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2-Amino-4-(4-chloro-1-ethyl-2,2-dioxo-1*H*-benzo[*c*][1,2]thiazin-3-yl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4*H*-chromene-3-carbonitrile: single-crystal X-ray diffraction study and Hirshfeld surface analysis

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Mariia O. Shyshkina,[a]* Dmitry A. Lega,[b] Volodymyr D. Goryachiy,[b] Ludmila M. Shemchuk,[b] Dmitriy V. Levashov[b] and Leonid A. Shemchuk[b]

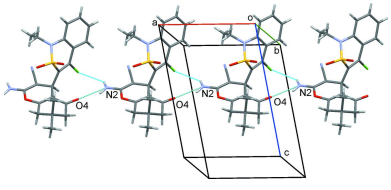
[a]SSI Institute for Single Crystals NAS of Ukraine, 60 Nauky ave., Kharkiv 61001, Ukraine, and [b]National University of Pharmacy, 4 Valentynivska st., Kharkiv 61168, Ukraine. *Correspondence e-mail: masha.o.shishkina@gmail.com

In the title compound, $C_{22}H_{22}ClN_3O_4S$, which has potential non-steroidal anti-inflammatory activity, the benzothiazine and cyclohexenone rings both adopt a distorted sofa conformation while the 4*H*-pyrane ring adopts a very flattened sofa conformation. The two bicyclic fragments are skewed to each other, with the dihedral angle between their least-squares planes being 72.8 (1)°. In the crystal, the molecules form a hydrogen-bonded chain parallel to the *a* axis due to N—H···O and N—H···Cl hydrogen bonds. Neighbouring chains are linked by C—H···N, C—H···O and π–π stacking interactions. Hirshfeld surface analysis was used to investigate the importance of the different types of intermolecular interactions whose contributions are: H···H = 44.7%, O···H/H···O = 21.8%, N···H/H···N = 11.9%, C···H/H···C = 9.5%, Cl···H/H···Cl = 7.2%. Parts of the molecule, *viz*. the phenyl ring and the ethyl side chain, are equally disordered over two sets of sites.

1. Chemical context

The 1*H*-benzo[*c*][1,2]thiazine 2,2-dioxide moiety and its derivatives have been the focus of chemists and pharmacologists for decades (Catsoulacos & Camoutsis, 1979; Ukrainets *et al.*, 2014; Iwatani *et al.*, 2013). These compounds have also gained additional value from a structural point of view because they can be regarded as bioisosteres of the 2,3-dihydro-4*H*-benzo[*e*][1,2]thiazin-4-one 1,1-dioxide core, which is a motif of well-known non-steroidal anti-inflammatory drugs (NSAIDs) of the 'oxicame' group (Lega *et al.*, 2016*b*).

While synthesizing new molecules, researchers often combine the 1*H*-benzo[*c*][1,2]thiazine 2,2-dioxide core with other pharmacophores of a heterocyclic nature (Tomita *et al.*, 2013; Popov *et al.*, 2010; Cecchetti *et al.*, 1982). Recently, we have reported a series of compounds comprising a condensed system of 1*H*-benzo[*c*][1,2]thiazine 2,2-dioxide and 2-amino-



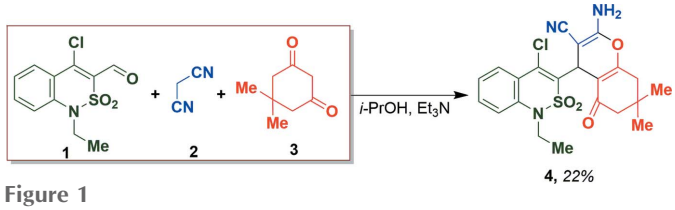
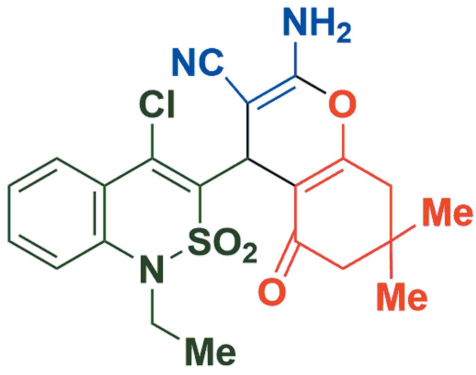


Figure 1
Synthesis scheme of the title compound **4**.

4*H*-pyran fragments (Lega *et al.*, 2017; Shemchuk *et al.*, 2014). The pronounced analgesic and anti-inflammatory properties of the products have also been confirmed (Lega *et al.*, 2016*a*).

A three-component reaction of 4-chloro-1-ethyl-1*H*-benzo[*c*][1,2]thiazin-3-carbaldehyde 2,2-dioxide, malononitrile and 5,5-dimethylcyclohexane-1,3-dione resulted in a new heterocyclic compound comprising σ-linked benzo[*c*]-[1,2]thiazine 2,2-dioxide and 2-amino-4*H*-pyran moieties (Fig. 1). Under consideration of all the above-mentioned points, the product of the reaction as well as similar structures are potential bioactive substances, particularly with regard to NSAID activity. In this context, the molecular and crystal structures were determined and a Hirshfeld surface analysis undertaken for the title compound, **4**.



2. Structural commentary

The dihydrothiazine ring of compound **4** adopts a distorted sofa conformation (Fig. 2) with puckering parameters (Zefirov *et al.*, 1990) of S = 0.63 (1), Θ = 52.5 (1)°, Ψ = 20.3 (1)°. The S1 and C8 atoms deviate from the least-squares plane of the remaining atoms of the ring by 0.863 (6) and 0.244 (2) Å respectively. The phenyl ring of the benzothiazine fragment is disordered over two positions (*A* and *B*) with equal occupancy. The partially saturated carbocycle has the same conformation as the hydrothiazine ring, with puckering parameters of S = 0.67 (1), Θ = 41.9 (1)°, Ψ = 11.8 (1)°. The deviations of the C13 and C14 atoms from the least-squares plane of the remaining atoms in the ring are 0.717 (2) and 0.132 (2) Å, respectively. The 4*H*-pyran ring adopts a very flattened sofa conformation with puckering parameters of S = 0.11 (1), Θ = 59.3 (1)°, Ψ = 3.2 (1)°, where the C9 atom deviates by 0.118 (2) Å from the plane of the remaining atoms in this ring. The C8—C9 bond is elongated to 1.525 (3) Å [the mean value (Orpen *et al.*, 1994) for a Csp^2—Csp^3 bond is 1.510 Å] to compensate for the steric repulsion between the bicyclic fragments. The bicycles are skewed in relation to each other [the dihedral angle between their mean planes is 72.8 (1)°]. The presence of the vicinal substituents on the 4*H*-pyran moiety results in an elongation of the C16—C17 bond to 1.347 (3) Å [the mean value for the Csp^2—Csp^2 bond is 1.331 Å; Orpen *et al.*, 1994] due to steric repulsion between them; the H2*B*···C18 distance is 2.57 (3) Å compared to the van der Waals radii sum (Zefirov, 1997) of 2.87 Å. The C21—C22 bond is located in a *syn*-clinal position to the C1—N1 endocyclic bond and the C22 atom is disordered over two positions (*A* and B*)* with equal occupancy due to rotation around the N1—C21 bond [the C22*A*—C21—N1—C1 torsion angle is 56.8 (9)° while the C22*B*—C21—N1—C1 torsion angle is 77.0 (11)°].

Table 1
Hydrogen-bond geometry (Å, °).

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N2—H2*A*···O4^{i}	0.92 (3)	2.03 (3)	2.857 (3)	150 (3)
N2—H2*B*···Cl1^{i}	0.91 (3)	2.84 (3)	3.583 (3)	140 (2)
C4*B*—H4*B*···N3^{ii}	0.93	2.49	3.381 (18)	160
C19—H19*C*···O3^{iii}	0.96	2.56	3.452 (3)	155
C20—H20*C*···O1^{iv}	0.96	2.56	3.443 (4)	153

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

3. Supramolecular features

In the crystal, molecules of **4** form hydrogen-bonded chains parallel to the *a* axis (Fig. 3) due to N2—H2*A*···O4^{i} and N2—H2*B*···Cl1^{i} intermolecular interactions [symmetry code: (i) 1 + *x*, *y*, *z*; Table 1]. Stacking interactions between dihydrothiazine fragments of neighbouring chains occur [the distance between dihydrothiazine rings is 3.77 (1) Å, the plane shift is

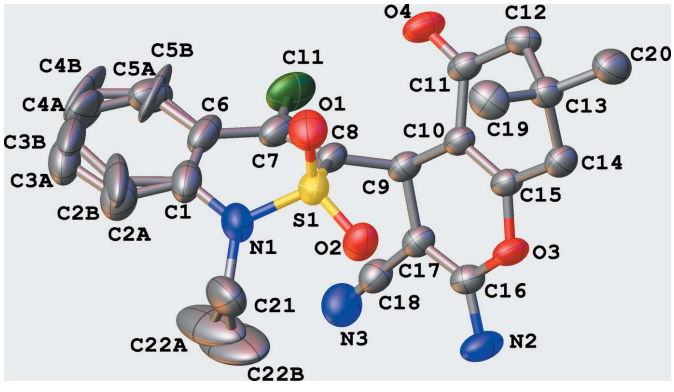


Figure 2
The molecular structure of compound **4**. Displacement ellipsoids are drawn at the 50% probability level.

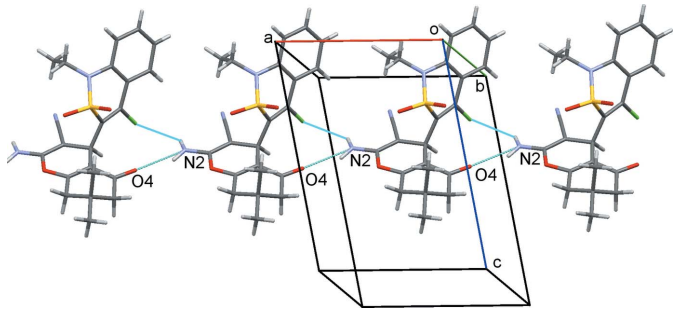


Figure 3
The chain of molecules **4** linked through N—H···O and N—H···Cl hydrogen bonds.

3.198 (1) Å]. As a result, layers parallel to (011) may be considered as secondary structural motifs.

Further stacking interactions between 4*H*-pyran rings of molecules belonging to neighbouring layers are found [the distance between ring planes is 3.38 (1) Å and the plane shift is 1.247 (1) Å]. Molecules are arranged in a head-to-tail manner in both types of stacking dimers. Additional C—H···N and C—H···O hydrogen-bonding interactions of a weak nature (Table 1) consolidate the packing of the molecules in the crystal structure.

4. Hirshfeld surface analysis

Hirshfeld surface analysis (Turner *et al.*, 2017) was used to identify and visualize different types of intra- and intermolecular interactions in the crystal structure. The molecular Hirshfeld surface of the title compound was constructed using a standard (high) surface resolution with three-dimensional d_{norm} surfaces. The areas coloured red on the d_{norm} surfaces correspond to contacts that are shorter than the van der Waals radii sum of the closest atoms (Fig. 4). Red spots on the Hirshfeld surface indicate atoms participating in hydrogen bonding or short contacts. The brightest red spots are observed at one of hydrogen atoms of the amino group and at the carbonyl oxygen atom of the cyclohexenone fragment, indicating the strong intermolecular N—H···O hydrogen bond. The smaller red areas are found at the other hydrogen atom of the amino group and the chlorine atom that indicates the N—H···Cl hydrogen bond. In addition, small spots are present at some of hydrogen atoms, as well as at the pyrane oxygen atom.

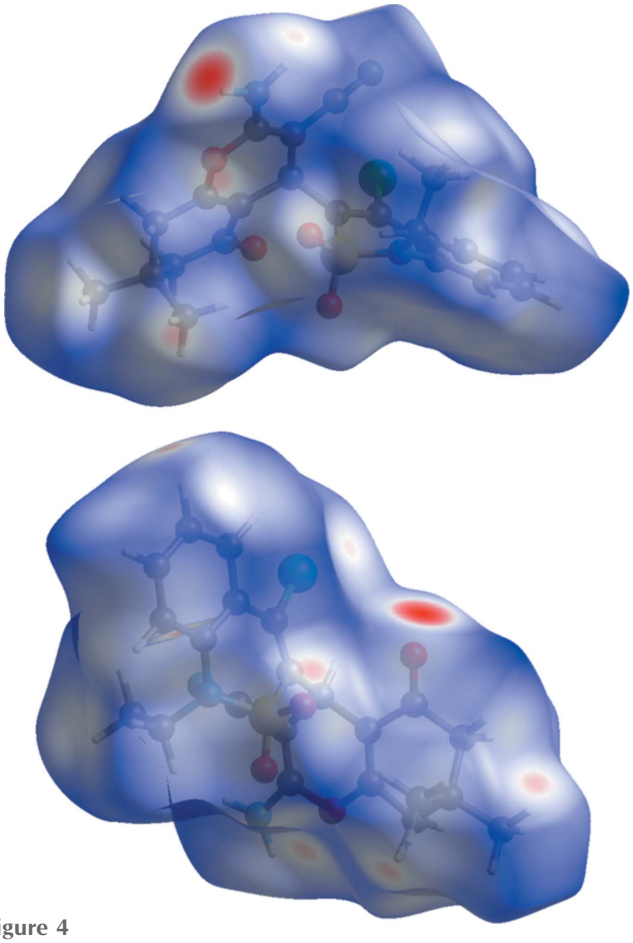


Figure 4
Two views of the Hirshfeld surface of molecule **4** mapped over d_{norm} in the range −0.495 to 1.558 a.u.

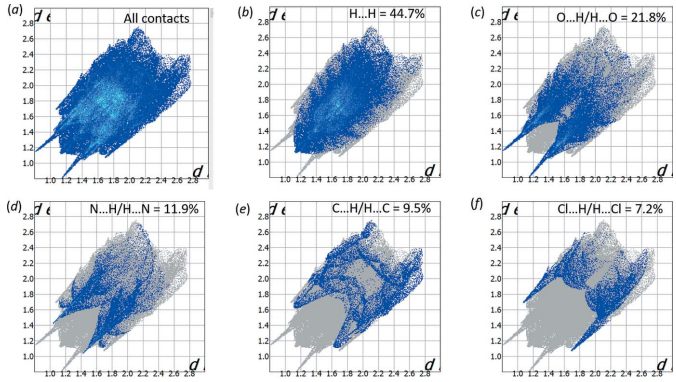


Figure 5
Two-dimensional fingerprint plot for compound **4** showing (*a*) all interactions, and delineated into (*b*) H···H, (*c*) O···H/ H···O, (*d*) N···H/H···O, (*e*) C···H/H···C and (*f*) Cl···H/H···Cl contacts.

All of the hydrogen bonds and short contacts of the title compound are evident on the two-dimensional fingerprint plot presented in Fig. 5*a*. The pair of sharp spikes indicates the presence of strong hydrogen bonds in the crystal structure. The main contribution with respect to these spikes (21.8%) is provided by O···H/H···O interactions (Fig. 5*c*), while the highest contribution is from H···H contacts (44.7%). The contributions of N···H/H···N (11.9%), C···H/H···C (9.5%) and Cl···H/H···Cl (7.2%) (Fig. 5*d*, 5*e*, 5*f*) interactions are similar, but the presence of sharp spikes on the fingerprint plot containing only N···H/H···N or Cl···H/H···Cl interactions suggests that the latter contacts are much stronger.

5. Database survey

A search of the Cambridge Structural Database (CSD Version 5.41, update of November 2019; Groom *et al.*, 2016) for the benzothiazine fragment revealed 44 hits. However, a chloro-substituted derivative was not found among these structures. It should be noted that the conformation of the benzothiazine ring and redistribution of the electron density in the title compound is very similar to those found in the structures containing a methyl group or a hydrogen atom instead of the chlorine substituent [refcodes: KEGNAO (Nguyen & Retailleau, 2017), KESJEA (Ghandi *et al.*, 2014*a*), OWUQII (Azotla-Cruz *et al.*, 2016), POJHUU, POJJAC, POJJEG, POJJIK, POJJOQ, POJJUW, POJKAD, POJKEH (Ukrainets *et al.*, 2018), ROJNOV (Ghandi *et al.*, 2014*b*), VAZQEV, VAZQIZ (Azotla-Cruz *et al.*, 2017), ZIJQER (Shishkina *et al.*, 2018)].

The bicyclic fragment containing 4*H*-pyrane, cycloxenenone as well as amino and cyano substituents is found in 102 hits

Table 2
Experimental details.

Crystal data	
Chemical formula	$C_{22}H_{22}ClN_3O_4S$
M_r	459.93
Crystal system, space group	Triclinic, $P\overline{1}$
Temperature (K)	293
a, b, c (Å)	8.6739 (5), 10.5490 (5), 12.4021 (8)
α, β, γ (°)	91.351 (4), 101.065 (5), 97.235 (4)
V (Å^3)	1103.51 (11)
Z	2
Radiation type	Mo $K\alpha$
μ (mm^{-1})	0.30
Crystal size (mm)	0.20 × 0.20 × 0.15
Data collection	
Diffractometer	Rigaku Oxford Diffraction Xcalibur, Sapphire3
Absorption correction	Multi-scan (*CrysAlis PRO*; Rigaku OD, 2018)
T_{min}, T_{max}	0.495, 1.000
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	11902, 6933, 3942
R_{int}	0.057
(sin $\theta/\lambda)_{max}$ (Å^{-1})	0.754
Refinement	
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.073, 0.232, 1.00
No. of reflections	6933
No. of parameters	337
No. of restraints	12
H-atom treatment	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}$, $\Delta\rho_{min}$ (e Å^{-3})	0.33, −0.72

Computer programs: *CrysAlis PRO* (Rigaku OD, 2018), *SHELXT2014/5* (Sheldrick, 2015*a*), *SHELXL2016/6* (Sheldrick, 2015*b*), *Mercury* (Macrae *et al.*, 2020) and *publCIF* (Westrip, 2010).

extracted from the CSD. In all of these structures, the conformation of this fragment is similar.

6. Synthesis and crystallization

A mixture of 4-chloro-1-ethyl-1*H*-benzo[*c*][1,2]thiazin-3-carbaldehyde 2,2-dioxide (**1**) (0.271 g, 0.01 mol), malononitrile (**2**) (0.066 g, 0.01 mol) and 5,5-dimethylcyclohexane-1,3-dione (**3**) (0.140 g, 0.01 mol) was dissolved in 20 ml of *i*-PrOH and then triethylamine (0.1 mol%) was added (Fig. 1). The mixture was refluxed for 4 h, then cooled to room temperature and left for an1 h. The resulting precipitate of compound **4** was filtered off, washed with *i*-PrOH, dried in air and recrystallized from *i*-PrOH. Yield 0.101 g (22%); colourless crystals; m.p. > 523 K.

7. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. The bond lengths in the two disordered fragments were modelled with fixed values (Csp^3—Csp^3 = 1.54 Å for the ethyl side chain C21—C22; Csp^2—Csp^2 = 1.38 Å for the phenyl ring C1–C6), and with an equal occupancy for the two sets of sites. All hydrogen atoms were located in difference-Fourier maps. They were included in calculated positions and treated as riding with C—H = 0.96 Å, U_{iso}(H) = 1.5U_{eq}(C) for methyl groups and with Car—H = 0.93 Å, Csp^3—H = 0.97 Å, U_{iso}(H) = 1.2U_{eq}(C) for all other hydrogen atoms. The hydrogen atoms of the amino group were refined freely.

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supporting information

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2-Amino-4-(4-chloro-1-ethyl-2,2-dioxo-1*H*-benzo[*c*][1,2]thiazin-3-yl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4*H*-chromene-3-carbonitrile: single-crystal X-ray diffraction study and Hirshfeld surface analysis

Mariia O. Shyshkina, Dmitry A. Lega, Volodymyr D. Goryachiy, Ludmila M. Shemchuk, Dmitriy V. Levashov and Leonid A. Shemchuk

Computing details

Data collection: *CrysAlis PRO* (Rigaku OD, 2018); cell refinement: *CrysAlis PRO* (Rigaku OD, 2018); data reduction: *CrysAlis PRO* (Rigaku OD, 2018); program(s) used to solve structure: *SHELXT2014/5* (Sheldrick, 2015a); program(s) used to refine structure: *SHELXL2016/6* (Sheldrick, 2015b); molecular graphics: *Mercury* (Macrae *et al.*, 2020); software used to prepare material for publication: *publCIF* (Westrip, 2010).

2-Amino-4-(4-chloro-1-ethyl-2,2-dioxo-1*H*-benzo[*c*][1,2]thiazin-3-yl)-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4*H*-chromene-3-carbonitrile

Crystal data

$C_{22}H_{22}ClN_3O_4S$
M_r = 459.93
Triclinic, $P\overline{1}$
a = 8.6739 (5) Å
b = 10.5490 (5) Å
c = 12.4021 (8) Å
α = 91.351 (4)°
β = 101.065 (5)°
γ = 97.235 (4)°
V = 1103.51 (11) Å^3
Z = 2
$F(000)$ = 480
D_x = 1.384 Mg m^{-3}
Mo $K\alpha$ radiation, λ = 0.71073 Å
Cell parameters from 2322 reflections
θ = 3.6–29.8°
μ = 0.30 mm^{-1}
T = 293 K
Block, colourless
0.20 × 0.20 × 0.15 mm

Data collection

Rigaku Oxford Diffraction Xcalibur, Sapphire3 diffractometer
Radiation source: Enhance (Mo) X-ray Source
Detector resolution: 16.1827 pixels mm^{-1}
ω scans
Absorption correction: multi-scan (CrysAlisPro; Rigaku OD, 2018)
T_{min} = 0.495, T_{max} = 1.000
11902 measured reflections
6933 independent reflections
3942 reflections with $I > 2\sigma(I)$
R_{int} = 0.057
θ_{max} = 32.4°, θ_{min} = 3.2°
h = −12→11
k = −15→15
l = −18→18

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.073
$wR(F^2)$ = 0.232
S = 1.00
6933 reflections

337 parameters
12 restraints
Hydrogen site location: mixed
H atoms treated by a mixture of independent and constrained refinement

$w = 1/[\sigma^2(F_o^2) + (0.1119P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} < 0.001$
$\Delta\rho_{max} = 0.33$ e Å^{-3}
$\Delta\rho_{min} = -0.72$ e Å^{-3}

Special details

Geometry. All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.

Fractional atomic coordinates and isotropic or equivalent isotropic displacement parameters (Å^2)

	x	*y*	*z*	U_{iso}*/U_{eq}	Occ. (<1)
Cl1	0.03972 (9)	0.51417 (8)	0.26644 (8)	0.0788 (3)	
S1	0.20928 (7)	0.15439 (6)	0.25028 (5)	0.04761 (19)	
O1	0.0808 (2)	0.07168 (18)	0.27577 (16)	0.0648 (5)	
O2	0.3663 (2)	0.12600 (17)	0.29009 (15)	0.0575 (5)	
O3	0.58348 (18)	0.26894 (16)	0.50631 (14)	0.0477 (4)	
O4	0.0502 (2)	0.31102 (17)	0.50362 (17)	0.0592 (5)	
N1	0.1851 (3)	0.1610 (2)	0.11726 (17)	0.0620 (6)	
N2	0.7433 (3)	0.3725 (2)	0.4084 (2)	0.0616 (6)	
H2A	0.821 (4)	0.340 (3)	0.456 (2)	0.064 (8)*	
H2B	0.772 (4)	0.429 (3)	0.359 (3)	0.065 (9)*	
N3	0.5170 (3)	0.5555 (2)	0.2211 (2)	0.0720 (7)	
C1	0.0509 (4)	0.2134 (3)	0.0640 (2)	0.0685 (8)	
C2A	−0.0047 (19)	0.1696 (12)	−0.0450 (6)	0.075 (3)	0.5
H2AA	0.046249	0.110365	−0.076725	0.090*	0.5
C3A	−0.1356 (18)	0.2143 (15)	−0.1057 (12)	0.081 (4)	0.5
H3A	−0.177591	0.188100	−0.178732	0.097*	0.5
C4A	−0.198 (2)	0.302 (2)	−0.0480 (12)	0.085 (3)	0.5
H4A	−0.291494	0.328402	−0.084953	0.102*	0.5
C5A	−0.1415 (12)	0.3545 (14)	0.0572 (9)	0.079 (4)	0.5
H5A	−0.190299	0.416714	0.086940	0.095*	0.5
C2B	−0.0394 (19)	0.1748 (17)	−0.0399 (7)	0.115 (7)	0.5
H2BA	−0.013639	0.107213	−0.079432	0.139*	0.5
C3B	−0.167 (2)	0.236 (2)	−0.0844 (13)	0.120 (8)	0.5
H3B	−0.219377	0.206308	−0.154646	0.144*	0.5
C4B	−0.227 (2)	0.335 (2)	−0.0391 (14)	0.122 (7)	0.5
H4B	−0.311513	0.374797	−0.073359	0.146*	0.5
C5B	−0.1391 (13)	0.3653 (16)	0.0656 (11)	0.121 (7)	0.5
H5B	−0.171095	0.428779	0.106286	0.146*	0.5
C6	−0.0073 (3)	0.3099 (3)	0.1166 (3)	0.0697 (9)	
C7	0.0800 (3)	0.3652 (3)	0.2261 (2)	0.0551 (6)	
C8	0.1906 (2)	0.3107 (2)	0.29209 (19)	0.0442 (5)	
C9	0.3034 (3)	0.3711 (2)	0.39527 (19)	0.0423 (5)	
H9	0.265613	0.450631	0.414792	0.051*	
C10	0.3097 (2)	0.28831 (19)	0.49249 (18)	0.0397 (4)	

C11	0.1699 (2)	0.2645 (2)	0.54253 (19)	0.0428 (5)	
C12	0.1814 (3)	0.1897 (2)	0.6451 (2)	0.0487 (5)	
H12A	0.076892	0.146673	0.648431	0.058*	
H12B	0.215222	0.248890	0.708728	0.058*	
C13	0.2968 (3)	0.0896 (2)	0.65146 (19)	0.0472 (5)	
C14	0.4558 (3)	0.1565 (2)	0.6339 (2)	0.0475 (5)	
H14A	0.508114	0.206829	0.700312	0.057*	
H14B	0.522224	0.092238	0.621679	0.057*	
C15	0.4416 (2)	0.2413 (2)	0.53984 (18)	0.0407 (4)	
C16	0.5947 (3)	0.3529 (2)	0.4253 (2)	0.0436 (5)	
C17	0.4688 (3)	0.4055 (2)	0.37333 (19)	0.0433 (5)	
C18	0.4938 (3)	0.4890 (2)	0.2889 (2)	0.0490 (5)	
C19	0.2299 (4)	−0.0175 (2)	0.5635 (2)	0.0593 (7)	
H19A	0.212443	0.018081	0.492353	0.089*	
H19B	0.131409	−0.059562	0.577396	0.089*	
H19C	0.303981	−0.078220	0.565607	0.089*	
C20	0.3193 (4)	0.0330 (3)	0.7645 (2)	0.0671 (7)	
H20A	0.368584	0.098819	0.819591	0.101*	
H20B	0.385352	−0.033648	0.766154	0.101*	
H20C	0.217960	−0.001696	0.779089	0.101*	
C21	0.3116 (5)	0.1391 (4)	0.0592 (3)	0.1013 (13)	
H21A	0.272294	0.077199	−0.002026	0.122*	0.5
H21B	0.398128	0.107737	0.108434	0.122*	0.5
H21C	0.263219	0.099482	−0.012681	0.122*	0.5
H21D	0.372926	0.078161	0.099154	0.122*	0.5
C22A	0.367 (2)	0.2700 (12)	0.0182 (19)	0.168 (9)	0.5
H22A	0.276172	0.306634	−0.018768	0.252*	0.5
H22B	0.436355	0.259743	−0.031876	0.252*	0.5
H22C	0.421703	0.325606	0.079685	0.252*	0.5
C22B	0.426 (2)	0.2569 (18)	0.043 (2)	0.197 (11)	0.5
H22D	0.389262	0.332725	0.067156	0.295*	0.5
H22E	0.431822	0.261267	−0.033255	0.295*	0.5
H22F	0.529782	0.250560	0.085562	0.295*	0.5

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
Cl1	0.0616 (5)	0.0790 (5)	0.1052 (7)	0.0370 (4)	0.0187 (4)	0.0310 (4)
S1	0.0426 (3)	0.0562 (4)	0.0414 (3)	0.0044 (2)	0.0036 (2)	−0.0003 (2)
O1	0.0626 (12)	0.0652 (11)	0.0621 (11)	−0.0073 (9)	0.0108 (9)	0.0075 (9)
O2	0.0534 (11)	0.0619 (10)	0.0564 (10)	0.0198 (8)	0.0023 (8)	−0.0081 (8)
O3	0.0299 (8)	0.0596 (9)	0.0571 (10)	0.0133 (6)	0.0115 (7)	0.0114 (8)
O4	0.0368 (9)	0.0688 (11)	0.0778 (13)	0.0201 (8)	0.0158 (8)	0.0165 (9)
N1	0.0603 (14)	0.0807 (15)	0.0413 (11)	0.0041 (11)	0.0047 (10)	−0.0001 (10)
N2	0.0351 (11)	0.0729 (14)	0.0812 (17)	0.0109 (10)	0.0177 (11)	0.0219 (13)
N3	0.0721 (17)	0.0741 (15)	0.0679 (16)	0.0045 (13)	0.0106 (13)	0.0187 (13)
C1	0.0552 (16)	0.094 (2)	0.0467 (14)	−0.0058 (15)	−0.0051 (12)	0.0159 (14)
C2A	0.071 (7)	0.085 (6)	0.065 (7)	0.012 (5)	−0.001 (4)	0.015 (5)

C3A	0.074 (8)	0.105 (7)	0.052 (6)	0.000 (5)	−0.009 (5)	0.015 (4)
C4A	0.047 (8)	0.134 (10)	0.076 (7)	0.043 (6)	−0.006 (5)	0.036 (7)
C5A	0.059 (7)	0.112 (8)	0.079 (8)	0.036 (6)	0.026 (6)	0.035 (6)
C2B	0.081 (9)	0.194 (14)	0.040 (5)	−0.052 (8)	−0.023 (4)	0.015 (6)
C3B	0.058 (8)	0.23 (2)	0.054 (8)	−0.009 (9)	−0.018 (7)	0.038 (11)
C4B	0.041 (7)	0.179 (19)	0.126 (12)	0.010 (8)	−0.037 (8)	0.087 (10)
C5B	0.048 (7)	0.189 (15)	0.097 (9)	−0.014 (7)	−0.050 (6)	0.066 (9)
C6	0.0370 (13)	0.102 (2)	0.0637 (17)	0.0021 (14)	−0.0051 (12)	0.0342 (17)
C7	0.0351 (12)	0.0692 (15)	0.0622 (15)	0.0106 (11)	0.0081 (11)	0.0204 (13)
C8	0.0310 (10)	0.0559 (12)	0.0456 (12)	0.0085 (9)	0.0051 (8)	0.0101 (10)
C9	0.0327 (10)	0.0438 (10)	0.0507 (12)	0.0099 (8)	0.0058 (9)	0.0021 (9)
C10	0.0324 (10)	0.0442 (10)	0.0425 (11)	0.0077 (8)	0.0062 (8)	−0.0016 (8)
C11	0.0323 (10)	0.0439 (10)	0.0524 (12)	0.0088 (8)	0.0076 (9)	−0.0047 (9)
C12	0.0405 (12)	0.0576 (12)	0.0516 (13)	0.0104 (10)	0.0157 (10)	−0.0011 (11)
C13	0.0430 (12)	0.0556 (12)	0.0462 (12)	0.0131 (10)	0.0117 (10)	0.0061 (10)
C14	0.0392 (12)	0.0566 (12)	0.0482 (12)	0.0140 (10)	0.0066 (9)	0.0068 (10)
C15	0.0308 (10)	0.0479 (10)	0.0446 (11)	0.0079 (8)	0.0087 (8)	−0.0006 (9)
C16	0.0357 (11)	0.0460 (11)	0.0502 (12)	0.0052 (8)	0.0113 (9)	0.0013 (9)
C17	0.0369 (11)	0.0451 (10)	0.0477 (12)	0.0084 (8)	0.0061 (9)	0.0024 (9)
C18	0.0401 (12)	0.0519 (12)	0.0527 (13)	0.0040 (9)	0.0045 (10)	0.0040 (11)
C19	0.0695 (18)	0.0482 (12)	0.0622 (16)	0.0073 (12)	0.0181 (13)	0.0027 (11)
C20	0.0603 (17)	0.0899 (19)	0.0576 (16)	0.0202 (15)	0.0191 (13)	0.0192 (15)
C21	0.081 (3)	0.166 (4)	0.0550 (18)	0.002 (2)	0.0214 (17)	−0.022 (2)
C22A	0.117 (15)	0.214 (15)	0.159 (14)	−0.104 (10)	0.087 (13)	−0.092 (11)
C22B	0.102 (13)	0.29 (2)	0.177 (18)	−0.112 (12)	0.082 (12)	−0.066 (14)

Geometric parameters (Å, º)

Cl1—C7	1.735 (3)	C9—C10	1.502 (3)
S1—O1	1.4168 (19)	C9—C17	1.512 (3)
S1—O2	1.4287 (18)	C9—H9	0.9800
S1—N1	1.627 (2)	C10—C15	1.341 (3)
S1—C8	1.753 (2)	C10—C11	1.462 (3)
O3—C16	1.364 (3)	C11—C12	1.506 (3)
O3—C15	1.373 (3)	C12—C13	1.538 (3)
O4—C11	1.225 (3)	C12—H12A	0.9700
N1—C1	1.408 (4)	C12—H12B	0.9700
N1—C21	1.461 (5)	C13—C20	1.525 (4)
N2—C16	1.337 (3)	C13—C14	1.525 (3)
N2—H2A	0.92 (3)	C13—C19	1.528 (3)
N2—H2B	0.91 (3)	C14—C15	1.483 (3)
N3—C18	1.139 (3)	C14—H14A	0.9700
C1—C2A	1.391 (5)	C14—H14B	0.9700
C1—C6	1.394 (5)	C16—C17	1.347 (3)
C1—C2B	1.395 (4)	C17—C18	1.415 (3)
C2A—C3A	1.380 (5)	C19—H19A	0.9600
C2A—H2AA	0.9300	C19—H19B	0.9600
C3A—C4A	1.378 (5)	C19—H19C	0.9600

C3A—H3A	0.9300	C20—H20A	0.9600
C4A—C5A	1.381 (5)	C20—H20B	0.9600
C4A—H4A	0.9300	C20—H20C	0.9600
C5A—C6	1.394 (4)	C21—C22B	1.533 (5)
C5A—H5A	0.9300	C21—C22A	1.534 (5)
C2B—C3B	1.380 (5)	C21—H21A	0.9700
C2B—H2BA	0.9300	C21—H21B	0.9700
C3B—C4B	1.377 (5)	C21—H21C	0.9700
C3B—H3B	0.9300	C21—H21D	0.9700
C4B—C5B	1.380 (5)	C22A—H22A	0.9600
C4B—H4B	0.9300	C22A—H22B	0.9600
C5B—C6	1.399 (5)	C22A—H22C	0.9600
C5B—H5B	0.9300	C22B—H22D	0.9600
C6—C7	1.488 (4)	C22B—H22E	0.9600
C7—C8	1.334 (3)	C22B—H22F	0.9600
C8—C9	1.525 (3)		

O1—S1—O2	118.26 (12)	C11—C12—C13	113.76 (19)
O1—S1—N1	108.63 (12)	C11—C12—H12A	108.8
O2—S1—N1	107.59 (13)	C13—C12—H12A	108.8
O1—S1—C8	107.85 (12)	C11—C12—H12B	108.8
O2—S1—C8	110.65 (10)	C13—C12—H12B	108.8
N1—S1—C8	102.75 (12)	H12A—C12—H12B	107.7
C16—O3—C15	119.25 (17)	C20—C13—C14	109.1 (2)
C1—N1—C21	120.9 (3)	C20—C13—C19	109.2 (2)
C1—N1—S1	116.6 (2)	C14—C13—C19	111.0 (2)
C21—N1—S1	121.3 (2)	C20—C13—C12	110.0 (2)
C16—N2—H2A	118 (2)	C14—C13—C12	108.06 (19)
C16—N2—H2B	121.8 (19)	C19—C13—C12	109.5 (2)
H2A—N2—H2B	119 (3)	C15—C14—C13	113.40 (18)
C2A—C1—C6	124.9 (6)	C15—C14—H14A	108.9
C6—C1—C2B	113.5 (7)	C13—C14—H14A	108.9
C2A—C1—N1	114.5 (6)	C15—C14—H14B	108.9
C6—C1—N1	120.4 (2)	C13—C14—H14B	108.9
C2B—C1—N1	126.1 (7)	H14A—C14—H14B	107.7
C3A—C2A—C1	119.7 (12)	C10—C15—O3	122.8 (2)
C3A—C2A—H2AA	120.1	C10—C15—C14	125.8 (2)
C1—C2A—H2AA	120.1	O3—C15—C14	111.38 (18)
C4A—C3A—C2A	113.6 (13)	N2—C16—C17	127.6 (2)
C4A—C3A—H3A	123.2	N2—C16—O3	110.3 (2)
C2A—C3A—H3A	123.2	C17—C16—O3	122.1 (2)
C3A—C4A—C5A	128.8 (11)	C16—C17—C18	117.1 (2)
C3A—C4A—H4A	115.6	C16—C17—C9	123.0 (2)
C5A—C4A—H4A	115.6	C18—C17—C9	119.70 (19)
C4A—C5A—C6	116.7 (8)	N3—C18—C17	178.6 (3)
C4A—C5A—H5A	121.7	C13—C19—H19A	109.5
C6—C5A—H5A	121.7	C13—C19—H19B	109.5
C3B—C2B—C1	120.6 (12)	H19A—C19—H19B	109.5

C3B—C2B—H2BA	119.7	C13—C19—H19C	109.5
C1—C2B—H2BA	119.7	H19A—C19—H19C	109.5
C4B—C3B—C2B	129.0 (14)	H19B—C19—H19C	109.5
C4B—C3B—H3B	115.5	C13—C20—H20A	109.5
C2B—C3B—H3B	115.5	C13—C20—H20B	109.5
C3B—C4B—C5B	108.4 (13)	H20A—C20—H20B	109.5
C3B—C4B—H4B	125.8	C13—C20—H20C	109.5
C5B—C4B—H4B	125.8	H20A—C20—H20C	109.5
C4B—C5B—C6	126.5 (11)	H20B—C20—H20C	109.5
C4B—C5B—H5B	116.7	N1—C21—C22B	116.6 (12)
C6—C5B—H5B	116.7	N1—C21—C22A	105.2 (9)
C1—C6—C5A	115.9 (6)	N1—C21—H21A	110.7
C1—C6—C5B	121.9 (7)	C22A—C21—H21A	110.7
C1—C6—C7	119.9 (2)	N1—C21—H21B	110.7
C5A—C6—C7	124.1 (6)	C22A—C21—H21B	110.7
C5B—C6—C7	118.0 (6)	H21A—C21—H21B	108.8
C8—C7—C6	124.5 (3)	N1—C21—H21C	108.1
C8—C7—Cl1	118.5 (2)	C22B—C21—H21C	108.1
C6—C7—Cl1	116.9 (2)	N1—C21—H21D	108.1
C7—C8—C9	127.2 (2)	C22B—C21—H21D	108.1
C7—C8—S1	114.9 (2)	H21C—C21—H21D	107.3
C9—C8—S1	117.90 (15)	C21—C22A—H22A	109.5
C10—C9—C17	109.45 (17)	C21—C22A—H22B	109.5
C10—C9—C8	113.45 (17)	H22A—C22A—H22B	109.5
C17—C9—C8	110.8 (2)	C21—C22A—H22C	109.5
C10—C9—H9	107.6	H22A—C22A—H22C	109.5
C17—C9—H9	107.6	H22B—C22A—H22C	109.5
C8—C9—H9	107.6	C21—C22B—H22D	109.5
C15—C10—C11	118.2 (2)	C21—C22B—H22E	109.5
C15—C10—C9	122.7 (2)	H22D—C22B—H22E	109.5
C11—C10—C9	118.99 (18)	C21—C22B—H22F	109.5
O4—C11—C10	119.4 (2)	H22D—C22B—H22F	109.5
O4—C11—C12	121.9 (2)	H22E—C22B—H22F	109.5
C10—C11—C12	118.57 (19)		

O1—S1—N1—C1	63.5 (2)	O1—S1—C8—C9	105.95 (19)
O2—S1—N1—C1	−167.3 (2)	O2—S1—C8—C9	−24.8 (2)
C8—S1—N1—C1	−50.5 (2)	N1—S1—C8—C9	−139.41 (19)
O1—S1—N1—C21	−128.9 (3)	C7—C8—C9—C10	131.5 (3)
O2—S1—N1—C21	0.3 (3)	S1—C8—C9—C10	−50.9 (3)
C8—S1—N1—C21	117.1 (3)	C7—C8—C9—C17	−104.9 (3)
C21—N1—C1—C2A	38.9 (9)	S1—C8—C9—C17	72.7 (2)
S1—N1—C1—C2A	−153.4 (8)	C17—C9—C10—C15	−8.0 (3)
C21—N1—C1—C6	−135.3 (3)	C8—C9—C10—C15	116.3 (2)
S1—N1—C1—C6	32.4 (4)	C17—C9—C10—C11	167.86 (18)
C21—N1—C1—C2B	47.2 (11)	C8—C9—C10—C11	−67.8 (3)
S1—N1—C1—C2B	−145.1 (11)	C15—C10—C11—O4	176.9 (2)
C6—C1—C2A—C3A	−6.0 (19)	C9—C10—C11—O4	0.8 (3)

N1—C1—C2A—C3A	−179.9 (13)	C15—C10—C11—C12	0.6 (3)
C1—C2A—C3A—C4A	0 (3)	C9—C10—C11—C12	−175.43 (18)
C2A—C3A—C4A—C5A	5 (4)	O4—C11—C12—C13	152.7 (2)
C3A—C4A—C5A—C6	−4 (4)	C10—C11—C12—C13	−31.1 (3)
C6—C1—C2B—C3B	4 (2)	C11—C12—C13—C20	171.6 (2)
N1—C1—C2B—C3B	−178.5 (15)	C11—C12—C13—C14	52.6 (3)
C1—C2B—C3B—C4B	−2 (4)	C11—C12—C13—C19	−68.4 (3)
C2B—C3B—C4B—C5B	−2 (4)	C20—C13—C14—C15	−165.8 (2)
C3B—C4B—C5B—C6	3 (4)	C19—C13—C14—C15	73.8 (3)
C2A—C1—C6—C5A	7.0 (12)	C12—C13—C14—C15	−46.2 (3)
N1—C1—C6—C5A	−179.4 (7)	C11—C10—C15—O3	−173.24 (19)
C2B—C1—C6—C5B	−3.1 (14)	C9—C10—C15—O3	2.7 (3)
N1—C1—C6—C5B	179.2 (9)	C11—C10—C15—C14	5.8 (3)
C2A—C1—C6—C7	−168.8 (9)	C9—C10—C15—C14	−178.3 (2)
C2B—C1—C6—C7	−177.4 (10)	C16—O3—C15—C10	3.6 (3)
N1—C1—C6—C7	4.8 (4)	C16—O3—C15—C14	−175.57 (18)
C4A—C5A—C6—C1	−2.2 (19)	C13—C14—C15—C10	19.0 (3)
C4A—C5A—C6—C7	173.3 (14)	C13—C14—C15—O3	−161.91 (19)
C4B—C5B—C6—C1	0 (3)	C15—O3—C16—N2	176.7 (2)
C4B—C5B—C6—C7	174.1 (19)	C15—O3—C16—C17	−3.2 (3)
C1—C6—C7—C8	−16.8 (4)	N2—C16—C17—C18	1.6 (4)
C5A—C6—C7—C8	167.8 (8)	O3—C16—C17—C18	−178.6 (2)
C5B—C6—C7—C8	168.6 (9)	N2—C16—C17—C9	176.8 (2)
C1—C6—C7—Cl1	160.2 (2)	O3—C16—C17—C9	−3.4 (3)
C5A—C6—C7—Cl1	−15.2 (8)	C10—C9—C17—C16	8.4 (3)
C5B—C6—C7—Cl1	−14.4 (9)	C8—C9—C17—C16	−117.4 (2)
C6—C7—C8—C9	168.9 (2)	C10—C9—C17—C18	−176.56 (19)
Cl1—C7—C8—C9	−8.1 (4)	C8—C9—C17—C18	57.6 (3)
C6—C7—C8—S1	−8.7 (4)	C1—N1—C21—C22B	77.0 (11)
Cl1—C7—C8—S1	174.30 (13)	S1—N1—C21—C22B	−90.1 (11)
O1—S1—C8—C7	−76.2 (2)	C1—N1—C21—C22A	56.8 (9)
O2—S1—C8—C7	153.1 (2)	S1—N1—C21—C22A	−110.3 (8)
N1—S1—C8—C7	38.5 (2)		

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N2—H2*A*···O4^{i}	0.92 (3)	2.03 (3)	2.857 (3)	150 (3)
N2—H2*B*···Cl1^{i}	0.91 (3)	2.84 (3)	3.583 (3)	140 (2)
C4*B*—H4*B*···N3^{ii}	0.93	2.49	3.381 (18)	160
C19—H19*C*···O3^{iii}	0.96	2.56	3.452 (3)	155
C20—H20*C*···O1^{iv}	0.96	2.56	3.443 (4)	153

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