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Ethyl 2-({6-amino-2-(benzylsulfanyl)-5-[2-(ethoxycarbonyl)prop-2-enyl]pyrimidin-4-yloxy}methyl)-acrylate

Colin L. Gibson, Judith K. Huggan, Alan R. Kennedy and Colin J. Suckling*

WestCHEM, Department of Pure and Applied Chemistry, University of Strathclyde, Glasgow G1 1XL, Scotland

Correspondence e-mail: a.r.kennedy@strath.ac.uk

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Key indicators

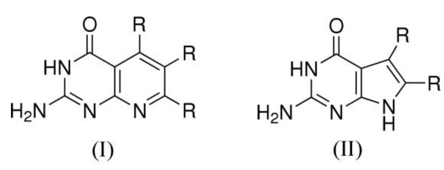
Single-crystal X-ray study
T = 123 K
Mean σ(C–C) = 0.002 Å
Disorder in main residue
R factor = 0.040
wR factor = 0.091
Data-to-parameter ratio = 14.7

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

A new synthesis of carbon–carbon bonds at the 5-position of 2-thiosubstituted pyrimidines *via* the Claisen rearrangement is reported. A direct route towards the synthesis of carbon bonds at the 5-position of 2-thiobenzyl pyrimidines when reacted with ethyl 2-(bromomethyl)acrylate at 328 K delivered the unexpected title compound, $C_{23}H_{27}N_3O_5S$. Structural elucidation showed this compound to have undergone *O*-allylation followed by *ortho*-Claisen rearrangement and subsequent secondary *O*-allylation with excess ethyl 2-(bromomethyl)acrylate. Disorder about the centre of symmetry allows it to exist as two conformers with different orientations of the phenyl group.

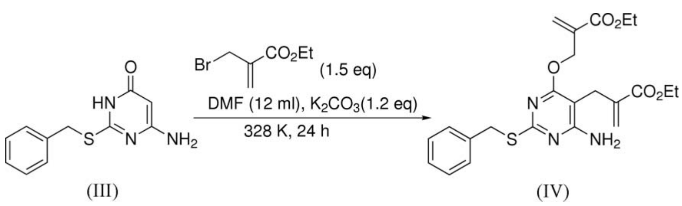
Comment

In order to extend and illustrate our endeavours to develop further the C-5 carbon–carbon bond formation of 2-thiosubstituted pyrimidines (Huggan *et al.*, 2005; La Rosa *et al.*, 2002) we sought to utilize the Claisen rearrangement (Claisen & Tietze, 1925) within the context of designing routes towards the synthesis of pyrido[2,3-*d*]-pyrimidines, (I), and pyrrolo[2,3-*d*]-pyrimidines, (II), as potential inhibitors of enzymes in the folic acid biosynthesis pathway. When an N atom is present at the 2-position, the formation of C—C bonds at the 5-position is relatively straightforward. However, our solid phase route (Gibson *et al.*, 2003) utilizes an S atom at the 2-position and previous attempts at C—C bond formation in solution phase with sulfur at the 2-position have proved unsuccessful.



where R = aryl, allyl or H

Structurally related folic acid antagonists (Taylor *et al.*, 1983) have been shown to possess a range of biological properties, such as antitumour (Grivsky *et al.*, 1980), antibacterial (Matsumoto & Minami, 1975) and antifungal (Heckler *et al.*, 1991) activity, and hence their efficient synthesis, along with the synthesis of other novel compounds, would be advantageous. The commercially available 6-amino-2-mercaptopyrimidin-4(3*H*)-one was reacted with benzyl mercaptan to yield 6-amino-2-(benzylsulfanyl)-4(3*H*)-pyrimidinone, (III) (90%). Compound (III) was then reacted with ethyl 2-(bromomethyl)acrylate to give products, from which the title compound, (IV), was surprisingly isolated and identified.



The molecular structure of (IV) is shown in Fig. 1, and selected bond distances and angles are given in Table 1. As can be seen in Fig. 1, structural elucidation showed this compound to have been formed through *O*-allylation followed by *ortho*-Claisen rearrangement and subsequent secondary *O*-allylation with excess ethyl 2-(bromomethyl)acrylate.

Disorder about a centre of symmetry allows (IV) to exist as two conformers with different orientations of the phenyl group. An alternative solution in the non-centrosymmetric space group *P*1 was rejected as the disorder was still present. The two vinyl groups adopt different geometries. The torsion angles C13—C12—C14—O4 and C7—C6—C8—O2 [−13.1 (2) and 176.8 (2)°, respectively] indicate the *syn* and *anti* relationship of the vinyl and ketone groups and, whilst the presence of O1 allows the C7-centred group to bo coplanar with the heterocyclic ring, the absence of an equivalent atom forces the C13-centred substituent out of this plane. A search of the Cambridge Structural Database (Version 5 with updates to October 2005; Allen, 2002) found 140 similar non-cyclic vinyl fragments and indicated that the geometric parameters of (IV) (Table 1) are all within normal ranges. A similar search showed that the geometry of the hetrocyclic fragment is also in agreement with the known literature.

In the crystal structure of (IV) both the amine H atoms form hydrogen bonds with atoms O4 and N2 of symmetry-related molecules acting as acceptors (Table 2). This results in the formation of hydrogen-bonded chains of molecules.

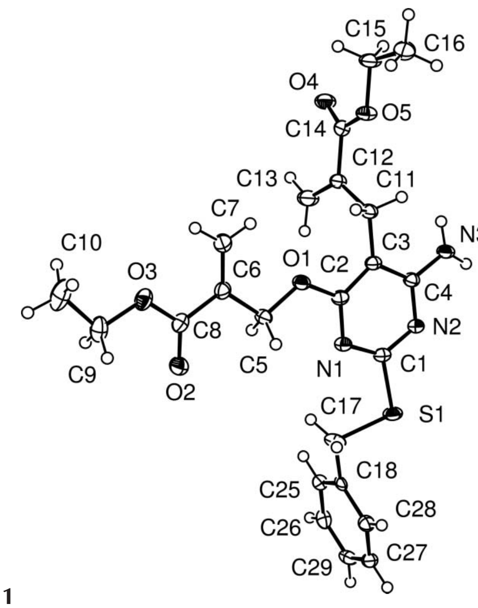


Figure 1
Molecular structure of (IV), with displacement ellipsoids drawn at the 50% probability level. Only one position of the disordered benzyl unit is shown for clarity.

Experimental

Compound (III) (0.69 g, 2.95 mmol) was dissolved in dimethylformamide (12 ml, anhydrous) at room temperature under nitrogen. Ethyl 2-(bromomethyl)acrylate (610 µl, 4.40 mmol, 1.5 equivalents) and K_2CO_3 (0.50 g, 3.62 mmol, 1.2 equivalents) were added and the reaction was stirred in an oil bath at 328 K for 24 h. Once the reaction was complete (by thin-layer chromatography) the mixture was cooled to room temperature and the solvent was evaporated under reduced pressure. The residue was dissolved in dichloromethane, extracted with brine, and then collected, dried ($MgSO_4$) and concentrated under reduced pressure to give a yellow oil. The title compound (IV) was separated by column chromatography using ethyl acetate/hexane (1:1) as eluant, and was isolated as a white solid (0.114 g, 0.25 mmol, 8%). Crystals of (IV) were grown by slow recrystallization from methanol at room temperature (m.p. 383–385 K). IR (KBr): 3407, 3323, 3191, 1707, 1652, 1572, 1555, 1493, 1474, 1444, 1427, 1401, 1376, 1353, 1316, 1280, 1264, 1227, 1158, 1123, 1050, 1027, 855, 776, 708 cm^{-1}; LC–MS: (M+1) = 458.3; ^{1}H NMR (DMSO-d_6): δ 7.41–7.39 [2H, *m*, 2 × C(2)H], 7.31–7.19 [3H, *m*, 2 × C(3)H, 1 × C(1)H], 6.19 (2H, *br s*, NH2), 6.19 [1H, *s*, C(18A)H], 5.99 [1H, *s*, C(12B)H], 5.75 [1H, *s*, C(12A)H], 5.14 [1H, *s*, C(18B)H], 4.98 [2H, *s*, C(16)H2], 4.29 [2H, *s*, C(5)H2], 4.20–4.09 [4H, *d* of *q*, 1 × 2H, *q*, C(20)H, 1 × 2H, *q*, C(14)H], 3.33 [2H, *s*, C(10)H2], 1.26–1.15 [6H, *d* of *t*, 1 × 3H, *t*, C(21)H, 1 × 3H, *t*, C(15)H]; ^{13}C NMR (DMSO-d_6): δ 166.39 (C-19), 166.18 (C-13), 165.44 (C-7), 164.75 (C-6), 163.39 (C-9), 138.66 (C-4), 137.02 (C-17), 136.31 (C-11), 128.77 (C-2), 128.28 (C-3), 126.82 (C-1), 126.08 (C-12), 123.07 (C-18), 90.74 (C-8), 63.49 (C-16), 60.49 (C-20), 60.34 (C-14), 33.83 (C-5), 24.39 (C-10), 14.04 (C-15), 13.91 (C-21).

Crystal data

$C_{23}H_{27}N_3O_5S$	Z = 2
M_r = 457.54	D_x = 1.344 Mg m^{-3}
Triclinic, $P\bar{1}$	Mo $K\alpha$ radiation
a = 7.3668 (2) Å	Cell parameters from 5141 reflections
b = 11.5842 (3) Å	θ = 1.0–27.5°
c = 14.5700 (4) Å	μ = 0.18 mm^{-1}
α = 111.692 (2)°	T = 123 (2) K
β = 99.520 (2)°	Prism, colourless
γ = 93.076 (2)°	0.45 × 0.15 × 0.10 mm
V = 1130.44 (5) Å^3	

Data collection

Nonius KappaCCD diffractometer	R_{int} = 0.044
φ and ω scans	θ_{max} = 27.5°
Absorption correction: none	h = −9 → 9
25883 measured reflections	k = −15 → 13
5178 independent reflections	l = −18 → 18
3777 reflections with $I > 2\sigma(I)$	

Refinement

Refinement on F^2	$w = 1/[\sigma^2(F_o^2) + (0.0315P)^2 + 0.4141P]$ where $P = (F_o^2 + 2F_c^2)/3$
$R[F^2 > 2\sigma(F^2)]$ = 0.040	$(\Delta/\sigma)_{max}$ = 0.001
$wR(F^2)$ = 0.091	$\Delta\rho_{max}$ = 0.25 e Å^{-3}
S = 1.04	$\Delta\rho_{min}$ = −0.27 e Å^{-3}
5178 reflections	
353 parameters	
H atoms treated by a mixture of independent and constrained refinement	

Table 1
Selected geometric parameters (Å, °).

O2—C8	1.2094 (18)	C2—C3	1.386 (2)
O4—C14	1.2153 (19)	C3—C4	1.407 (2)
N1—C1	1.3341 (19)	C6—C7	1.313 (2)
N1—C2	1.3424 (18)	C6—C8	1.484 (2)
N2—C1	1.3317 (19)	C12—C13	1.318 (2)
N2—C4	1.3611 (18)	C12—C14	1.496 (2)
N3—C4	1.347 (2)		
C1—N1—C2	113.72 (13)	N1—C2—C3	125.47 (14)
C1—N2—C4	116.39 (13)	C2—C3—C4	114.93 (13)
N2—C1—N1	128.05 (13)	N2—C4—C3	121.35 (14)
C5—O1—C2—N1	−5.5 (2)	C13—C12—C14—O4	−13.1 (2)
C7—C6—C8—O2	176.82 (19)	C1—S1—C17—C18	160.97 (14)
C4—C3—C11—C12	96.68 (18)	C1—S1—C17—C19	−85.22 (17)

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

D—H···A	D—H	H···A	D···A	D—H···A
N3—H1N···O4^{i}	0.872 (18)	2.133 (19)	2.9832 (18)	164.8 (16)
N3—H2N···N2^{ii}	0.883 (19)	2.20 (2)	3.0868 (19)	176.8 (17)

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

After several trial calculations, the disordered CH_2Ph group was modelled over two sites each with occupancy 0.5. The methylene H atoms of this group were found in a difference synthesis and then constrained to ride on the parent C atom. The amine H atoms were refined freely, but all other H atoms were positioned geometrically at distances of 0.95 (CH and vinyl CH_2), 0.98 (CH_3) or 0.99 Å (CH_2) from the parent C atoms; a riding model was used [$U_{iso}(H) = 1.5U_{eq}(C)$ for CH_3 and $U_{iso}(H) = 1.2U_{eq}(C)$ for all others] during refinement.

Data collection: *COLLECT* (Hooft, 1998) and *DENZO* (Otwinowski & Minor, 1997); cell refinement: *DENZO*; data reduction: *DENZO*; program(s) used to solve structure: *SHELXS97* (Sheldrick, 1997); program(s) used to refine structure: *SHELXL97* (Sheldrick, 1997); molecular graphics: *ORTEPII* (Johnson, 1976); software used to prepare material for publication: *SHELXL97*.

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supporting information

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The molecular structure of (IV) is shown in Fig. 1, and selected bond distances and angles are given in Table 1. As can be seen in Fig. 1, structural elucidation showed this compound to have been formed through *O*-allylation followed by *ortho* Claisen rearrangement and subsequent secondary *O*-allylation with excess ethyl 2-(bromomethyl)acrylate.

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In the crystal structure of (IV) both the amine H atoms form hydrogen bonds with atoms O4 and N2, acting as acceptors, of symmetry-related molecules (Table 2). This results in the formation of hydrogen-bonded chains of molecules.

S2. Experimental

Compound (III) (0.69 g, 2.95 mmol) was dissolved in dimethylformamide (12 ml, anhydrous) at room temperature under nitrogen. Ethyl 2-(bromomethyl)acrylate (610 μl, 4.40 mmol, 1.5 equivalents) and K_2CO_3 (0.50 g, 3.62 mmol, 1.2 equivalents) were added and the reaction was stirred in an oil bath at 328 K for 24 h. Once the reaction was complete (by thin-layer chromatography) the mixture was cooled to room temperature and the solvent was evaporated under reduced pressure. The residue was dissolved in dichloromethane, extracted with brine, and then collected, dried ($MgSO_4$) and concentrated under reduced pressure to give a yellow oil. The title compound (IV) was separated by column chromatography using ethyl acetate/hexane (1:1) as eluant and was isolated as a white solid (0.114 g, 0.25 mmol, 8%). Crystals of (IV) were grown by slow recrystallization from methanol at room temperature (m.p. 383–385 K). IR (KBr): 3407, 3323, 3191, 1707, 1652, 1572, 1555, 1493, 1474, 1444, 1427, 1401, 1376, 1353, 1316, 1280, 1264, 1227, 1158, 1123, 1050, 1027, 855, 776, 708 cm^{-1}; LC–MS: (*M*+1) = 458.3; ^{1}H NMR (DMSO-d_6): δ 7.41–7.39 [2H, *m*, 2 × C(2)H], 7.31–7.19 [3H, *m*, 2 × C(3)H, 1 × C(1)H], 6.19 (2*H*, *br s*, NH2), 6.19 [1H, *s*, C(18 A)H], 5.99 [1H, *s*, C(12B)H], 5.75 [1H, *s*, C(12 A)H], 5.14 [1H, *s*, C(18B)H], 4.98 [2H, *s*, C(16)H2], 4.29 [2H, *s*, C(5)H2], 4.20–4.09 [4H, *d* of *q*, 1 × 2H, *q*, C(20)H, 1 × 2H, q, C(14)H], 3.33 [2H, *s*, C(10)H2], 1.26–1.15 [6H, *d* of *t*, 1 × 3H, *t*, C(21)H, 1 × 3H, t, C(15)H]; ^{13}C NMR (DMSO-d_6): δ 166.39 (C-19), 166.18 (C-13), 165.44 (C-7), 164.75 (C-6), 163.39 (C-9), 138.66 (C-4), 137.02 (C-17), 136.31 (C-11), 128.77 (C-2), 128.28 (C-3), 126.82 (C-1), 126.08 (C-12), 123.07 (C-18), 90.74 (C-8), 63.49 (C-16), 60.49 (C-20), 60.34 (C-14), 33.83 (C-5), 24.39 (C-10), 14.04 (C-15), 13.91 (C-21).

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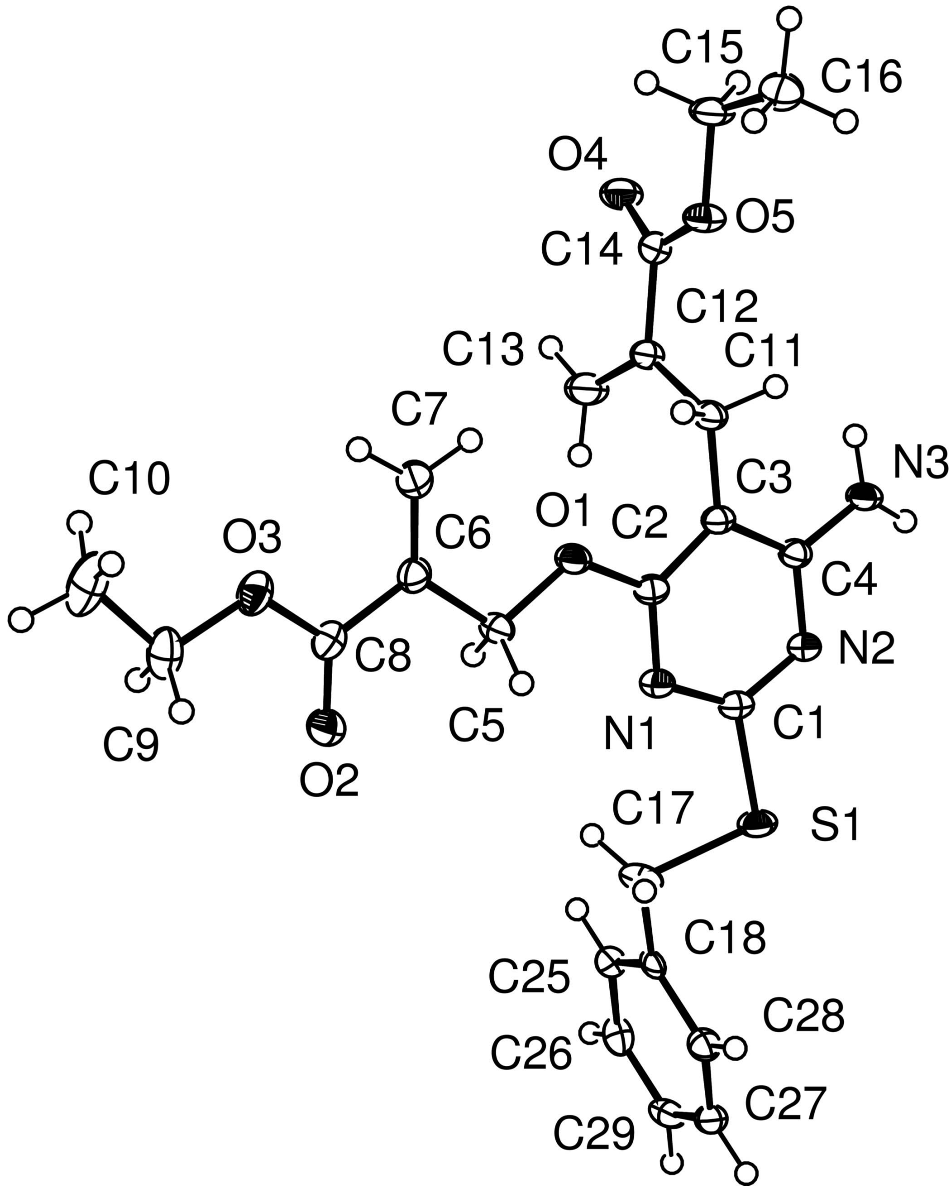
After several trial calculations, the disordered CH_2Ph group was modelled over two sites each with occupancy 0.5. The methylene H atoms of this group were found in a difference synthesis and then constrained to ride on the parent C atom. The amine H atoms were refined freely, but all other H atoms were positioned geometrically at distances of 0.95 (CH and vinyl CH_2), 0.98 (CH_3) or 0.99 Å (CH_2) from the parent C atoms; a riding model was used [U_{iso}(H) = 1.5U_{eq}(C) for CH_3 and U_{iso}(H) = 1.2U_{eq}(C) for all others] during refinement.



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α = 111.692 (2)°
β = 99.520 (2)°
γ = 93.076 (2)°
V = 1130.44 (5) Å^3
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Cell parameters from 5141 reflections
θ = 1.0–27.5°

μ = 0.18 mm^{-1}
T = 123 K

Prism, colourless
0.45 × 0.15 × 0.10 mm

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Nonius KappaCCD diffractometer
Radiation source: fine-focus sealed tube
Graphite monochromator
φ and ω scans
25883 measured reflections
5178 independent reflections

3777 reflections with $I > 2\sigma(I)$
R_{int} = 0.044
θ_{max} = 27.5°, θ_{min} = 1.5°
h = −9→9
k = −15→13
l = −18→18

Refinement

Refinement on F^2
Least-squares matrix: full
$R[F^2 > 2\sigma(F^2)]$ = 0.040
$wR(F^2)$ = 0.091
S = 1.04
5178 reflections
353 parameters
0 restraints
Primary atom site location: structure-invariant direct methods

Secondary atom site location: difference Fourier map
Hydrogen site location: inferred from neighbouring sites
H atoms treated by a mixture of independent and constrained refinement
$w = 1/[\sigma^2(F_o^2) + (0.0315P)^2 + 0.4141P]$
where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{max}$ = 0.001
$\Delta\rho_{max}$ = 0.25 e Å^{-3}
$\Delta\rho_{min}$ = −0.27 e Å^{-3}

Special details

Experimental. Refinement in non-c *sp*. gr. P1 did NOT give a less disordered structure.

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

Refinement. Refinement of F^2 against ALL reflections. The weighted R-factor wR and goodness 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 threshold expression of $F^2 > \sigma(F^2)$ is used only for calculating R-factors(gt) *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 (Å^2)

	x	y	z	U_{iso}*/U_{eq}	Occ. (<1)
S1	0.20722 (6)	0.26789 (4)	0.25469 (3)	0.02608 (12)	
O1	0.12101 (15)	−0.08791 (9)	0.36607 (8)	0.0232 (2)	
O2	0.39994 (17)	0.10122 (11)	0.66437 (9)	0.0312 (3)	
O3	0.32728 (16)	−0.06824 (11)	0.69722 (9)	0.0294 (3)	
O4	0.08880 (16)	−0.57502 (10)	0.08081 (9)	0.0311 (3)	
O5	−0.18394 (15)	−0.50840 (9)	0.11282 (8)	0.0260 (3)	
N1	0.16820 (17)	0.07612 (11)	0.31459 (10)	0.0203 (3)	
N2	0.06085 (17)	0.04205 (11)	0.14103 (10)	0.0204 (3)	
N3	−0.0786 (2)	−0.14863 (13)	0.02310 (11)	0.0248 (3)	
C1	0.1387 (2)	0.11156 (13)	0.23660 (12)	0.0196 (3)	
C2	0.1026 (2)	−0.04373 (14)	0.29136 (11)	0.0195 (3)	
C3	0.0150 (2)	−0.12776 (13)	0.19635 (11)	0.0194 (3)	
C4	0.0002 (2)	−0.07975 (13)	0.12009 (12)	0.0199 (3)	

C5	0.2241 (2)	−0.00740 (14)	0.46359 (11)	0.0209 (3)	
H5A	0.1626	0.0684	0.4912	0.025*	
H5B	0.3511	0.0189	0.4588	0.025*	
C6	0.2317 (2)	−0.07954 (15)	0.53091 (12)	0.0230 (3)	
C7	0.1612 (3)	−0.19702 (17)	0.50120 (16)	0.0488 (6)	
H7A	0.1706	−0.2370	0.5479	0.059*	
H7B	0.1008	−0.2420	0.4330	0.059*	
C8	0.3274 (2)	−0.00539 (15)	0.63655 (12)	0.0224 (3)	
C9	0.4260 (3)	−0.00267 (18)	0.80075 (13)	0.0335 (4)	
H9A	0.3692	0.0735	0.8341	0.040*	
H9B	0.5575	0.0225	0.8025	0.040*	
C10	0.4129 (3)	−0.0912 (2)	0.85374 (16)	0.0488 (6)	
H10A	0.2841	−0.1060	0.8600	0.073*	
H10B	0.4925	−0.0545	0.9210	0.073*	
H10C	0.4536	−0.1707	0.8148	0.073*	
C11	−0.0638 (2)	−0.25956 (13)	0.17688 (12)	0.0216 (3)	
H11A	−0.1669	−0.2879	0.1175	0.026*	
H11B	−0.1166	−0.2581	0.2355	0.026*	
C12	0.0730 (2)	−0.35458 (14)	0.15849 (12)	0.0217 (3)	
C13	0.2550 (2)	−0.32689 (16)	0.18107 (14)	0.0345 (4)	
H13A	0.3320	−0.3920	0.1686	0.041*	
H13B	0.3091	−0.2418	0.2099	0.041*	
C14	−0.0029 (2)	−0.49037 (14)	0.11337 (12)	0.0229 (3)	
C15	−0.2680 (2)	−0.63874 (15)	0.07418 (14)	0.0303 (4)	
H15A	−0.2157	−0.6802	0.1193	0.036*	
H15B	−0.2433	−0.6850	0.0061	0.036*	
C16	−0.4726 (2)	−0.63746 (17)	0.06984 (15)	0.0358 (4)	
H16A	−0.4951	−0.5925	0.1377	0.054*	
H16B	−0.5341	−0.7237	0.0433	0.054*	
H16C	−0.5222	−0.5954	0.0256	0.054*	
C17	0.3703 (2)	0.32554 (15)	0.37483 (12)	0.0269 (4)	
H17A	0.4563	0.2621	0.3767	0.032*	
H17B	0.2837	0.3432	0.4141	0.032*	0.50
H17C	0.4503	0.3784	0.3757	0.032*	0.50
C18	0.4761 (4)	0.4401 (3)	0.3713 (2)	0.0186 (6)	0.50
C19	0.3027 (4)	0.3770 (3)	0.4741 (2)	0.0206 (7)	0.50
C20	0.1845 (4)	0.4685 (3)	0.4844 (2)	0.0249 (7)	0.50
H20	0.1484	0.4946	0.4302	0.030*	0.50
C21	0.1187 (5)	0.5222 (3)	0.5721 (3)	0.0284 (8)	0.50
H21	0.0365	0.5838	0.5774	0.034*	0.50
C22	0.1722 (8)	0.4866 (7)	0.6525 (6)	0.0311 (15)	0.50
H22	0.1264	0.5237	0.7127	0.037*	0.50
C23	0.2909 (12)	0.3982 (6)	0.6455 (7)	0.0270 (18)	0.50
H23	0.3295	0.3749	0.7011	0.032*	0.50
C24	0.3553 (5)	0.3419 (3)	0.5556 (3)	0.0270 (7)	0.50
H24	0.4357	0.2793	0.5502	0.032*	0.50
C25	0.6559 (4)	0.4328 (3)	0.3536 (2)	0.0232 (7)	0.50
H25	0.7087	0.3570	0.3431	0.028*	0.50

C26	0.7586 (8)	0.5350 (8)	0.3512 (5)	0.0265 (15)	0.50
H26	0.8814	0.5292	0.3393	0.032*	0.50
C27	0.5038 (5)	0.6542 (3)	0.3830 (2)	0.0234 (7)	0.50
H27	0.4514	0.7299	0.3926	0.028*	0.50
C28	0.4009 (4)	0.5524 (3)	0.3860 (2)	0.0221 (7)	0.50
H28	0.2783	0.5590	0.3981	0.027*	0.50
C29	0.6825 (15)	0.6457 (6)	0.3661 (7)	0.0239 (15)	0.50
H29	0.7533	0.7158	0.3646	0.029*	0.50
H1N	−0.092 (2)	−0.2301 (18)	0.0018 (13)	0.030 (5)*	
H2N	−0.072 (2)	−0.1151 (17)	−0.0219 (14)	0.035 (5)*	

Atomic displacement parameters (Å²)

	U^{11}	U^{22}	U^{33}	U^{12}	U^{13}	U^{23}
S1	0.0351 (2)	0.01458 (19)	0.0273 (2)	−0.00139 (16)	0.00509 (18)	0.00771 (17)
O1	0.0308 (6)	0.0174 (5)	0.0194 (6)	−0.0028 (5)	0.0024 (5)	0.0066 (5)
O2	0.0386 (7)	0.0261 (6)	0.0263 (7)	−0.0032 (5)	−0.0007 (5)	0.0111 (5)
O3	0.0319 (7)	0.0344 (7)	0.0296 (7)	0.0050 (5)	0.0060 (5)	0.0209 (6)
O4	0.0286 (7)	0.0180 (6)	0.0398 (7)	0.0020 (5)	0.0037 (5)	0.0049 (5)
O5	0.0263 (6)	0.0163 (5)	0.0322 (7)	−0.0027 (5)	0.0064 (5)	0.0063 (5)
N1	0.0226 (7)	0.0158 (6)	0.0212 (7)	−0.0001 (5)	0.0048 (5)	0.0060 (6)
N2	0.0222 (7)	0.0154 (6)	0.0220 (7)	0.0007 (5)	0.0029 (6)	0.0062 (6)
N3	0.0340 (8)	0.0153 (7)	0.0219 (8)	−0.0033 (6)	0.0008 (6)	0.0062 (6)
C1	0.0183 (8)	0.0152 (7)	0.0248 (9)	0.0016 (6)	0.0070 (7)	0.0061 (7)
C2	0.0197 (8)	0.0170 (7)	0.0223 (8)	0.0010 (6)	0.0063 (6)	0.0075 (7)
C3	0.0195 (8)	0.0153 (7)	0.0228 (8)	0.0006 (6)	0.0043 (6)	0.0068 (7)
C4	0.0174 (8)	0.0166 (7)	0.0235 (8)	0.0004 (6)	0.0030 (6)	0.0060 (7)
C5	0.0216 (8)	0.0181 (7)	0.0201 (8)	−0.0016 (6)	0.0028 (6)	0.0051 (7)
C6	0.0187 (8)	0.0231 (8)	0.0286 (9)	0.0024 (6)	0.0015 (7)	0.0127 (7)
C7	0.0598 (14)	0.0305 (10)	0.0489 (13)	−0.0166 (9)	−0.0254 (10)	0.0252 (10)
C8	0.0186 (8)	0.0265 (9)	0.0271 (9)	0.0050 (7)	0.0067 (7)	0.0149 (7)
C9	0.0342 (10)	0.0468 (11)	0.0250 (10)	0.0140 (9)	0.0073 (8)	0.0182 (9)
C10	0.0592 (14)	0.0665 (14)	0.0414 (12)	0.0312 (12)	0.0206 (11)	0.0366 (11)
C11	0.0236 (8)	0.0173 (7)	0.0222 (8)	−0.0026 (6)	0.0030 (7)	0.0068 (7)
C12	0.0260 (9)	0.0163 (7)	0.0203 (8)	−0.0010 (6)	0.0016 (7)	0.0058 (6)
C13	0.0274 (10)	0.0199 (8)	0.0479 (12)	0.0012 (7)	0.0011 (8)	0.0065 (8)
C14	0.0253 (8)	0.0204 (8)	0.0217 (8)	−0.0002 (7)	0.0004 (7)	0.0087 (7)
C15	0.0326 (10)	0.0159 (8)	0.0372 (10)	−0.0053 (7)	0.0042 (8)	0.0065 (7)
C16	0.0305 (10)	0.0305 (9)	0.0461 (12)	−0.0052 (8)	0.0010 (9)	0.0182 (9)
C17	0.0308 (9)	0.0184 (8)	0.0258 (9)	−0.0060 (7)	0.0074 (7)	0.0025 (7)
C18	0.0257 (16)	0.0178 (15)	0.0098 (14)	−0.0041 (12)	−0.0032 (12)	0.0061 (12)
C19	0.0170 (15)	0.0149 (14)	0.0249 (17)	−0.0045 (12)	0.0003 (13)	0.0046 (13)
C20	0.0272 (18)	0.0212 (16)	0.0239 (17)	−0.0001 (14)	0.0018 (14)	0.0079 (14)
C21	0.0301 (19)	0.0216 (16)	0.032 (2)	0.0027 (14)	0.0091 (15)	0.0076 (15)
C22	0.037 (4)	0.026 (3)	0.028 (2)	−0.004 (3)	0.013 (3)	0.005 (2)
C23	0.025 (4)	0.032 (5)	0.021 (3)	−0.006 (4)	0.000 (2)	0.010 (5)
C24	0.0248 (18)	0.0201 (16)	0.033 (2)	−0.0002 (13)	0.0006 (15)	0.0091 (15)
C25	0.0266 (17)	0.0201 (16)	0.0203 (17)	0.0014 (13)	−0.0001 (13)	0.0070 (13)

C26	0.024 (4)	0.034 (4)	0.021 (2)	0.002 (3)	0.001 (3)	0.012 (3)
C27	0.0332 (19)	0.0173 (15)	0.0184 (16)	0.0017 (14)	0.0021 (14)	0.0068 (13)
C28	0.0230 (16)	0.0218 (16)	0.0215 (17)	−0.0015 (13)	0.0027 (13)	0.0096 (14)
C29	0.032 (3)	0.019 (3)	0.017 (3)	−0.006 (3)	0.004 (2)	0.003 (3)

Geometric parameters (Å, º)

S1—C1	1.7632 (15)	C13—H13A	0.9500
S1—C17	1.8187 (17)	C13—H13B	0.9500
O1—C2	1.3549 (18)	C15—C16	1.499 (2)
O1—C5	1.4327 (18)	C15—H15A	0.9900
O2—C8	1.2094 (18)	C15—H15B	0.9900
O3—C8	1.3369 (18)	C16—H16A	0.9800
O3—C9	1.453 (2)	C16—H16B	0.9800
O4—C14	1.2153 (19)	C16—H16C	0.9800
O5—C14	1.3367 (19)	C17—C18	1.524 (3)
O5—C15	1.4615 (18)	C17—C19	1.525 (3)
N1—C1	1.3341 (19)	C17—H17A	1.0000
N1—C2	1.3424 (18)	C17—H17B	0.9080
N2—C1	1.3317 (19)	C17—H17C	0.8220
N2—C4	1.3611 (18)	C18—C25	1.392 (4)
N3—C4	1.347 (2)	C18—C28	1.399 (4)
N3—H1N	0.872 (18)	C18—H17C	0.7576
N3—H2N	0.883 (19)	C19—C20	1.389 (4)
C2—C3	1.386 (2)	C19—C24	1.396 (5)
C3—C4	1.407 (2)	C19—H17B	0.7979
C3—C11	1.510 (2)	C20—C21	1.380 (5)
C5—C6	1.502 (2)	C20—H20	0.9500
C5—H5A	0.9900	C21—C22	1.385 (9)
C5—H5B	0.9900	C21—H21	0.9500
C6—C7	1.313 (2)	C22—C23	1.369 (8)
C6—C8	1.484 (2)	C22—H22	0.9500
C7—H7A	0.9500	C23—C24	1.405 (9)
C7—H7B	0.9500	C23—H23	0.9500
C9—C10	1.502 (3)	C24—H24	0.9500
C9—H9A	0.9900	C25—C26	1.386 (9)
C9—H9B	0.9900	C25—H25	0.9500
C10—H10A	0.9800	C26—C29	1.384 (7)
C10—H10B	0.9800	C26—H26	0.9500
C10—H10C	0.9800	C27—C29	1.381 (11)
C11—C12	1.513 (2)	C27—C28	1.385 (4)
C11—H11A	0.9900	C27—H27	0.9500
C11—H11B	0.9900	C28—H28	0.9500
C12—C13	1.318 (2)	C29—H29	0.9500
C12—C14	1.496 (2)		
C1—S1—C17	102.74 (7)	O5—C15—H15A	110.3
C2—O1—C5	118.00 (11)	C16—C15—H15A	110.3

C8—O3—C9	116.27 (13)	O5—C15—H15B	110.3
C14—O5—C15	116.03 (12)	C16—C15—H15B	110.3
C1—N1—C2	113.72 (13)	H15A—C15—H15B	108.5
C1—N2—C4	116.39 (13)	C15—C16—H16A	109.5
C4—N3—H1N	119.5 (12)	C15—C16—H16B	109.5
C4—N3—H2N	118.1 (12)	H16A—C16—H16B	109.5
H1N—N3—H2N	117.4 (17)	C15—C16—H16C	109.5
N2—C1—N1	128.05 (13)	H16A—C16—H16C	109.5
N2—C1—S1	112.15 (11)	H16B—C16—H16C	109.5
N1—C1—S1	119.80 (11)	C18—C17—C19	103.65 (18)
N1—C2—O1	118.31 (13)	C18—C17—S1	101.61 (14)
N1—C2—C3	125.47 (14)	C19—C17—S1	120.89 (15)
O1—C2—C3	116.22 (13)	C18—C17—H17A	110.0
C2—C3—C4	114.93 (13)	C19—C17—H17A	109.8
C2—C3—C11	122.49 (14)	S1—C17—H17A	110.0
C4—C3—C11	122.56 (13)	C18—C17—H17B	114.5
N3—C4—N2	115.60 (14)	S1—C17—H17B	96.2
N3—C4—C3	123.02 (14)	H17A—C17—H17B	121.5
N2—C4—C3	121.35 (14)	C19—C17—H17C	107.7
O1—C5—C6	107.65 (12)	S1—C17—H17C	109.8
O1—C5—H5A	110.2	H17A—C17—H17C	95.6
C6—C5—H5A	110.2	H17B—C17—H17C	123.7
O1—C5—H5B	110.2	C25—C18—C28	118.7 (3)
C6—C5—H5B	110.2	C25—C18—C17	118.5 (2)
H5A—C5—H5B	108.5	C28—C18—C17	122.8 (3)
C7—C6—C8	121.96 (16)	C25—C18—H17C	103.5
C7—C6—C5	124.34 (16)	C28—C18—H17C	137.4
C8—C6—C5	113.70 (13)	C20—C19—C24	118.0 (3)
C6—C7—H7A	120.0	C20—C19—C17	117.0 (3)
C6—C7—H7B	120.0	C24—C19—C17	124.9 (3)
H7A—C7—H7B	120.0	C20—C19—H17B	100.1
O2—C8—O3	123.51 (15)	C24—C19—H17B	136.2
O2—C8—C6	122.92 (14)	C21—C20—C19	121.2 (3)
O3—C8—C6	113.56 (13)	C21—C20—H20	119.4
O3—C9—C10	107.21 (16)	C19—C20—H20	119.4
O3—C9—H9A	110.3	C20—C21—C22	120.2 (4)
C10—C9—H9A	110.3	C20—C21—H21	119.9
O3—C9—H9B	110.3	C22—C21—H21	119.9
C10—C9—H9B	110.3	C23—C22—C21	120.2 (7)
H9A—C9—H9B	108.5	C23—C22—H22	119.9
C9—C10—H10A	109.5	C21—C22—H22	119.9
C9—C10—H10B	109.5	C22—C23—C24	119.6 (7)
H10A—C10—H10B	109.5	C22—C23—H23	120.2
C9—C10—H10C	109.5	C24—C23—H23	120.2
H10A—C10—H10C	109.5	C19—C24—C23	120.8 (4)
H10B—C10—H10C	109.5	C19—C24—H24	119.6
C3—C11—C12	115.26 (13)	C23—C24—H24	119.6
C3—C11—H11A	108.5	C26—C25—C18	120.6 (4)

C12—C11—H11A	108.5	C26—C25—H25	119.7
C3—C11—H11B	108.5	C18—C25—H25	119.7
C12—C11—H11B	108.5	C29—C26—C25	120.1 (7)
H11A—C11—H11B	107.5	C29—C26—H26	120.0
C13—C12—C14	117.25 (15)	C25—C26—H26	120.0
C13—C12—C11	124.92 (14)	C29—C27—C28	120.1 (4)
C14—C12—C11	117.82 (13)	C29—C27—H27	119.9
C12—C13—H13A	120.0	C28—C27—H27	119.9
C12—C13—H13B	120.0	C27—C28—C18	120.5 (3)
H13A—C13—H13B	120.0	C27—C28—H28	119.8
O4—C14—O5	123.58 (14)	C18—C28—H28	119.8
O4—C14—C12	124.08 (15)	C27—C29—C26	120.0 (8)
O5—C14—C12	112.34 (13)	C27—C29—H29	120.0
O5—C15—C16	107.13 (13)	C26—C29—H29	120.0

C4—N2—C1—N1	1.5 (2)	C15—O5—C14—O4	2.7 (2)
C4—N2—C1—S1	−178.81 (11)	C15—O5—C14—C12	−177.32 (13)
C2—N1—C1—N2	−2.9 (2)	C13—C12—C14—O4	−13.1 (2)
C2—N1—C1—S1	177.38 (11)	C11—C12—C14—O4	168.24 (15)
C17—S1—C1—N2	−162.15 (11)	C13—C12—C14—O5	166.93 (15)
C17—S1—C1—N1	17.62 (14)	C11—C12—C14—O5	−11.8 (2)
C1—N1—C2—O1	−178.17 (13)	C14—O5—C15—C16	−174.00 (14)
C1—N1—C2—C3	1.3 (2)	C1—S1—C17—C18	160.97 (14)
C5—O1—C2—N1	−5.5 (2)	C1—S1—C17—C19	−85.22 (17)
C5—O1—C2—C3	174.97 (13)	C19—C17—C18—C25	128.3 (3)
N1—C2—C3—C4	1.3 (2)	S1—C17—C18—C25	−105.6 (2)
O1—C2—C3—C4	−179.17 (13)	C19—C17—C18—C28	−51.1 (3)
N1—C2—C3—C11	−176.88 (14)	S1—C17—C18—C28	75.0 (3)
O1—C2—C3—C11	2.6 (2)	C18—C17—C19—C20	61.2 (3)
C1—N2—C4—N3	179.86 (13)	S1—C17—C19—C20	−51.6 (3)
C1—N2—C4—C3	1.7 (2)	C18—C17—C19—C24	−116.7 (3)
C2—C3—C4—N3	179.07 (14)	S1—C17—C19—C24	130.6 (3)
C11—C3—C4—N3	−2.7 (2)	C24—C19—C20—C21	−0.9 (5)
C2—C3—C4—N2	−2.9 (2)	C17—C19—C20—C21	−178.9 (3)
C11—C3—C4—N2	175.33 (14)	C19—C20—C21—C22	1.0 (6)
C2—O1—C5—C6	−177.40 (12)	C20—C21—C22—C23	0.1 (9)
O1—C5—C6—C7	2.6 (2)	C21—C22—C23—C24	−1.2 (11)
O1—C5—C6—C8	−177.24 (12)	C20—C19—C24—C23	−0.3 (6)
C9—O3—C8—O2	−1.9 (2)	C17—C19—C24—C23	177.6 (4)
C9—O3—C8—C6	177.35 (13)	C22—C23—C24—C19	1.3 (9)
C7—C6—C8—O2	176.82 (19)	C28—C18—C25—C26	0.4 (5)
C5—C6—C8—O2	−3.3 (2)	C17—C18—C25—C26	−179.1 (4)
C7—C6—C8—O3	−2.4 (2)	C18—C25—C26—C29	−0.3 (9)
C5—C6—C8—O3	177.41 (13)	C29—C27—C28—C18	−0.4 (6)
C8—O3—C9—C10	−178.31 (14)	C25—C18—C28—C27	−0.1 (4)
C2—C3—C11—C12	−85.26 (19)	C17—C18—C28—C27	179.3 (3)
C4—C3—C11—C12	96.68 (18)	C28—C27—C29—C26	0.5 (11)
C3—C11—C12—C13	16.7 (2)	C25—C26—C29—C27	−0.2 (12)

C3—C11—C12—C14	−164.74 (14)

Hydrogen-bond geometry (Å, º)

D—H···*A*	*D*—H	H···*A*	*D*···*A*	*D*—H···*A*
N3—H1*N*···O4^{i}	0.872 (18)	2.133 (19)	2.9832 (18)	164.8 (16)
N3—H2*N*···N2^{ii}	0.883 (19)	2.20 (2)	3.0868 (19)	176.8 (17)

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