347 (2)
F3A—B1	1.365 (8)	C7—C8	1.520 (2)
F3B—B1	1.392 (7)	C8—C9	1.393 (2)
F4A—B1	1.379 (5)	C8—C13	1.391 (2)

F4B—B1	1.371 (5)	C9—C10	1.386 (2)
O1—C10	1.377 (2)	C10—C11	1.397 (2)
O1—C14	1.443 (2)	C11—C12	1.400 (2)
O2—C11	1.3802 (19)	C12—C13	1.394 (2)
O2—C15	1.435 (2)	C6—H6	0.95
O3—C16	1.435 (2)	C7—H7A	0.99
O3—C12	1.368 (2)	C7—H7B	0.99
N1—C2	1.356 (2)	C9—H9	0.95
N1—C6	1.364 (2)	C13—H13	0.95
N2—C2	1.330 (2)	C14—H14B	0.98
N3—C2	1.331 (2)	C14—H14A	0.98
N3—C4	1.347 (2)	C14—H14C	0.98
N4—C4	1.322 (2)	C15—H15B	0.98
N1—H1	0.88	C15—H15A	0.98
N2—H2B	0.88	C15—H15C	0.98
N2—H2A	0.88	C16—H16C	0.98
N4—H4A	0.88	C16—H16A	0.98
N4—H4B	0.88	C16—H16B	0.98
C4—C5	1.441 (2)		

F1···C16^{i}	3.368 (2)	C9···H15A^{iii}	3.0620
F1···C2^{i}	2.9212 (18)	C9···H14C	2.7394
F1···N1^{i}	3.0584 (17)	C9···H16C^{vii}	3.0218
F1···N3^{i}	2.9986 (17)	C10···H2A^{vi}	2.7763
F1···N2^{ii}	2.8851 (17)	C11···H2A^{vi}	3.0749
F1···C4^{i}	3.136 (2)	C12···H14C^{iii}	2.8703
F1···C5^{i}	3.302 (2)	C12···H15C	2.8987
F1···C6^{i}	3.239 (2)	C13···H16C	2.7550
F2···N1^{ii}	2.8445 (17)	C13···H16A	2.7409
F3A···C16^{i}	3.288 (8)	C13···H14C^{iii}	2.9945
F3A···C9^{iii}	2.995 (9)	C14···H2A^{vi}	2.8183
F3A···C7^{iii}	3.282 (8)	C14···H4B^{iii}	3.0896
F3B···C16^{iv}	3.318 (7)	C14···H9	2.4843
F3B···C7^{iii}	3.279 (8)	C16···H7B^{vii}	2.9178
F3B···C16^{i}	3.365 (7)	C16···H13	2.5261
F3B···C9^{iii}	3.213 (7)	B1···H16A^{i}	2.9217
F4B···C15	3.323 (8)	B1···H1^{ii}	2.8443
F1···H16A^{i}	2.7629	B1···H2B^{ii}	2.7082
F1···H2B^{ii}	2.0078	H1···H2B	2.2865
F1···H13^{i}	2.6100	H1···F2^{viii}	1.9656
F2···H1^{ii}	1.9656	H1···B1^{viii}	2.8443
F3A···H9^{iii}	2.3818	H2A···O2^{ix}	2.7789
F3A···H14A^{iii}	2.8522	H2A···O1^{ix}	2.1012
F3A···H7B^{iii}	2.8258	H2A···C10^{ix}	2.7763
F3A···H16A^{i}	2.6715	H2A···C11^{ix}	3.0749
F3A···H16B^{iv}	2.8039	H2A···C14^{ix}	2.8183
F3B···H16B^{iv}	2.5723	H2B···F1^{viii}	2.0078
F3B···H2B^{ii}	2.6183	H2B···B1^{viii}	2.7082

F3B···H7B^{iii}	2.7261	H2B···H1	2.2865
F3B···H9^{iii}	2.6571	H2B···F3B^{viii}	2.6183
F3B···H16A^{i}	2.8106	H4A···N3^{x}	2.2886
F4A···H14B^{v}	2.5018	H4A···H4A^{x}	2.5725
F4B···H16A^{i}	2.7889	H4B···C7	2.5689
F4B···H15A	2.8661	H4B···C14^{iii}	3.0896
F4B···H14B^{v}	2.6619	H4B···O1^{iii}	2.3604
O1···N2^{vi}	2.9345 (18)	H4B···C8	2.8977
O1···O2	2.6600 (18)	H4B···H7A	2.2117
O1···N4^{iii}	2.9210 (18)	H6···O2^{vii}	2.4983
O2···O3	2.7108 (18)	H6···H7B	2.3462
O2···C6^{vii}	3.171 (2)	H6···O3^{vii}	2.6741
O2···O1	2.6600 (18)	H7A···H4B	2.2117
O3···C15	3.022 (2)	H7A···N4	2.7165
O3···O2	2.7108 (18)	H7A···H15A^{iii}	2.4411
O1···H4B^{iii}	2.3604	H7A···H9	2.3813
O1···H2A^{vi}	2.1012	H7A···H15B^{xiii}	2.5464
O2···H6^{vii}	2.4983	H7B···H6	2.3462
O2···H2A^{vi}	2.7789	H7B···O3^{vii}	2.7738
O3···H15C	2.4582	H7B···C16^{vii}	2.9178
O3···H7B^{vii}	2.7738	H7B···F3A^{iii}	2.8258
O3···H6^{vii}	2.6741	H7B···F3B^{iii}	2.7261
N1···F2^{viii}	2.8445 (17)	H9···H14A	2.2838
N1···F1^{i}	3.0584 (17)	H9···H14C	2.2565
N2···F1^{viii}	2.8851 (17)	H9···C14	2.4843
N2···O1^{ix}	2.9345 (18)	H9···H7A	2.3813
N3···F1^{i}	2.9986 (17)	H9···F3B^{iii}	2.6571
N3···N4^{x}	3.121 (2)	H9···F3A^{iii}	2.3818
N4···O1^{iii}	2.9210 (18)	H9···H15A^{iii}	2.3830
N4···C14^{iii}	3.385 (2)	H13···H16A	2.3638
N4···N3^{x}	3.121 (2)	H13···C5	2.6875
N4···C8	3.418 (2)	H13···C6	3.0840
N3···H4A^{x}	2.2886	H13···C16	2.5261
N4···H14B^{iii}	2.9079	H13···H16C	2.2633
N4···H7A	2.7165	H13···F1^{i}	2.6100
C2···F1^{i}	2.9212 (18)	H14A···C9	2.7167
C4···F1^{i}	3.136 (2)	H14A···F3A^{iii}	2.8522
C5···F1^{i}	3.302 (2)	H14A···H9	2.2838
C6···C6^{xi}	3.594 (2)	H14B···F4B^{xiv}	2.6619
C6···O2^{vii}	3.171 (2)	H14B···F4A^{xiv}	2.5018
C6···F1^{i}	3.239 (2)	H14B···N4^{iii}	2.9079
C7···F3A^{iii}	3.282 (8)	H14C···H9	2.2565
C7···F3B^{iii}	3.279 (8)	H14C···C9	2.7394
C8···C16^{vii}	3.518 (2)	H14C···C12^{iii}	2.8703
C8···N4	3.418 (2)	H14C···C13^{iii}	2.9945
C9···F3A^{iii}	2.995 (9)	H15A···F4B	2.8661
C9···F3B^{iii}	3.213 (7)	H15A···C9^{iii}	3.0620
C9···C10^{iii}	3.552 (2)	H15A···H7A^{iii}	2.4411

C10···C9^{iii}	3.552 (2)	H15A···H9^{iii}	2.3830
C12···C13^{vii}	3.549 (2)	H15B···H7A^{xv}	2.5464
C13···C12^{vii}	3.549 (2)	H15C···O3	2.4582
C13···C13^{vii}	3.598 (2)	H15C···C12	2.8987
C14···N4^{iii}	3.385 (2)	H16A···F3B^{i}	2.8106
C15···O3	3.022 (2)	H16A···C13	2.7409
C15···F4B	3.323 (8)	H16A···H13	2.3638
C16···F3B^{xii}	3.318 (7)	H16A···F1^{i}	2.7629
C16···F1^{i}	3.368 (2)	H16A···F3A^{i}	2.6715
C16···C8^{vii}	3.518 (2)	H16A···B1^{i}	2.9217
C16···F3B^{i}	3.365 (7)	H16A···F4B^{i}	2.7889
C16···F3A^{i}	3.288 (8)	H16B···F3A^{xii}	2.8039
C5···H13	2.6875	H16B···F3B^{xii}	2.5723
C6···H13	3.0840	H16C···C13	2.7550
C7···H4B	2.5689	H16C···H13	2.2633
C8···H4B	2.8977	H16C···C8^{vii}	2.8661
C8···H16C^{vii}	2.8661	H16C···C9^{vii}	3.0218
C9···H14A	2.7167		

C10—O1—C14	116.47 (12)	C5—C6—H6	119.38
C11—O2—C15	114.69 (13)	C5—C7—H7A	108.05
C12—O3—C16	116.53 (12)	C5—C7—H7B	108.02
C2—N1—C6	120.15 (13)	C8—C7—H7A	108.05
C2—N3—C4	118.36 (14)	C8—C7—H7B	107.99
C2—N1—H1	119.95	H7A—C7—H7B	107.29
C6—N1—H1	119.90	C8—C9—H9	120.04
C2—N2—H2A	120.02	C10—C9—H9	120.05
H2A—N2—H2B	120.02	C8—C13—H13	120.08
C2—N2—H2B	119.96	C12—C13—H13	120.19
H4A—N4—H4B	120.02	O1—C14—H14A	109.47
C4—N4—H4A	119.95	O1—C14—H14B	109.44
C4—N4—H4B	120.03	O1—C14—H14C	109.52
N2—C2—N3	119.35 (15)	H14A—C14—H14B	109.44
N1—C2—N2	118.59 (14)	H14A—C14—H14C	109.50
N1—C2—N3	122.06 (15)	H14B—C14—H14C	109.47
N3—C4—C5	122.06 (14)	O2—C15—H15A	109.52
N4—C4—C5	120.69 (15)	O2—C15—H15B	109.46
N3—C4—N4	117.24 (15)	O2—C15—H15C	109.45
C4—C5—C6	116.06 (15)	H15A—C15—H15B	109.47
C6—C5—C7	121.62 (15)	H15A—C15—H15C	109.46
C4—C5—C7	122.30 (14)	H15B—C15—H15C	109.47
N1—C6—C5	121.27 (15)	O3—C16—H16A	109.46
C5—C7—C8	117.06 (14)	O3—C16—H16B	109.48
C7—C8—C9	117.45 (15)	O3—C16—H16C	109.46
C7—C8—C13	122.04 (14)	H16A—C16—H16B	109.47
C9—C8—C13	120.24 (14)	H16A—C16—H16C	109.47
C8—C9—C10	119.91 (15)	H16B—C16—H16C	109.48
O1—C10—C9	123.88 (15)	F1—B1—F2	108.92 (14)

O1—C10—C11	115.49 (14)	F1—B1—F3A	111.4 (4)
C9—C10—C11	120.61 (15)	F1—B1—F4A	105.5 (4)
O2—C11—C12	121.87 (15)	F1—B1—F3B	102.4 (3)
C10—C11—C12	119.09 (14)	F1—B1—F4B	116.1 (5)
O2—C11—C10	118.96 (15)	F2—B1—F3A	111.0 (3)
O3—C12—C11	115.08 (14)	F2—B1—F4A	105.9 (6)
C11—C12—C13	120.37 (16)	F2—B1—F3B	104.3 (3)
O3—C12—C13	124.55 (15)	F2—B1—F4B	114.0 (3)
C8—C13—C12	119.73 (15)	F3A—B1—F4A	113.8 (7)
N1—C6—H6	119.35	F3B—B1—F4B	109.9 (4)
C14—O1—C10—C9	−4.2 (2)	C6—C5—C7—C8	−103.87 (18)
C14—O1—C10—C11	174.71 (14)	C5—C7—C8—C13	27.9 (2)
C15—O2—C11—C10	109.92 (17)	C5—C7—C8—C9	−158.03 (14)
C15—O2—C11—C12	−73.51 (19)	C13—C8—C9—C10	1.9 (2)
C16—O3—C12—C11	167.55 (14)	C7—C8—C13—C12	171.44 (14)
C16—O3—C12—C13	−13.3 (2)	C7—C8—C9—C10	−172.26 (14)
C6—N1—C2—N3	1.2 (2)	C9—C8—C13—C12	−2.4 (2)
C6—N1—C2—N2	−178.38 (15)	C8—C9—C10—C11	0.1 (2)
C2—N1—C6—C5	−0.2 (2)	C8—C9—C10—O1	179.02 (14)
C4—N3—C2—N1	−2.3 (2)	C9—C10—C11—O2	175.11 (14)
C4—N3—C2—N2	177.29 (15)	O1—C10—C11—C12	179.46 (13)
C2—N3—C4—N4	−178.46 (15)	O1—C10—C11—O2	−3.9 (2)
C2—N3—C4—C5	2.5 (2)	C9—C10—C11—C12	−1.6 (2)
N4—C4—C5—C6	179.43 (16)	O2—C11—C12—O3	3.7 (2)
N3—C4—C5—C7	176.87 (15)	O2—C11—C12—C13	−175.57 (14)
N3—C4—C5—C6	−1.5 (2)	C10—C11—C12—O3	−179.77 (14)
N4—C4—C5—C7	−2.2 (2)	C10—C11—C12—C13	1.0 (2)
C7—C5—C6—N1	−178.02 (15)	O3—C12—C13—C8	−178.17 (14)
C4—C5—C6—N1	0.4 (2)	C11—C12—C13—C8	1.0 (2)
C4—C5—C7—C8	77.84 (19)		

Symmetry codes: (i) −*x*+1, −*y*+1, −*z*+1; (ii) *x*, *y*−1, *z*+1; (iii) −*x*, −*y*+1, −*z*+1; (iv) *x*, *y*−1, *z*; (v) *x*+1, *y*, *z*; (vi) *x*−1, *y*, *z*+1; (vii) −*x*, −*y*+2, −*z*+1; (viii) *x*, *y*+1, *z*−1; (ix) *x*+1, *y*, *z*−1; (x) −*x*+1, −*y*+1, −*z*; (xi) −*x*, −*y*+2, −*z*; (xii) *x*, *y*+1, *z*; (xiii) *x*, *y*, *z*−1; (xiv) *x*−1, *y*, *z*; (xv) *x*, *y*, *z*+1.

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N1—H1···F2^{viii}	0.88	1.97	2.8445 (17)	177
N2—H2*A*···O1^{ix}	0.88	2.10	2.9345 (18)	158
N2—H2*B*···F1^{viii}	0.88	2.01	2.8851 (17)	174
N4—H4*A*···N3^{x}	0.88	2.29	3.121 (2)	158
N4—H4*B*···O1^{iii}	0.88	2.36	2.9210 (18)	122
C6—H6···O2^{vii}	0.95	2.50	3.171 (2)	128
C9—H9···F3*A*^{iii}	0.95	2.38	2.995 (9)	122
C14—H14*B*···F4*A*^{xiv}	0.98	2.50	3.414 (10)	155
C15—H15*C*···O3	0.98	2.46	3.022 (2)	116

Symmetry codes: (iii) −*x*, −*y*+1, −*z*+1; (vii) −*x*, −*y*+2, −*z*+1; (viii) *x*, *y*+1, *z*−1; (ix) *x*+1, *y*, *z*−1; (x) −*x*+1, −*y*+1, −*z*; (xiv) *x*−1, *y*, *z*.