Crystal structures of two alanylpiperidine analogues

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The structure of ethyl 1-[N-(4-methylphenyl)-N-(methylsulfonyl)alanyl]-piperidine-4-carboxylate, $C_{19}H_{28}N_2O_5S$, I, a compound of interest as activator of Ubiquitin C-terminal Hydrolase-L1 (UCH-L1), was determined by single-crystal X-ray diffraction (SCXRD) analysis. In order to find new activators, a derivative of compound I, namely, 1-[N-(4-methylphenyl)-N-(methylsulfonyl)-alanyl]piperidine-4-carboxylic acid, $C_{17}H_{24}N_2O_5S$, II, was studied. The synthesis and crystal structure are also reported. Despite being analogues, different crystal packings are observed. Compound II bears a carboxylic group, which favors a strong hydrogen bond. A polymorph risk assessment was carried out to study interactions in compound II.

1. Chemical context

Ubiquitin C-terminal Hydrolase-L1 is a deubiquitinase that represents 2% of the neuronal soluble proteins in the brain and is involved in the neuropathogenesis of neurodegenerative diseases. Studies have shown that several mutations have an impact on the hydrolase activity of UCH-L1 (Leroy *et al.*, 1998; Maraganore *et al.*, 1999) and that its down-regulation is associated with idiopathic Parkinson's disease (Choi *et al.*, 2004). Finding potentiators of UCH-L1 could be a therapeutic pathway for these diseases (Mitsui *et al.*, 2010). Ethyl 1-[N-(methylsulfonyl)-N-(p-tolyl)-alanyl]piperidine-4-carboxylate was discovered through *in silico* drug screening as an activator of UCH-L1, with a hydrolase activity up to 111% at 63 μM (Mitsui *et al.*, 2010). We studied the only known activator in the literature, compound I. Derivatives of compound I were then investigated as potential activators and compound II was obtained after a saponification. Compound II bears a carboxylic acid group, which opens up the possibility for co-crystallization and salification in order to modulate the physicochemical properties, such as the solubility. We report the crystal structures of these two compounds as well as a survey of the interactions observed in compound II.
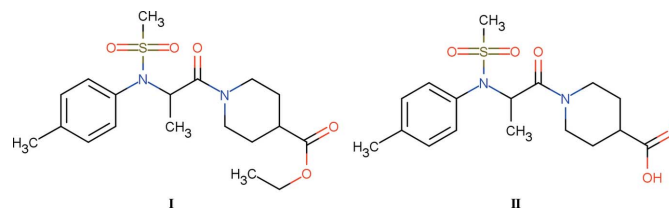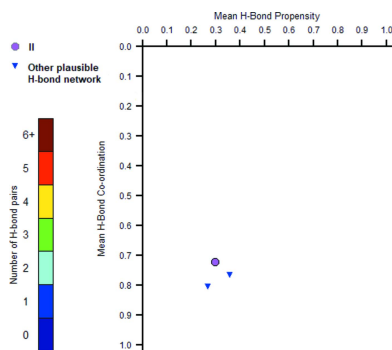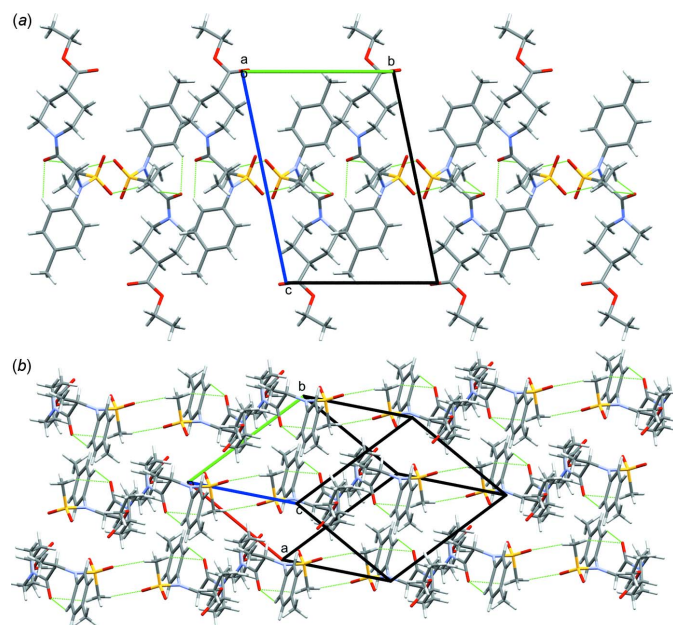

2. Structural commentary

Both compounds crystallize as colorless plate-like crystals but in different space groups. Compound I crystallizes in the
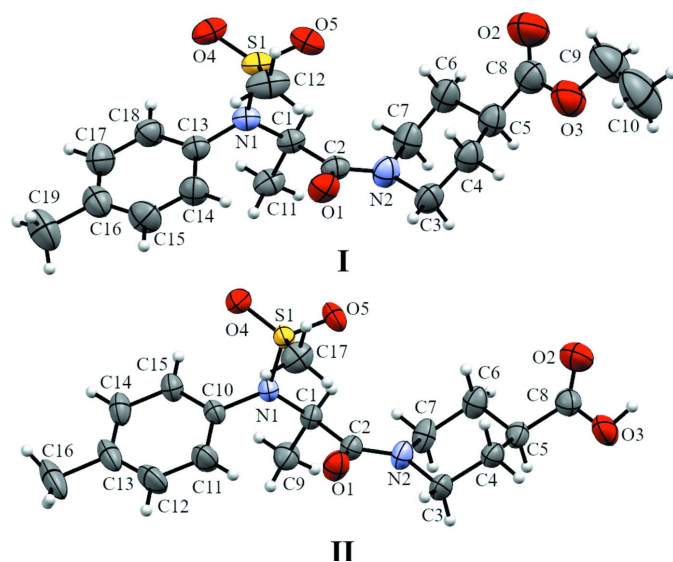
Figure 1
The asymmetric units of compounds **I** and **II**, with displacement ellipsoids drawn at the 50% probability level.

triclinic $P\bar{1}$ space groups and compound **II** in the monoclinic $P2_1/n$ space group. The asymmetric units are shown in Fig. 1. Both compounds crystallize as a racemic mixture and have one molecule in the asymmetric unit in a similar conformation. The torsion angle N1—C1—C2—N2 is 156.2 (1) and −153.5 (1)° for **I** and **II** respectively. The only slight difference between the two compounds is the geometry of N2. In compound **I**, the distance between N2 and the plane formed by C2, C3 and C7 is 0.114 (2) Å whereas in compound **II** this distance is 0.014 (2) Å. A more planar arrangement of N2 in

Table 1
Hydrogen-bond geometry (Å, °) for compound **I**.

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
C12—H12$B\cdots$O1	0.96	2.50	3.210 (2)	130
C12—H12$C\cdots$O4^i	0.96	2.44	3.376 (2)	164
C14—H14$\cdots$O1	0.93	2.48	3.177 (2)	132

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

Table 2
Hydrogen-bond geometry (Å, °) for compound **II**.

D—H$\cdots A$	D—H	H$\cdots A$	$D\cdots A$	D—H$\cdots A$
O3—H3$\cdots$O5^i	0.90 (3)	1.88 (3)	2.7463 (15)	161 (2)
C17—H17$A\cdots$O1	0.96	2.48	3.144 (2)	127
C4—H4$B\cdots$O2^i	0.97	2.52	3.471 (2)	167
C11—H11$\cdots$O1	0.93	2.56	3.2558 (19)	132

Symmetry code: (i) $-x + 2, -y + 1, -z + 1$.

compound **II** is noticed, probably caused by the crystal packing. Single crystals represent the bulk samples as the powder patterns calculated from SCXRD data are similar to the experimental ones.

3. Supramolecular features

As compound **I** does not have any strong hydrogen-bond acceptors, only weak hydrogen bonds are observed in the crystal structure (see Table 1). The amide oxygen atom O1 participates in the formation of two intramolecular hydrogen bonds [$S_1^1(7)$ motifs; Etter *et al.*, 1990]. The oxygen atom O4 is inter-connected with atom H12C of the sulfonyl methyl of an adjacent molecule [d(H$\cdots$O) 2.44 Å; Table 1], forming an $R_2^2(8)$ hydrogen bond motif along the *a*-axis direction (Fig. 2). As compound **I** bears a tolyl moiety, π–π interactions were expected but were not observed in this crystal packing.

Compound **II** bearing a carboxylic moiety instead of an ester has an impact on the hydrogen bonds and thus on the

Figure 2
Crystal packing of **I** with hydrogen bonds highlighted in green (*a*) showing one layer of molecules, viewed down the *a* axis and (*b*) showing adjacent layers of molecules.
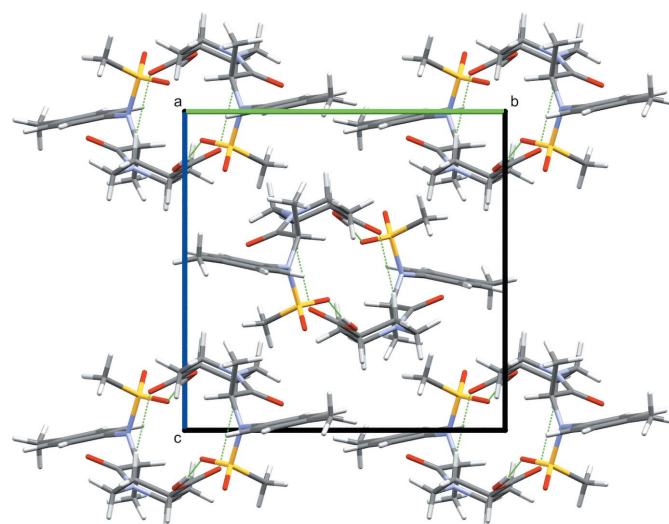
Figure 3
Crystal packing of **II** showing the tubular arrangement viewed down the *a* axis. Hydrogen bonds are highlighted in green.

Table 3
Hydrogen-bond propensity calculation for compound **II**.

Donor	Acceptor	Propensity
O3	O2	0.36
O3	O4	0.30
O3	O5	0.30

crystal packing. In compound **II**, a tubular arrangement (Fig. 3) can be observed, which is different from that of compound **I**. In compound **II**, a hydrogen-bonded ring with an $R_2^2(24)$ motif is formed by a strong hydrogen bond between H3 of the carboxylic acid group and O5 from an adjacent molecule $[d(H\cdots O)$ 1.88 (3) Å; Table 2]. In addition, two intra-molecular $[S_1^1(7)$ motifs] and one intermolecular $[R_2^2(10)$ motif] weak hydrogen bonds are detected. As in compound **I**, no π–π interactions are noticed in the crystal structure. A dimer synthon is observed in the crystal packing in both cases, but for compound **I** it is ensured by weak hydrogen bonds in contrast to compound **II** where the dimer is based on strong hydrogen bonds.
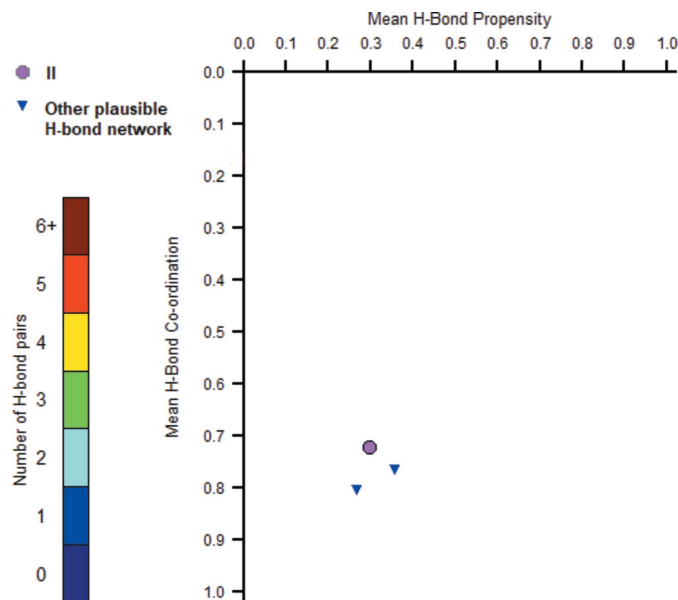

Figure 4
Hydrogen-bond propensity chart for compound **II**.

4. Database survey

Searches of the Cambridge Structural Database (CSD, version 5.42, update September 2021; Groom *et al.* 2016) were carried out with the exact structures of compounds **I** and **II** and with substructures containing the significant fragments (alanyl-piperidine with and without the sulfonyl methyl and tolyl group). No comparable structures came out of this survey.

A polymorph risk assessment based on the hydrogen bonds in the CSD was carried out. This statistical analysis allows us to estimate which atoms are the donors and the acceptors for hydrogen bonds in the crystal structure (Chemburkar *et al.*, 2000; Galek *et al.*, 2007). This quantifies the probability of hydrogen-bond formation and thus the different probable polymorphs that can arise from a specific compound. The results are summarized in Table 3. A hydrogen-bonding interaction between two carboxylic groups is predicted with the highest probability. We did not observe the carboxylic dimer but rather this group interacting with one oxygen of the sulfonyl methyl. The analysis also predicts other plausible hydrogen-bonded networks (Fig. 4), one that is statistically slightly more likely to be formed than the current one. This suggests that another potential polymorph could be obtained. Thus, we undertook a polymorph screening by several crystallization experiments of compound **II**. The recrystallization solvents that we tested were cyclohexane, toluene, ethyl acetate, chloroform, dichloromethane, acetone, acetonitrile, 2-propanol, ethanol and methanol. They all lead to the same polymorph.

5. Synthesis and crystallization

Compound I: This was purchased from Evotech (Hamburg, Germany). The product was crystallized by slow evaporation from non-anhydrous ethyl acetate, which provided colorless plate-like crystals suitable for SCXRD. M.p. 442.2 K

Compound II: In a round-bottom flask, compound **I** (405.1 mg, 1.02 mmol, 1.0 eq) dissolved in 8 mL of THF was added to a solution of LiOH (81.9 mg, 3.40 mmol, 3.4 eq) dissolved in 5 mL of water. The mixture was stirred at room temperature for 8 h. The resulting mixture was washed with ether. The aqueous phase was then acidified with HCl 37% to a pH of 2 and extracted with dichloromethane. The combined organic phases were dried over anhydrous Na_2SO_4 and concentrated under vacuum to yield a white solid (351.0 mg, 93%). The product was crystallized by slow evaporation from methanol, which provided colorless plate-like crystals suitable for SCXRD. ^{1}H NMR (DMSO): 12.32 (*s*, 1H, carboxylic acid), 7.39 (*d*, 2H, CH$_{arom}$), 7.20 (*d*, 2H, CH$_{arom}$), 5.20 (*s*, 1H, CH$_\alpha$), 4.03–3.15 (*m*, 4H, CH$_{pip}$), 2.96 (*s*, 3H, CH$_{SO2Me}$), 2.79 (*m*, 1H, CH$_{pip}$), 2.31 (*s*, 3H, CH$_{PheMe}$), 1.83–1.36 (*m*, 4H, CH$_{pip}$), 1.03 (*d*, 3H, CH$_{\alpha Me}$) ^{13}C NMR (DMSO): 169.1, 168.7, 138.2, 133.5, 132.0, 129.4, 53.3, 44.5, 41.3, 28.5, 20.7, 16.8. M.p. 496.2 K

6. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 4. All H atoms, except one of the -OH group in **II**, were refined using a riding model, with C—H = 0.93 (aromatic), 0.96 (methyl) or 0.98 Å (tertiary carbon). Coordinates of the hydrogen atom of the -OH group were refined. The isotropic atomic displacement parameters of the H atoms were set at $1.5U_{eq}$ of the parent atom for the methyl and alcohol groups, and at $1.2U_{eq}$ otherwise.

Acknowledgements

Table 4
Experimental details.

	I	II
Crystal data		
Chemical formula	$C_{19}H_{28}N_2O_5S$	$C_{17}H_{24}N_2O_5S$
M_r	396.49	368.44
Crystal system, space group	Triclinic, $P\bar{1}$	Monoclinic, $P2_1/n$
Temperature (K)	295	295
a, b, c (Å)	8.5368 (6), 9.6594 (6), 13.5173 (12)	12.1013 (2), 12.3092 (2), 12.4348 (3)
α, β, γ (°)	75.947 (6), 79.302 (6), 74.554 (5)	90, 100.546 (2), 90
V (Å^3)	1033.47 (14)	1820.97 (6)
Z	2	4
Radiation type	Mo $K\alpha$	Mo $K\alpha$
μ (mm^{-1})	0.19	0.21
Crystal size (mm)	$0.79 \times 0.18 \times 0.05$	$0.77 \times 0.18 \times 0.11$
Data collection		
Diffractometer	Oxford Diffraction Xcalibur, Gemini Ultra R	Oxford Diffraction Xcalibur, Gemini Ultra R
Absorption correction	Analytical [*CrysAlis PRO* (Rigaku OD, 2018), based on expressions derived by Clark & Reid (1995)]	Analytical [*CrysAlis PRO* (Rigaku OD, 2018), based on expressions derived by Clark & Reid (1995)]
T_{min}, T_{max}	0.923, 0.991	0.882, 0.980
No. of measured, independent and observed [$I > 2\sigma(I)$] reflections	13200, 6870, 4304	29518, 6284, 4779
R_{int}	0.026	0.026
$(\sin\theta/\lambda)_{max}$ (Å^{-1})	0.762	0.761
Refinement		
$R[F^2 > 2\sigma(F^2)]$, $wR(F^2)$, S	0.054, 0.158, 1.02	0.043, 0.126, 1.02
No. of reflections	6870	6284
No. of parameters	248	232
H-atom treatment	H-atom parameters constrained	H atoms treated by a mixture of independent and constrained refinement
$\Delta\rho_{max}, \Delta\rho_{min}$ (e Å^{-3})	0.34, −0.38	0.29, −0.29

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

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Crystal structures of two alanylpiperidine analogues

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Computing details

For both structures, 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 (Sheldrick, 2015a); program(s) used to refine structure: *SHELXL2016* (Sheldrick, 2015b); molecular graphics: *Mercury* (Macrae *et al.*, 2020); software used to prepare material for publication: *publCIF* (Westrip, 2010).

Ethyl 1-[*N*-(4-methylphenyl)-*N*-(methylsulfonyl)alanyl]piperidine-4-carboxylate (I)

Crystal data

$C_{19}H_{28}N_2O_5S$	$Z = 2$
$M_r = 396.49$	$F(000) = 424$
Triclinic, $P\bar{1}$	$D_x = 1.274$ Mg m^{-3}
$a = 8.5368$ (6) Å	Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
$b = 9.6594$ (6) Å	Cell parameters from 3246 reflections
$c = 13.5173$ (12) Å	$\theta = 2.4$–30.5°
$\alpha = 75.947$ (6)°	$\mu = 0.19$ mm^{-1}
$\beta = 79.302$ (6)°	$T = 295$ K
$\gamma = 74.554$ (5)°	Plate, colorless
$V = 1033.47$ (14) Å^3	$0.79 \times 0.18 \times 0.05$ mm

Data collection

Oxford Diffraction Xcalibur, Gemini Ultra R diffractometer	$T_{min} = 0.923$, $T_{max} = 0.991$
Radiation source: fine-focus sealed X-ray tube	13200 measured reflections
Graphite monochromator	6870 independent reflections
Detector resolution: 10.3712 pixels mm^{-1}	4304 reflections with $I > 2\sigma(I)$
ω scans	$R_{int} = 0.026$
Absorption correction: analytical [CrysAlisPro (Rigaku OD, 2018), based on expressions derived by Clark & Reid (1995)]	$\theta_{max} = 32.8°$, $\theta_{min} = 2.2°$
	$h = -12 \rightarrow 10$
	$k = -13 \rightarrow 14$
	$l = -20 \rightarrow 19$

Refinement

Refinement on F^2	Secondary atom site location: dual
Least-squares matrix: full	Hydrogen site location: mixed
$R[F^2 > 2\sigma(F^2)] = 0.054$	H-atom parameters constrained
$wR(F^2) = 0.158$	$w = 1/[\sigma^2(F_o^2) + (0.0633P)^2 + 0.1206P]$
$S = 1.02$	where $P = (F_o^2 + 2F_c^2)/3$
6870 reflections	$(\Delta/\sigma)_{max} < 0.001$
248 parameters	$\Delta\rho_{max} = 0.34$ e Å^{-3}
0 restraints	$\Delta\rho_{min} = -0.37$ e Å^{-3}
Primary atom site location: dual	

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 (Å²)

	x	y	z	U_{iso}*/U_{eq}
S1	0.21006 (5)	0.11226 (4)	0.49970 (3)	0.04597 (14)
O1	0.20546 (16)	0.42592 (12)	0.58010 (10)	0.0542 (3)
O2	0.2688 (3)	−0.0438 (2)	1.00683 (16)	0.1150 (8)
O3	0.1551 (3)	0.16259 (18)	1.06193 (12)	0.0894 (5)
O4	0.21136 (17)	0.03480 (13)	0.42186 (11)	0.0618 (4)
O5	0.25664 (18)	0.02943 (13)	0.59697 (11)	0.0624 (4)
N1	0.33461 (16)	0.22121 (13)	0.45549 (10)	0.0404 (3)
N2	0.3882 (2)	0.31933 (16)	0.69243 (11)	0.0543 (4)
C1	0.4352 (2)	0.24222 (16)	0.52607 (12)	0.0407 (3)
H1	0.484975	0.145601	0.564865	0.049*
C2	0.3309 (2)	0.33501 (16)	0.60307 (13)	0.0435 (4)
C3	0.2942 (3)	0.4081 (2)	0.76676 (14)	0.0622 (5)
H3A	0.212739	0.487753	0.733487	0.075*
H3B	0.367076	0.450568	0.791143	0.075*
C4	0.2099 (3)	0.3155 (2)	0.85723 (15)	0.0598 (5)
H4A	0.126979	0.283509	0.834039	0.072*
H4B	0.155721	0.374364	0.908049	0.072*
C5	0.3330 (3)	0.1809 (2)	0.90679 (14)	0.0595 (5)
H5	0.409068	0.216659	0.934903	0.071*
C6	0.4334 (3)	0.0960 (2)	0.82547 (15)	0.0631 (5)
H6A	0.517049	0.016237	0.856466	0.076*
H6B	0.362540	0.054116	0.798864	0.076*
C7	0.5139 (3)	0.1963 (2)	0.73772 (15)	0.0617 (5)
H7A	0.590425	0.233317	0.763271	0.074*
H7B	0.574515	0.141684	0.685678	0.074*
C8	0.2494 (3)	0.0852 (2)	0.99538 (17)	0.0714 (6)
C9	0.0650 (4)	0.0879 (3)	1.1529 (2)	0.1069 (10)
H9A	0.004626	0.029494	1.132728	0.128*
H9B	0.140898	0.023064	1.198758	0.128*
C10	−0.0456 (5)	0.1958 (4)	1.2040 (2)	0.1357 (14)
H10A	0.012297	0.263307	1.213528	0.204*
H10B	−0.091589	0.148539	1.269779	0.204*
H10C	−0.131975	0.248210	1.163132	0.204*
C11	0.5719 (2)	0.31422 (19)	0.46630 (14)	0.0503 (4)
H11A	0.636931	0.256036	0.418334	0.075*
H11B	0.639730	0.321567	0.513158	0.075*
H11C	0.525388	0.410564	0.429625	0.075*
C12	0.0118 (2)	0.2217 (2)	0.5200 (2)	0.0700 (6)
H12A	−0.017746	0.283965	0.455966	0.105*

H12B	0.008836	0.280954	0.568219	0.105*
H12C	−0.064229	0.159986	0.546811	0.105*
C13	0.3206 (2)	0.31143 (16)	0.35381 (13)	0.0431 (4)
C14	0.2231 (2)	0.45197 (18)	0.33966 (14)	0.0543 (4)
H14	0.166814	0.491483	0.396039	0.065*
C15	0.2097 (3)	0.5336 (2)	0.24101 (16)	0.0641 (5)
H15	0.144679	0.628604	0.232086	0.077*
C16	0.2899 (3)	0.4784 (2)	0.15543 (15)	0.0617 (5)
C17	0.3898 (3)	0.3385 (2)	0.17173 (16)	0.0675 (6)
H17	0.447572	0.299605	0.115395	0.081*
C18	0.4060 (3)	0.25519 (19)	0.26953 (14)	0.0569 (5)
H18	0.474265	0.161520	0.278607	0.068*
C19	0.2674 (4)	0.5688 (3)	0.04839 (17)	0.0908 (8)
H19A	0.162225	0.569619	0.032294	0.136*
H19B	0.351973	0.526722	−0.000565	0.136*
H19C	0.273737	0.667492	0.045582	0.136*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
S1	0.0381 (2)	0.0362 (2)	0.0636 (3)	−0.00995 (16)	−0.00197 (19)	−0.01207 (17)
O1	0.0444 (7)	0.0491 (6)	0.0645 (8)	0.0048 (5)	−0.0079 (6)	−0.0194 (5)
O2	0.157 (2)	0.0689 (11)	0.1072 (15)	−0.0226 (12)	0.0015 (14)	−0.0131 (10)
O3	0.1050 (15)	0.0800 (10)	0.0695 (10)	−0.0174 (10)	0.0144 (9)	−0.0133 (8)
O4	0.0598 (9)	0.0532 (7)	0.0829 (9)	−0.0212 (6)	−0.0043 (7)	−0.0280 (6)
O5	0.0629 (9)	0.0520 (7)	0.0669 (8)	−0.0211 (6)	−0.0053 (7)	0.0039 (6)
N1	0.0352 (7)	0.0367 (6)	0.0492 (7)	−0.0082 (5)	−0.0054 (6)	−0.0089 (5)
N2	0.0541 (10)	0.0534 (8)	0.0517 (8)	0.0017 (7)	−0.0076 (7)	−0.0191 (6)
C1	0.0333 (8)	0.0376 (7)	0.0507 (9)	−0.0047 (6)	−0.0051 (7)	−0.0119 (6)
C2	0.0389 (9)	0.0382 (7)	0.0527 (9)	−0.0075 (6)	−0.0036 (7)	−0.0114 (6)
C3	0.0761 (15)	0.0538 (10)	0.0557 (11)	−0.0053 (10)	−0.0049 (10)	−0.0226 (8)
C4	0.0598 (13)	0.0600 (11)	0.0568 (11)	−0.0007 (9)	−0.0072 (9)	−0.0214 (9)
C5	0.0600 (13)	0.0647 (11)	0.0542 (11)	−0.0060 (9)	−0.0145 (9)	−0.0170 (8)
C6	0.0635 (14)	0.0587 (10)	0.0620 (12)	0.0094 (9)	−0.0241 (10)	−0.0167 (9)
C7	0.0490 (12)	0.0749 (12)	0.0598 (11)	0.0038 (9)	−0.0152 (9)	−0.0247 (9)
C8	0.0784 (17)	0.0663 (13)	0.0668 (13)	−0.0071 (11)	−0.0187 (12)	−0.0122 (10)
C9	0.114 (3)	0.0948 (18)	0.0859 (19)	−0.0194 (18)	0.0136 (18)	0.0053 (15)
C10	0.125 (3)	0.143 (3)	0.092 (2)	−0.013 (2)	0.033 (2)	0.009 (2)
C11	0.0363 (9)	0.0539 (9)	0.0644 (11)	−0.0139 (7)	−0.0001 (8)	−0.0200 (8)
C12	0.0332 (10)	0.0571 (11)	0.1202 (19)	−0.0110 (8)	0.0035 (11)	−0.0288 (11)
C13	0.0396 (9)	0.0410 (8)	0.0493 (9)	−0.0094 (7)	−0.0059 (7)	−0.0105 (6)
C14	0.0528 (11)	0.0484 (9)	0.0554 (10)	0.0016 (8)	−0.0105 (9)	−0.0109 (8)
C15	0.0567 (13)	0.0568 (11)	0.0695 (13)	0.0007 (9)	−0.0188 (10)	−0.0030 (9)
C16	0.0607 (13)	0.0713 (12)	0.0540 (11)	−0.0235 (10)	−0.0112 (10)	−0.0024 (9)
C17	0.0791 (16)	0.0693 (12)	0.0534 (11)	−0.0223 (11)	0.0062 (10)	−0.0168 (9)
C18	0.0627 (13)	0.0471 (9)	0.0573 (11)	−0.0109 (8)	0.0035 (9)	−0.0143 (8)
C19	0.092 (2)	0.1060 (19)	0.0624 (14)	−0.0224 (16)	−0.0167 (14)	0.0085 (13)

Geometric parameters (Å, º)

S1—O5	1.4285 (14)	C7—H7A	0.9700
S1—O4	1.4286 (13)	C7—H7B	0.9700
S1—N1	1.6278 (13)	C9—C10	1.428 (4)
S1—C12	1.7526 (19)	C9—H9A	0.9700
O1—C2	1.227 (2)	C9—H9B	0.9700
O2—C8	1.188 (3)	C10—H10A	0.9600
O3—C8	1.324 (3)	C10—H10B	0.9600
O3—C9	1.462 (3)	C10—H10C	0.9600
N1—C13	1.445 (2)	C11—H11A	0.9600
N1—C1	1.476 (2)	C11—H11B	0.9600
N2—C2	1.346 (2)	C11—H11C	0.9600
N2—C3	1.464 (2)	C12—H12A	0.9600
N2—C7	1.466 (2)	C12—H12B	0.9600
C1—C11	1.519 (2)	C12—H12C	0.9600
C1—C2	1.537 (2)	C13—C14	1.380 (2)
C1—H1	0.9800	C13—C18	1.381 (2)
C3—C4	1.516 (3)	C14—C15	1.382 (3)
C3—H3A	0.9700	C14—H14	0.9300
C3—H3B	0.9700	C15—C16	1.379 (3)
C4—C5	1.535 (3)	C15—H15	0.9300
C4—H4A	0.9700	C16—C17	1.384 (3)
C4—H4B	0.9700	C16—C19	1.514 (3)
C5—C8	1.514 (3)	C17—C18	1.381 (3)
C5—C6	1.526 (3)	C17—H17	0.9300
C5—H5	0.9800	C18—H18	0.9300
C6—C7	1.521 (3)	C19—H19A	0.9600
C6—H6A	0.9700	C19—H19B	0.9600
C6—H6B	0.9700	C19—H19C	0.9600
O5—S1—O4	118.43 (8)	O2—C8—O3	123.4 (2)
O5—S1—N1	106.30 (8)	O2—C8—C5	125.1 (2)
O4—S1—N1	108.16 (8)	O3—C8—C5	111.50 (18)
O5—S1—C12	108.50 (11)	C10—C9—O3	108.7 (2)
O4—S1—C12	107.33 (10)	C10—C9—H9A	110.0
N1—S1—C12	107.71 (8)	O3—C9—H9A	110.0
C8—O3—C9	119.1 (2)	C10—C9—H9B	110.0
C13—N1—C1	122.65 (12)	O3—C9—H9B	110.0
C13—N1—S1	117.57 (11)	H9A—C9—H9B	108.3
C1—N1—S1	118.92 (10)	C9—C10—H10A	109.5
C2—N2—C3	119.21 (16)	C9—C10—H10B	109.5
C2—N2—C7	126.42 (15)	H10A—C10—H10B	109.5
C3—N2—C7	112.45 (15)	C9—C10—H10C	109.5
N1—C1—C11	110.73 (13)	H10A—C10—H10C	109.5
N1—C1—C2	111.57 (13)	H10B—C10—H10C	109.5
C11—C1—C2	109.61 (12)	C1—C11—H11A	109.5
N1—C1—H1	108.3	C1—C11—H11B	109.5

C11—C1—H1	108.3	H11A—C11—H11B	109.5
C2—C1—H1	108.3	C1—C11—H11C	109.5
O1—C2—N2	121.94 (15)	H11A—C11—H11C	109.5
O1—C2—C1	120.33 (15)	H11B—C11—H11C	109.5
N2—C2—C1	117.58 (15)	S1—C12—H12A	109.5
N2—C3—C4	110.73 (15)	S1—C12—H12B	109.5
N2—C3—H3A	109.5	H12A—C12—H12B	109.5
C4—C3—H3A	109.5	S1—C12—H12C	109.5
N2—C3—H3B	109.5	H12A—C12—H12C	109.5
C4—C3—H3B	109.5	H12B—C12—H12C	109.5
H3A—C3—H3B	108.1	C14—C13—C18	119.67 (16)
C3—C4—C5	111.24 (18)	C14—C13—N1	121.20 (15)
C3—C4—H4A	109.4	C18—C13—N1	119.13 (14)
C5—C4—H4A	109.4	C13—C14—C15	119.47 (17)
C3—C4—H4B	109.4	C13—C14—H14	120.3
C5—C4—H4B	109.4	C15—C14—H14	120.3
H4A—C4—H4B	108.0	C16—C15—C14	122.01 (18)
C8—C5—C6	112.44 (17)	C16—C15—H15	119.0
C8—C5—C4	111.67 (19)	C14—C15—H15	119.0
C6—C5—C4	110.22 (16)	C15—C16—C17	117.39 (18)
C8—C5—H5	107.4	C15—C16—C19	120.6 (2)
C6—C5—H5	107.4	C17—C16—C19	122.0 (2)
C4—C5—H5	107.4	C18—C17—C16	121.65 (19)
C7—C6—C5	110.66 (16)	C18—C17—H17	119.2
C7—C6—H6A	109.5	C16—C17—H17	119.2
C5—C6—H6A	109.5	C13—C18—C17	119.76 (17)
C7—C6—H6B	109.5	C13—C18—H18	120.1
C5—C6—H6B	109.5	C17—C18—H18	120.1
H6A—C6—H6B	108.1	C16—C19—H19A	109.5
N2—C7—C6	109.70 (17)	C16—C19—H19B	109.5
N2—C7—H7A	109.7	H19A—C19—H19B	109.5
C6—C7—H7A	109.7	C16—C19—H19C	109.5
N2—C7—H7B	109.7	H19A—C19—H19C	109.5
C6—C7—H7B	109.7	H19B—C19—H19C	109.5
H7A—C7—H7B	108.2		
O5—S1—N1—C13	176.09 (11)	C2—N2—C7—C6	−103.4 (2)
O4—S1—N1—C13	47.92 (13)	C3—N2—C7—C6	60.5 (2)
C12—S1—N1—C13	−67.78 (14)	C5—C6—C7—N2	−57.7 (2)
O5—S1—N1—C1	−14.24 (14)	C9—O3—C8—O2	−2.2 (4)
O4—S1—N1—C1	−142.40 (12)	C9—O3—C8—C5	−179.8 (2)
C12—S1—N1—C1	101.89 (14)	C6—C5—C8—O2	6.3 (4)
C13—N1—C1—C11	−25.36 (19)	C4—C5—C8—O2	130.8 (3)
S1—N1—C1—C11	165.51 (11)	C6—C5—C8—O3	−176.2 (2)
C13—N1—C1—C2	97.02 (16)	C4—C5—C8—O3	−51.7 (3)
S1—N1—C1—C2	−72.11 (15)	C8—O3—C9—C10	−171.3 (3)
C3—N2—C2—O1	3.0 (3)	C1—N1—C13—C14	−76.6 (2)
C7—N2—C2—O1	165.98 (18)	S1—N1—C13—C14	92.68 (17)

C3—N2—C2—C1	178.66 (15)	C1—N1—C13—C18	103.66 (19)
C7—N2—C2—C1	−18.4 (3)	S1—N1—C13—C18	−87.07 (18)
N1—C1—C2—O1	−28.1 (2)	C18—C13—C14—C15	1.3 (3)
C11—C1—C2—O1	94.89 (19)	N1—C13—C14—C15	−178.45 (17)
N1—C1—C2—N2	156.17 (14)	C13—C14—C15—C16	0.7 (3)
C11—C1—C2—N2	−80.81 (18)	C14—C15—C16—C17	−2.1 (3)
C2—N2—C3—C4	106.1 (2)	C14—C15—C16—C19	177.7 (2)
C7—N2—C3—C4	−59.1 (2)	C15—C16—C17—C18	1.7 (3)
N2—C3—C4—C5	54.5 (2)	C19—C16—C17—C18	−178.1 (2)
C3—C4—C5—C8	−178.38 (17)	C14—C13—C18—C17	−1.7 (3)
C3—C4—C5—C6	−52.6 (2)	N1—C13—C18—C17	178.02 (17)
C8—C5—C6—C7	179.54 (18)	C16—C17—C18—C13	0.2 (3)
C4—C5—C6—C7	54.2 (2)		

Hydrogen-bond geometry (Å, º)

D—H⋯A	D—H	H⋯A	D⋯A	D—H⋯A
C12—H12B⋯O1	0.96	2.50	3.210 (2)	130
C12—H12C⋯O4^i	0.96	2.44	3.376 (2)	164
C14—H14⋯O1	0.93	2.48	3.177 (2)	132

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

1-[N-(4-methylphenyl)-N-(methylsulfonyl)alanyl]piperidine-4-carboxylic acid (II)

Crystal data

$C_{17}H_{24}N_2O_5S$	$F(000) = 784$
$M_r = 368.44$	$D_x = 1.344$ Mg m^{-3}
Monoclinic, $P2_1/n$	Mo $K\alpha$ radiation, $\lambda = 0.71073$ Å
$a = 12.1013$ (2) Å	Cell parameters from 8359 reflections
$b = 12.3092$ (2) Å	$\theta = 2.7$–31.5°
$c = 12.4348$ (3) Å	$\mu = 0.21$ mm^{-1}
$\beta = 100.546$ (2)°	$T = 295$ K
$V = 1820.97$ (6) Å^3	Plate, colorless
$Z = 4$	$0.77 \times 0.18 \times 0.11$ mm

Data collection

Oxford Diffraction Xcalibur, Gemini Ultra R diffractometer	$T_{min} = 0.882$, $T_{max} = 0.980$
Radiation source: fine-focus sealed X-ray tube	29518 measured reflections
Graphite monochromator	6284 independent reflections
Detector resolution: 10.3712 pixels mm^{-1}	4779 reflections with $I > 2\sigma(I)$
ω scans	$R_{int} = 0.026$
Absorption correction: analytical [CrysAlisPro (Rigaku OD, 2018), based on expressions derived by Clark & Reid (1995)]	$\theta_{max} = 32.7°$, $\theta_{min} = 2.2°$
	$h = -18 \rightarrow 18$
	$k = -18 \rightarrow 17$
	$l = -17 \rightarrow 18$

Refinement

Refinement on F^2	6284 reflections
Least-squares matrix: full	232 parameters
$R[F^2 > 2\sigma(F^2)] = 0.043$	0 restraints
$wR(F^2) = 0.126$	Primary atom site location: dual
$S = 1.02$	Secondary atom site location: dual

Hydrogen site location: difference Fourier map
H atoms treated by a mixture of independent and constrained refinement

$w = 1/[\sigma^2(F_o^2) + (0.0593P)^2 + 0.3685P]$
where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max} = 0.001$
$\Delta\rho_{max} = 0.29$ e Å^{-3}
$\Delta\rho_{min} = -0.29$ 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 (Å²)

	x	*y*	*z*	$U_{iso}*/U_{eq}$
S1	0.58667 (2)	0.35673 (2)	0.60942 (2)	0.03513 (9)
O1	0.68078 (9)	0.19851 (8)	0.41698 (10)	0.0531 (3)
O2	1.04956 (12)	0.60661 (11)	0.37887 (13)	0.0780 (4)
O3	1.13713 (10)	0.46783 (11)	0.31848 (13)	0.0732 (4)
H3	1.195 (2)	0.509 (2)	0.352 (2)	0.110*
O4	0.50845 (8)	0.37442 (9)	0.68112 (8)	0.0479 (2)
O5	0.65804 (8)	0.44541 (8)	0.59029 (9)	0.0501 (2)
N1	0.51748 (8)	0.32221 (9)	0.48974 (8)	0.0344 (2)
N2	0.73982 (9)	0.33804 (10)	0.32395 (10)	0.0447 (3)
C1	0.56084 (10)	0.35539 (10)	0.39054 (10)	0.0359 (2)
H1	0.580679	0.432597	0.397240	0.043*
C17	0.67424 (14)	0.24889 (13)	0.66359 (13)	0.0555 (4)
H17A	0.726630	0.233560	0.616194	0.083*
H17B	0.629402	0.185582	0.669483	0.083*
H17C	0.714621	0.268508	0.734742	0.083*
C2	0.66661 (10)	0.29079 (11)	0.37903 (10)	0.0392 (3)
C3	0.83897 (11)	0.27729 (13)	0.30503 (13)	0.0488 (3)
H3A	0.832698	0.263103	0.227419	0.059*
H3B	0.842307	0.208002	0.342640	0.059*
C4	0.94599 (11)	0.34095 (12)	0.34608 (11)	0.0427 (3)
H4A	1.009763	0.302094	0.327725	0.051*
H4B	0.957054	0.347251	0.425085	0.051*
C5	0.94003 (11)	0.45455 (12)	0.29524 (11)	0.0438 (3)
H5	0.933185	0.446018	0.215935	0.053*
C6	0.83536 (12)	0.51356 (12)	0.31663 (13)	0.0510 (3)
H6A	0.841595	0.526101	0.394520	0.061*
H6B	0.829392	0.583548	0.280182	0.061*
C7	0.73079 (12)	0.44690 (14)	0.27497 (12)	0.0510 (4)
H7A	0.665534	0.483641	0.292748	0.061*
H7B	0.720557	0.440587	0.196007	0.061*
C8	1.04549 (13)	0.51874 (13)	0.33621 (12)	0.0489 (3)
C9	0.47176 (12)	0.34023 (14)	0.28791 (12)	0.0489 (3)
H9A	0.458064	0.264097	0.275037	0.073*
H9B	0.497692	0.371751	0.226417	0.073*

H9C	0.403409	0.375286	0.297628	0.073*
C10	0.42232 (10)	0.25039 (10)	0.48451 (10)	0.0364 (2)
C11	0.43049 (14)	0.14088 (12)	0.46161 (15)	0.0541 (4)
H11	0.498708	0.111490	0.451688	0.065*
C12	0.33581 (16)	0.07526 (14)	0.45357 (15)	0.0641 (4)
H12	0.341460	0.001934	0.437384	0.077*
C13	0.23387 (13)	0.11605 (14)	0.46894 (12)	0.0553 (4)
C14	0.22767 (12)	0.22528 (14)	0.49295 (13)	0.0519 (4)
H14	0.159834	0.254119	0.504670	0.062*
C15	0.32057 (10)	0.29283 (12)	0.49995 (11)	0.0423 (3)
H15	0.314406	0.366372	0.514958	0.051*
C16	0.13157 (17)	0.0435 (2)	0.45871 (17)	0.0843 (7)
H16A	0.085792	0.066468	0.509939	0.126*
H16B	0.155060	−0.030246	0.473939	0.126*
H16C	0.088916	0.048332	0.385744	0.126*

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
S1	0.03062 (14)	0.03481 (15)	0.03976 (16)	−0.00400 (11)	0.00588 (11)	−0.00067 (11)
O1	0.0514 (6)	0.0410 (5)	0.0722 (7)	0.0074 (4)	0.0248 (5)	0.0058 (5)
O2	0.0771 (9)	0.0640 (8)	0.0943 (10)	−0.0098 (7)	0.0193 (7)	−0.0239 (7)
O3	0.0402 (6)	0.0697 (8)	0.1097 (11)	−0.0137 (5)	0.0139 (6)	−0.0303 (7)
O4	0.0448 (5)	0.0571 (6)	0.0436 (5)	−0.0033 (4)	0.0129 (4)	−0.0075 (4)
O5	0.0436 (5)	0.0481 (5)	0.0563 (6)	−0.0190 (4)	0.0033 (4)	0.0010 (4)
N1	0.0293 (4)	0.0375 (5)	0.0373 (5)	−0.0058 (4)	0.0082 (4)	−0.0016 (4)
N2	0.0353 (5)	0.0490 (6)	0.0530 (6)	0.0044 (5)	0.0171 (5)	0.0037 (5)
C1	0.0321 (5)	0.0382 (6)	0.0387 (6)	−0.0001 (5)	0.0102 (4)	0.0020 (5)
C17	0.0548 (8)	0.0583 (9)	0.0515 (8)	0.0155 (7)	0.0051 (7)	0.0093 (7)
C2	0.0345 (6)	0.0428 (6)	0.0414 (6)	0.0005 (5)	0.0103 (5)	−0.0025 (5)
C3	0.0366 (6)	0.0525 (8)	0.0609 (9)	0.0005 (6)	0.0184 (6)	−0.0099 (7)
C4	0.0360 (6)	0.0486 (7)	0.0450 (7)	0.0029 (5)	0.0114 (5)	−0.0049 (5)
C5	0.0388 (6)	0.0551 (8)	0.0387 (6)	−0.0029 (6)	0.0107 (5)	0.0008 (6)
C6	0.0493 (8)	0.0481 (8)	0.0591 (8)	0.0065 (6)	0.0190 (7)	0.0149 (6)
C7	0.0397 (7)	0.0658 (9)	0.0499 (8)	0.0079 (6)	0.0147 (6)	0.0195 (7)
C8	0.0490 (8)	0.0517 (8)	0.0469 (7)	−0.0062 (6)	0.0107 (6)	−0.0010 (6)
C9	0.0407 (7)	0.0635 (9)	0.0411 (7)	0.0017 (6)	0.0039 (5)	0.0014 (6)
C10	0.0327 (5)	0.0359 (6)	0.0404 (6)	−0.0076 (5)	0.0059 (5)	0.0002 (5)
C11	0.0499 (8)	0.0397 (7)	0.0735 (10)	−0.0066 (6)	0.0131 (7)	−0.0083 (7)
C12	0.0713 (11)	0.0434 (8)	0.0759 (11)	−0.0228 (8)	0.0088 (9)	−0.0078 (7)
C13	0.0513 (8)	0.0660 (9)	0.0443 (7)	−0.0296 (7)	−0.0026 (6)	0.0081 (7)
C14	0.0316 (6)	0.0692 (10)	0.0534 (8)	−0.0112 (6)	0.0038 (5)	0.0085 (7)
C15	0.0320 (6)	0.0447 (7)	0.0500 (7)	−0.0045 (5)	0.0066 (5)	0.0028 (5)
C16	0.0732 (12)	0.1026 (16)	0.0695 (11)	−0.0573 (12)	−0.0065 (9)	0.0100 (11)

Geometric parameters (Å, º)

S1—O4	1.4309 (10)	C5—C8	1.508 (2)
S1—O5	1.4385 (10)	C5—C6	1.5252 (19)
S1—N1	1.6249 (10)	C5—H5	0.9800
S1—C17	1.7543 (15)	C6—C7	1.517 (2)
O1—C2	1.2300 (16)	C6—H6A	0.9700
O2—C8	1.2018 (19)	C6—H6B	0.9700
O3—C8	1.3269 (19)	C7—H7A	0.9700
O3—H3	0.90 (3)	C7—H7B	0.9700
N1—C10	1.4438 (15)	C9—H9A	0.9600
N1—C1	1.4834 (15)	C9—H9B	0.9600
N2—C2	1.3470 (17)	C9—H9C	0.9600
N2—C7	1.4677 (19)	C10—C15	1.3829 (18)
N2—C3	1.4688 (17)	C10—C11	1.3850 (19)
C1—C9	1.5238 (18)	C11—C12	1.390 (2)
C1—C2	1.5356 (17)	C11—H11	0.9300
C1—H1	0.9800	C12—C13	1.377 (3)
C17—H17A	0.9600	C12—H12	0.9300
C17—H17B	0.9600	C13—C14	1.382 (2)
C17—H17C	0.9600	C13—C16	1.513 (2)
C3—C4	1.5198 (19)	C14—C15	1.3882 (18)
C3—H3A	0.9700	C14—H14	0.9300
C3—H3B	0.9700	C15—H15	0.9300
C4—C5	1.531 (2)	C16—H16A	0.9600
C4—H4A	0.9700	C16—H16B	0.9600
C4—H4B	0.9700	C16—H16C	0.9600
O4—S1—O5	118.24 (6)	C7—C6—C5	110.50 (13)
O4—S1—N1	108.76 (6)	C7—C6—H6A	109.5
O5—S1—N1	105.74 (6)	C5—C6—H6A	109.5
O4—S1—C17	107.33 (7)	C7—C6—H6B	109.5
O5—S1—C17	107.40 (7)	C5—C6—H6B	109.5
N1—S1—C17	109.13 (7)	H6A—C6—H6B	108.1
C8—O3—H3	105.0 (16)	N2—C7—C6	110.97 (12)
C10—N1—C1	122.13 (10)	N2—C7—H7A	109.4
C10—N1—S1	118.32 (8)	C6—C7—H7A	109.4
C1—N1—S1	119.22 (8)	N2—C7—H7B	109.4
C2—N2—C7	126.82 (11)	C6—C7—H7B	109.4
C2—N2—C3	119.62 (12)	H7A—C7—H7B	108.0
C7—N2—C3	113.53 (11)	O2—C8—O3	122.04 (15)
N1—C1—C9	111.04 (10)	O2—C8—C5	125.76 (15)
N1—C1—C2	111.26 (10)	O3—C8—C5	112.20 (13)
C9—C1—C2	109.42 (11)	C1—C9—H9A	109.5
N1—C1—H1	108.3	C1—C9—H9B	109.5
C9—C1—H1	108.3	H9A—C9—H9B	109.5
C2—C1—H1	108.3	C1—C9—H9C	109.5
S1—C17—H17A	109.5	H9A—C9—H9C	109.5

S1—C17—H17B	109.5	H9B—C9—H9C	109.5
H17A—C17—H17B	109.5	C15—C10—C11	119.68 (12)
S1—C17—H17C	109.5	C15—C10—N1	119.04 (11)
H17A—C17—H17C	109.5	C11—C10—N1	121.26 (12)
H17B—C17—H17C	109.5	C10—C11—C12	119.43 (15)
O1—C2—N2	122.37 (12)	C10—C11—H11	120.3
O1—C2—C1	120.17 (11)	C12—C11—H11	120.3
N2—C2—C1	117.44 (11)	C13—C12—C11	121.70 (16)
N2—C3—C4	110.77 (12)	C13—C12—H12	119.1
N2—C3—H3A	109.5	C11—C12—H12	119.1
C4—C3—H3A	109.5	C12—C13—C14	118.04 (13)
N2—C3—H3B	109.5	C12—C13—C16	120.88 (18)
C4—C3—H3B	109.5	C14—C13—C16	121.08 (18)
H3A—C3—H3B	108.1	C13—C14—C15	121.38 (15)
C3—C4—C5	111.06 (12)	C13—C14—H14	119.3
C3—C4—H4A	109.4	C15—C14—H14	119.3
C5—C4—H4A	109.4	C10—C15—C14	119.76 (14)
C3—C4—H4B	109.4	C10—C15—H15	120.1
C5—C4—H4B	109.4	C14—C15—H15	120.1
H4A—C4—H4B	108.0	C13—C16—H16A	109.5
C8—C5—C6	111.72 (13)	C13—C16—H16B	109.5
C8—C5—C4	111.47 (12)	H16A—C16—H16B	109.5
C6—C5—C4	109.92 (11)	C13—C16—H16C	109.5
C8—C5—H5	107.9	H16A—C16—H16C	109.5
C6—C5—H5	107.9	H16B—C16—H16C	109.5
C4—C5—H5	107.9		
O4—S1—N1—C10	−39.35 (11)	C8—C5—C6—C7	−179.78 (12)
O5—S1—N1—C10	−167.31 (9)	C4—C5—C6—C7	−55.49 (15)
C17—S1—N1—C10	77.45 (11)	C2—N2—C7—C6	125.15 (15)
O4—S1—N1—C1	147.15 (9)	C3—N2—C7—C6	−56.90 (16)
O5—S1—N1—C1	19.20 (11)	C5—C6—C7—N2	56.02 (16)
C17—S1—N1—C1	−96.05 (11)	C6—C5—C8—O2	−1.4 (2)
C10—N1—C1—C9	20.64 (16)	C4—C5—C8—O2	−124.79 (17)
S1—N1—C1—C9	−166.13 (9)	C6—C5—C8—O3	179.68 (13)
C10—N1—C1—C2	−101.50 (13)	C4—C5—C8—O3	56.26 (17)
S1—N1—C1—C2	71.73 (12)	C1—N1—C10—C15	−106.70 (14)
C7—N2—C2—O1	179.61 (14)	S1—N1—C10—C15	80.01 (14)
C3—N2—C2—O1	1.8 (2)	C1—N1—C10—C11	71.61 (17)
C7—N2—C2—C1	1.4 (2)	S1—N1—C10—C11	−101.69 (14)
C3—N2—C2—C1	−176.43 (12)	C15—C10—C11—C12	0.5 (2)
N1—C1—C2—O1	28.24 (17)	N1—C10—C11—C12	−177.77 (14)
C9—C1—C2—O1	−94.83 (15)	C10—C11—C12—C13	−0.7 (3)
N1—C1—C2—N2	−153.51 (11)	C11—C12—C13—C14	0.0 (3)
C9—C1—C2—N2	83.42 (15)	C11—C12—C13—C16	179.38 (17)
C2—N2—C3—C4	−125.84 (14)	C12—C13—C14—C15	0.9 (2)
C7—N2—C3—C4	56.05 (17)	C16—C13—C14—C15	−178.47 (15)
N2—C3—C4—C5	−54.68 (15)	C11—C10—C15—C14	0.4 (2)

| C3—C4—C5—C8 | 179.52 (11) | N1—C10—C15—C14 | 178.68 (12) |
| C3—C4—C5—C6 | 55.07 (15) | C13—C14—C15—C10 | −1.1 (2) |

Hydrogen-bond geometry (Å, °)

D—H···A	D—H	H···A	D···A	D—H···A
O3—H3···O5ⁱ	0.90 (3)	1.88 (3)	2.7463 (15)	161 (2)
C17—H17*A*···O1	0.96	2.48	3.144 (2)	127
C4—H4*B*···O2ⁱ	0.97	2.52	3.471 (2)	167
C11—H11···O1	0.93	2.56	3.2558 (19)	132

Symmetry code: (i) −*x*+2, −*y*+1, −*z*+1.