

# Crystal structure of (*R*)-6'-bromo-3,3-dimethyl-3',4'-dihydro-2'*H*-spiro[cyclohexane-1,3'-1,2,4-benzothiadiazine] 1',1'-dioxide

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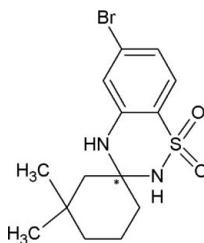
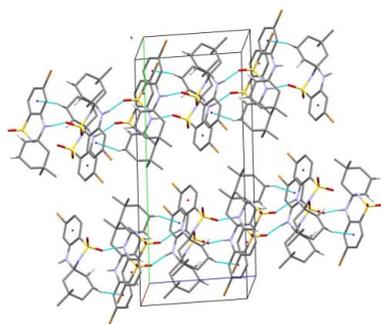
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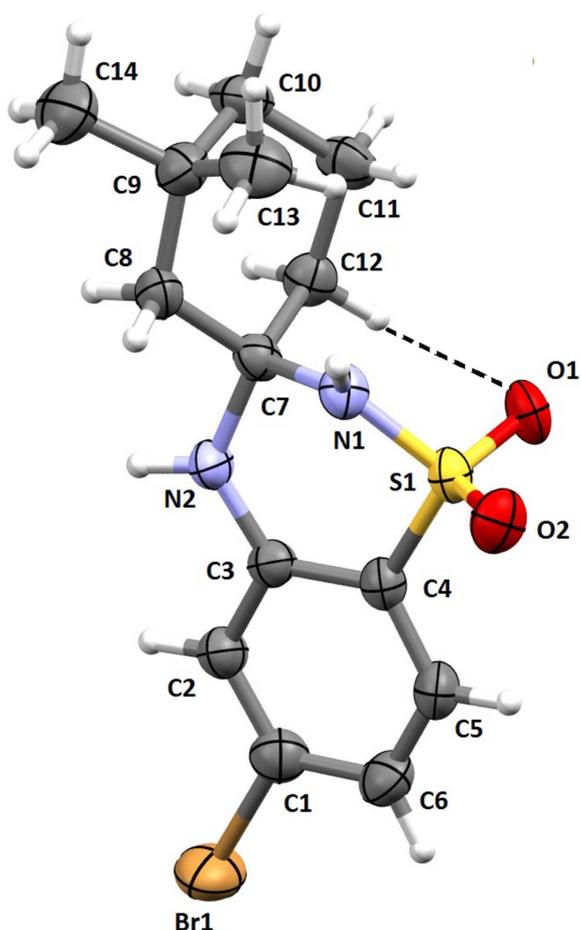
In the title compound, C<sub>14</sub>H<sub>19</sub>BrN<sub>2</sub>O<sub>2</sub>S, the 1,2,4-thiadiazinane ring adopts an envelope conformation with the N atom (attached to the sulfonyl group) as the flap, while the cyclohexane ring adopts a chair conformation. The mean plane of the cyclohexane ring is almost normal to the benzene ring and the mean plane of the 1,2,4-thiadiazinane ring, making dihedral angles of 70.4 (2) and 71.43 (19)°, respectively. Furthermore, the dihedral angle between the benzene ring and the mean plane of the 1,2,4-thiadiazinane ring is 4.91 (18)°. The molecular structure is stabilized by an intramolecular C—H···O hydrogen bond, which encloses an S(6) ring motif. In the crystal, molecules are linked by N—H···O hydrogen bonds into chains along [10 $\bar{1}$ ], forming a C(6) graph-set motif. These chains are interconnected *via* C—H··· $\pi$  interactions, leading to chains along [ $\bar{1}$ 01], so finally forming sheets parallel to (010).

## 1. Chemical context

The sulfonamide class of drugs have been widely reported for their antibacterial and antifungal activities (Trujillo *et al.*, 2009). 1,2,4-Benzothiadiazine 1,1-dioxides are used as anti-hypertensive, diuretic, antidiabetic, glutaminergic neuro modulators (Cordi *et al.*, 1996) and K-channel inhibitors (Di Bella *et al.*, 1983). Furthermore, benzothiadiazine-3-one 1,1-dioxide and its derivatives have been reported for their potential hypoglycemic (Scozzafava *et al.*, 2003), anticancer and anti-HIV activities (Casini *et al.*, 2002), and they have also been reported to serve as selective antagonists of CXR2 (Hayao *et al.*, 1968). In addition, 2-substituted-2*H*-1,2,4-benzothiadiazine-3(4*H*)one 1,1-dioxides have been found to exhibit varying degrees of sedative and hypotensive activities (Khelili *et al.*, 2012). A number of benzothiadiazine 1,1-dioxide derivatives have recently been reported to display numerous biological activities (Tullio *et al.*, 2011).



In view of their broad spectrum of biological activities, and in a continuation of our work on this class of compound, we have synthesized the title compound, (1), and report herein on its spectroscopic analysis and crystal structure.


**Figure 1**

A view of the molecular structure of the title molecule, showing the atom labelling. Displacement ellipsoids are drawn at the 50% probability level. The C–H···O hydrogen bond is shown as a dashed line (see Table 1 for details).

## 2. Structural commentary

The molecular structure of the title molecule is shown in Fig. 1. The relative configuration of the asymmetric center is *R* for atom C7. The cyclohexane ring (C7–C12) adopts a chair conformation, confirmed by the puckering amplitude of  $Q = 0.4285 \text{ \AA}$ . The 1,2,4-thiadiazinane ring (N1/S1/C4/C3/N2/C7) adopts an envelope conformation with the flap atom N1 deviating by  $0.565(3) \text{ \AA}$  from the mean plane defined by atoms C7/N2/C3/C4/S1 [maximum deviation =  $0.033(1) \text{ \AA}$  for atom S1]. The mean plane of the cyclohexane ring is almost normal to the benzene ring (C1–C6) and the mean plane of the

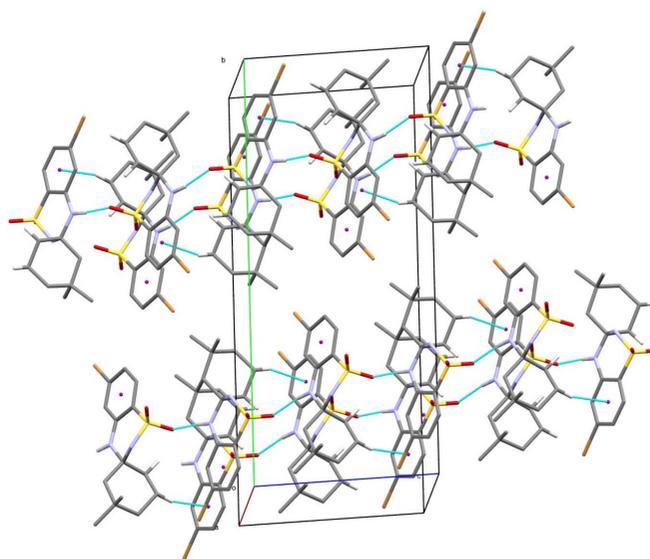
**Table 1**

Hydrogen-bond geometry ( $\text{\AA}$ ,  $^\circ$ ).

$C_g$  is the centroid of the C1–C6 ring.

| $D-H\cdots A$                           | $D-H$ | $H\cdots A$ | $D\cdots A$ | $D-H\cdots A$ |
|---|-------|-------------|-------------|---------------|
| C12–H12A···O1                           | 0.97  | 2.40        | 3.066 (5)   | 126           |
| N2–HN2···O1 <sup>i</sup>                | 0.86  | 2.26        | 3.101 (5)   | 166           |
| C11–H11A···C <sub>g</sub> <sup>ii</sup> | 0.97  | 2.58        | 3.506 (5)   | 160           |

Symmetry codes: (i)  $x + \frac{1}{2}, -y + \frac{1}{2}, z - \frac{1}{2}$ ; (ii)  $x + \frac{1}{2}, -y + \frac{1}{2}, z + \frac{1}{2}$ .


**Figure 2**

A view along the *a* axis of the crystal packing of the title compound. Hydrogen bonds are shown as thin blue lines (see Table 1 for details; H atoms not involved in hydrogen bonding have been omitted for clarity).

1,2,4-thiadiazinane ring, making dihedral angles of  $70.4(2)$  and  $71.43(19)^\circ$ , respectively. The dihedral angle between the benzene ring and the mean plane of the 1,2,4-thiadiazinane ring is  $4.91(18)^\circ$ . The molecular structure is stabilized by an intramolecular C–H···O hydrogen bond, which forms an *S*(6) ring motif (Table 1 and Fig. 1).

## 3. Supramolecular features

In the crystal, molecules are linked by N–H···O hydrogen bonds (Table 1 and Fig. 2), forming chains with a *C*(6) graph-set motif along  $[10\bar{1}]$ . The chains are linked *via* structure-directing C–H··· $\pi$  interactions, leading to the formation of *C*(6) chains along  $[\bar{1}01]$ . These interactions lead to the formation of sheets parallel to (010) (Table 1 and Fig. 2).

## 4. Database survey

In two similar structures, namely 6-bromo-4*H*-spiro[1,2,4-benzothiadiazine-3,1'-cyclobutane] 1,1-dioxide, (2) (Shinoj Kumar, 2014*a*, and 6-bromo-1'-ethyl-4*H*-spiro[1,2,4-benzothiadiazine-3,4'-piperidine] 1,1-dioxide, (3) (Shinoj Kumar, 2014*b*, the 1,2,4-thiadiazinane rings adopt a twisted chair conformation, in contrast to the envelope conformation observed in (1). In (2), the dihedral angle between the benzene ring and the mean plane of the cyclobutyl ring is  $73.76(1)^\circ$ , while that between the benzene ring and the mean plane of the 1,2,4-thiadiazinane ring is  $4.72(1)^\circ$ , and that between the mean plane of the cyclobutyl ring and the mean plane of the 1,2,4-thiadiazinane ring is  $78.44(1)^\circ$ . In (3), the same dihedral angles are similar, being  $73.61(1)$ ,  $6.73(1)$  and  $73.81(1)^\circ$ , respectively. These angles are also similar to those observed in the title compound, (1).

## 5. Synthesis and crystallization

To a cooled solution of 2-amino-4-bromobenzene sulfonamide (5 g, 19.9 mmol) and anhydrous magnesium sulfate ( $\text{MgSO}_4$ ; 3.5 g, 29.88 mmol) in dry toluene (60 ml), 3,3-dimethylcyclohexanone (22 mmol) was added followed by slow addition of polyphosphoric acid anhydride (T3P; 19 ml, 29.88 mmol, 50% solution in ethyl acetate). The reaction mixture was then refluxed in a sealed tube at 393 K for 6 h. It was cooled to 283 K and neutralized with saturated sodium bicarbonate solution (100 ml). The crude product was extracted with ethyl acetate (100 ml) and was finally washed with brine solution (50 ml). The organic phase was dried over anhydrous sodium sulfate and concentrated to give the crude product as a brown solid. It was then dissolved in a minimum amount of ethyl acetate (25 ml) and stirred for 1 h in an ice-cooled bath, filtered and washed with cold ethyl acetate (10 ml  $\times$  2) to give pure compound (1) (4.5 g, 75% yield) as a white solid. Colourless prisms of the title compound were obtained by slow evaporation of a solution of the compound in ethyl acetate.

## 6. Spectroscopic characterization

The IR spectra of the title compound exhibits strong bands at  $1374\text{ cm}^{-1}$  due to asymmetric ( $\text{S}=\text{O}$ ) stretching and a band at  $1165\text{ cm}^{-1}$  due to symmetric ( $\text{S}=\text{O}$ ) stretching. Further, a single band appearing at  $3110\text{ cm}^{-1}$  is due to the secondary N—H group of the sulfonamide, and a band at  $3308\text{ cm}^{-1}$  confirms the cyclization of sulfonamide through condensation with the ketone. Appearance of bands in the range of  $2970\text{--}2815\text{ cm}^{-1}$  is assigned to the C—H stretching is due to the presence of the saturated hydrocarbons. The  $^1\text{H}$  NMR spectrum shows peaks at  $\delta$  7.53 (s, 1H,  $\text{SO}_2\text{NH}$ ), 6.934–6.930 (d, 1H, Ar-H), 7.37–7.35 (d, 1H, Ar-H), 3.33 (s, 1H, NH), 2.51–1.28 (m, 9H,  $\text{CH}_2$ ), 0.9–1.1 (s, 6H,  $\text{CH}_3$ ). The  $^{13}\text{C}$  NMR spectrum shows peaks at  $\delta$  144 (C1), 119 (C2), 126 (C3), 127 (C4), 119 (C5), 118 (C6), 117 (C7), 71 (C8), 47 (C9), 36 (C10), 33 (C11), 31 (C12), 18 (C13 and C14). The LC–MS spectrum shows the appearance of molecular ion peaks at  $m/z$  358 and 357 values, confirming the structure of the compound.

## 7. Refinement

Crystal data, data collection and structure refinement details are summarized in Table 2. The NH hydrogens were located in a difference Fourier map. N- and C-bound H atoms were included in calculated positions (N—H = 0.86 and C—H = 0.93–0.97 Å) and allowed to ride on their parent atoms, with  $U_{\text{iso}}(\text{H}) = 1.5U_{\text{eq}}(\text{C})$  for methyl H atoms and  $1.2U_{\text{eq}}(\text{N,C})$  for other H atoms.

## Acknowledgements

The authors acknowledge the IOE X-ray diffractometer facility, University of Mysore, Mysore, for the data collection. PPSK, PAS, SS and DBAK are thankful to Tumkur University for providing the laboratory and instrumental facilities to carry out this work.

Table 2

Experimental details.

|  |  |
|--|--|
| Crystal data   |  |
| Chemical formula   | $\text{C}_{14}\text{H}_{19}\text{BrN}_2\text{O}_2\text{S}$ |
| $M_r$  | 359.28   |
| Crystal system, space group  | Monoclinic, $P2_1/n$                                       |
| Temperature (K)  | 293  |
| $a, b, c$ (Å)  | 6.4316 (7), 24.263 (3), 10.0829 (13)                       |
| $\beta$ (°)  | 105.604 (9)  |
| $V$ (Å <sup>3</sup> )  | 1515.5 (3)   |
| $Z$  | 4  |
| Radiation type   | Cu $K\alpha$   |
| $\mu$ (mm <sup>-1</sup> )  | 5.01   |
| Crystal size (mm)  | 0.44 $\times$ 0.24 $\times$ 0.19                           |
| Data collection  |  |
| Diffractometer   | Bruker APEXII  |
| Absorption correction  | Multi-scan (SADABS; Bruker, 2009)                          |
| $T_{\text{min}}$ , $T_{\text{max}}$  | 0.271, 0.386   |
| No. of measured, independent and observed [ $I > 2\sigma(I)$ ] reflections | 11574, 2515, 1860  |
| $R_{\text{int}}$   | 0.081  |
| $(\sin \theta/\lambda)_{\text{max}}$ (Å <sup>-1</sup> )                    | 0.586  |
| Refinement   |  |
| $R[F^2 > 2\sigma(F^2)]$ , $wR(F^2)$ , $S$                                  | 0.049, 0.154, 0.94   |
| No. of reflections   | 2515   |
| No. of parameters  | 183  |
| H-atom treatment   | H-atom parameters constrained                              |
| $\Delta\rho_{\text{max}}$ , $\Delta\rho_{\text{min}}$ (e Å <sup>-3</sup> ) | 0.61, -0.61  |

Computer programs: APEX2, SAINT-Plus and XPREP (Bruker, 2009), SHELXS97 and SHELXL97 (Sheldrick, 2008), and Mercury (Macrae *et al.*, 2008).

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## supporting information

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## Crystal structure of (*R*)-6'-bromo-3,3-dimethyl-3',4'-dihydro-2'*H*-spiro[cyclohexane-1,3'-1,2,4-benzothiadiazine] 1',1'-dioxide

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### Computing details

Data collection: *APEX2* (Bruker, 2009); cell refinement: *APEX2* and *SAINT-Plus* (Bruker, 2009); data reduction: *SAINT-Plus* and *XPREP* (Bruker, 2009); program(s) used to solve structure: *SHELXS97* (Sheldrick, 2008); program(s) used to refine structure: *SHELXL97* (Sheldrick, 2008); molecular graphics: *Mercury* (Macrae *et al.*, 2008); software used to prepare material for publication: *SHELXL97* (Sheldrick, 2008).

### (*R*)-6'-Bromo-3,3-dimethyl-3',4'-dihydro-2'*H*-spiro[cyclohexane-1,3'-1,2,4-benzothiadiazine] 1',1'-dioxide

#### Crystal data

C<sub>14</sub>H<sub>19</sub>BrN<sub>2</sub>O<sub>2</sub>S  
*M<sub>r</sub>* = 359.28  
 Monoclinic, *P2<sub>1</sub>/n*  
*a* = 6.4316 (7) Å  
*b* = 24.263 (3) Å  
*c* = 10.0829 (13) Å  
 $\beta$  = 105.604 (9)°  
*V* = 1515.5 (3) Å<sup>3</sup>  
*Z* = 4  
*F*(000) = 736

*D<sub>x</sub>* = 1.575 Mg m<sup>-3</sup>  
 Melting point: 418 K  
 Cu *K*α radiation,  $\lambda$  = 1.54178 Å  
 Cell parameters from 123 reflections  
 $\theta$  = 7.1–64.6°  
 $\mu$  = 5.01 mm<sup>-1</sup>  
*T* = 293 K  
 Prism, colourless  
 0.44 × 0.24 × 0.19 mm

#### Data collection

Bruker APEXII  
 diffractometer  
 Radiation source: fine-focus sealed tube  
 Graphite monochromator  
 phi and  $\varphi$  scans  
 Absorption correction: multi-scan  
 (*SADABS*; Bruker, 2009)  
*T<sub>min</sub>* = 0.271, *T<sub>max</sub>* = 0.386  
 11574 measured reflections

2515 independent reflections  
 1860 reflections with *I* > 2σ(*I*)  
*R<sub>int</sub>* = 0.081  
 $\theta_{\max}$  = 64.6°,  $\theta_{\min}$  = 7.1°  
*h* = -7→6  
*k* = -28→27  
*l* = -11→11  
 1 standard reflections every 1 reflections  
 intensity decay: 1%

#### Refinement

Refinement on *F*<sup>2</sup>  
 Least-squares matrix: full  
*R*[*F*<sup>2</sup> > 2σ(*F*<sup>2</sup>)] = 0.049  
*wR*(*F*<sup>2</sup>) = 0.154  
*S* = 0.94  
 2515 reflections

183 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-atom parameters constrained

$$w = 1/[\sigma^2(F_o^2) + (0.1058P)^2 + 0.1836P]$$

where  $P = (F_o^2 + 2F_c^2)/3$

$$(\Delta/\sigma)_{\max} < 0.001$$

$$\Delta\rho_{\max} = 0.61 \text{ e } \text{Å}^{-3}$$

$$\Delta\rho_{\min} = -0.61 \text{ e } \text{Å}^{-3}$$

*Special details*

**Experimental.** Melting points were determined in open capillaries and are uncorrected. The molecular structures of the synthesized compounds were established using IR, <sup>1</sup>H NMR, <sup>13</sup>C NMR and LC-MS studies. Solid state FT-IR Spectra were recorded as KBr discs on Jasco FT-IR Spectrometer. <sup>1</sup>H NMR and <sup>13</sup>C NMR were recorded in DMSO at 399.13 MHz and 75.50 MHz respectively on Bruker model avance II. All the chemical shifts were reported in parts per million (ppm) using tetramethyl silane (TMS) as an internal standard. Mass spectra of the compounds were recorded on Shimadzu LC-2010EV with ESI probe.

**Geometry.** All s.u.'s (except the s.u. in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell s.u.'s are taken into account individually in the estimation of s.u.'s in distances, angles and torsion angles; correlations between s.u.'s in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell s.u.'s is used for estimating s.u.'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  $F^2 > 2\sigma(F^2)$  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<sup>2</sup>)*

|      | <i>x</i>    | <i>y</i>     | <i>z</i>   | $U_{\text{iso}}^*/U_{\text{eq}}$ |
|------|-------------|--------------|------------|----------------------------------|
| C1   | 0.0489 (7)  | 0.09465 (19) | 0.8681 (5) | 0.0449 (11)                      |
| C2   | 0.0873 (7)  | 0.14863 (18) | 0.8441 (4) | 0.0398 (10)                      |
| H2   | 0.1873      | 0.1575       | 0.7959     | 0.048*                           |
| C3   | -0.0244 (6) | 0.19093 (16) | 0.8922 (4) | 0.0336 (9)                       |
| C4   | -0.1634 (6) | 0.17472 (17) | 0.9715 (4) | 0.0334 (9)                       |
| C5   | -0.2014 (7) | 0.11957 (18) | 0.9908 (4) | 0.0419 (10)                      |
| H5   | -0.2992     | 0.1101       | 1.0401     | 0.050*                           |
| C6   | -0.0993 (8) | 0.07862 (19) | 0.9394 (5) | 0.0465 (11)                      |
| H6   | -0.1275     | 0.0416       | 0.9514     | 0.056*                           |
| C7   | -0.0697 (6) | 0.29279 (16) | 0.9203 (4) | 0.0327 (9)                       |
| C8   | -0.1071 (7) | 0.33969 (17) | 0.8148 (4) | 0.0392 (10)                      |
| H8A  | -0.2288     | 0.3297       | 0.7384     | 0.047*                           |
| H8B  | 0.0186      | 0.3419       | 0.7792     | 0.047*                           |
| C9   | -0.1502 (7) | 0.39760 (18) | 0.8637 (5) | 0.0444 (11)                      |
| C10  | 0.0144 (8)  | 0.41054 (18) | 1.0010 (5) | 0.0491 (11)                      |
| H10A | -0.0274     | 0.4444       | 1.0382     | 0.059*                           |
| H10B | 0.1547      | 0.4165       | 0.9848     | 0.059*                           |
| C11  | 0.0326 (8)  | 0.36432 (19) | 1.1071 (4) | 0.0464 (11)                      |
| H11A | 0.1388      | 0.3744       | 1.1918     | 0.056*                           |
| H11B | -0.1053     | 0.3595       | 1.1277     | 0.056*                           |
| C12  | 0.0987 (6)  | 0.31045 (18) | 1.0527 (4) | 0.0378 (10)                      |
| H12A | 0.1127      | 0.2819       | 1.1220     | 0.045*                           |
| H12B | 0.2379      | 0.3150       | 1.0339     | 0.045*                           |
| C13  | -0.3793 (8) | 0.4038 (2)   | 0.8792 (6) | 0.0579 (13)                      |
| H13A | -0.3914     | 0.3838       | 0.9590     | 0.087*                           |

|      |               |              |              |             |
|------|---------------|--------------|--------------|-------------|
| H13B | -0.4809       | 0.3893       | 0.7988       | 0.087*      |
| H13C | -0.4094       | 0.4420       | 0.8895       | 0.087*      |
| C14  | -0.1192 (10)  | 0.4391 (2)   | 0.7572 (6)   | 0.0657 (15) |
| H14A | -0.1452       | 0.4756       | 0.7856       | 0.098*      |
| H14B | -0.2187       | 0.4311       | 0.6697       | 0.098*      |
| H14C | 0.0259        | 0.4366       | 0.7492       | 0.098*      |
| N1   | -0.2810 (5)   | 0.27879 (14) | 0.9457 (3)   | 0.0342 (8)  |
| HN1  | -0.3930       | 0.2988       | 0.9117       | 0.041*      |
| N2   | 0.0041 (5)    | 0.24419 (14) | 0.8593 (4)   | 0.0373 (8)  |
| HN2  | 0.0712        | 0.2499       | 0.7974       | 0.045*      |
| O1   | -0.1804 (5)   | 0.23557 (14) | 1.1797 (3)   | 0.0442 (8)  |
| O2   | -0.5208 (4)   | 0.21181 (13) | 1.0131 (3)   | 0.0469 (8)  |
| S1   | -0.29684 (15) | 0.22511 (4)  | 1.03879 (10) | 0.0352 (3)  |
| Br1  | 0.20573 (10)  | 0.03945 (2)  | 0.80348 (7)  | 0.0701 (3)  |

*Atomic displacement parameters (Å<sup>2</sup>)*

|     | $U^{11}$    | $U^{22}$    | $U^{33}$    | $U^{12}$     | $U^{13}$    | $U^{23}$     |
|-----|-------------|-------------|-------------|--------------|-------------|--------------|
| C1  | 0.043 (3)   | 0.043 (3)   | 0.047 (3)   | -0.001 (2)   | 0.010 (2)   | -0.002 (2)   |
| C2  | 0.041 (2)   | 0.038 (2)   | 0.044 (2)   | -0.0026 (19) | 0.0185 (19) | -0.0035 (18) |
| C3  | 0.035 (2)   | 0.031 (2)   | 0.033 (2)   | -0.0009 (17) | 0.0070 (16) | 0.0000 (16)  |
| C4  | 0.032 (2)   | 0.040 (2)   | 0.030 (2)   | -0.0002 (17) | 0.0097 (16) | 0.0006 (16)  |
| C5  | 0.048 (3)   | 0.045 (2)   | 0.036 (2)   | -0.002 (2)   | 0.0182 (19) | 0.0046 (19)  |
| C6  | 0.057 (3)   | 0.037 (2)   | 0.046 (3)   | -0.001 (2)   | 0.013 (2)   | 0.008 (2)    |
| C7  | 0.030 (2)   | 0.034 (2)   | 0.035 (2)   | 0.0003 (17)  | 0.0117 (16) | -0.0038 (16) |
| C8  | 0.046 (2)   | 0.041 (3)   | 0.032 (2)   | -0.006 (2)   | 0.0119 (18) | -0.0009 (18) |
| C9  | 0.052 (3)   | 0.037 (2)   | 0.044 (3)   | -0.003 (2)   | 0.013 (2)   | 0.0022 (19)  |
| C10 | 0.058 (3)   | 0.037 (3)   | 0.049 (3)   | -0.004 (2)   | 0.010 (2)   | -0.010 (2)   |
| C11 | 0.050 (3)   | 0.048 (3)   | 0.034 (2)   | -0.002 (2)   | 0.0005 (19) | -0.009 (2)   |
| C12 | 0.030 (2)   | 0.043 (2)   | 0.037 (2)   | -0.0027 (18) | 0.0044 (17) | 0.0009 (18)  |
| C13 | 0.049 (3)   | 0.055 (3)   | 0.067 (3)   | 0.014 (2)    | 0.009 (2)   | 0.001 (3)    |
| C14 | 0.091 (4)   | 0.052 (3)   | 0.051 (3)   | 0.000 (3)    | 0.013 (3)   | 0.011 (2)    |
| N1  | 0.0267 (16) | 0.040 (2)   | 0.0370 (19) | 0.0074 (14)  | 0.0098 (14) | 0.0041 (15)  |
| N2  | 0.0420 (19) | 0.0343 (19) | 0.044 (2)   | -0.0006 (15) | 0.0265 (16) | -0.0026 (15) |
| O1  | 0.0478 (18) | 0.060 (2)   | 0.0258 (15) | 0.0024 (15)  | 0.0112 (13) | -0.0019 (13) |
| O2  | 0.0286 (15) | 0.058 (2)   | 0.0562 (19) | -0.0040 (14) | 0.0153 (13) | 0.0033 (15)  |
| S1  | 0.0322 (5)  | 0.0435 (6)  | 0.0322 (6)  | 0.0004 (4)   | 0.0126 (4)  | 0.0007 (4)   |
| Br1 | 0.0868 (5)  | 0.0414 (4)  | 0.0966 (6)  | 0.0091 (3)   | 0.0495 (4)  | -0.0070 (3)  |

*Geometric parameters (Å, °)*

|        |           |          |           |
|--------|-----------|----------|-----------|
| C1—C2  | 1.366 (6) | C9—C10   | 1.533 (6) |
| C1—C6  | 1.394 (6) | C10—C11  | 1.533 (6) |
| C1—Br1 | 1.894 (5) | C10—H10A | 0.9700    |
| C2—C3  | 1.412 (6) | C10—H10B | 0.9700    |
| C2—H2  | 0.9300    | C11—C12  | 1.522 (6) |
| C3—N2  | 1.359 (5) | C11—H11A | 0.9700    |
| C3—C4  | 1.407 (5) | C11—H11B | 0.9700    |

|            |           |               |           |
|------------|-----------|---------------|-----------|
| C4—C5      | 1.383 (6) | C12—H12A      | 0.9700    |
| C4—S1      | 1.733 (4) | C12—H12B      | 0.9700    |
| C5—C6      | 1.368 (6) | C13—H13A      | 0.9600    |
| C5—H5      | 0.9300    | C13—H13B      | 0.9600    |
| C6—H6      | 0.9300    | C13—H13C      | 0.9600    |
| C7—N2      | 1.466 (5) | C14—H14A      | 0.9600    |
| C7—N1      | 1.489 (5) | C14—H14B      | 0.9600    |
| C7—C8      | 1.532 (6) | C14—H14C      | 0.9600    |
| C7—C12     | 1.537 (5) | N1—S1         | 1.624 (3) |
| C8—C9      | 1.539 (6) | N1—HN1        | 0.8600    |
| C8—H8A     | 0.9700    | N2—HN2        | 0.8600    |
| C8—H8B     | 0.9700    | O1—S1         | 1.439 (3) |
| C9—C13     | 1.530 (6) | O2—S1         | 1.430 (3) |
| C9—C14     | 1.523 (6) |               |           |
|            |           |               |           |
| C2—C1—C6   | 122.7 (4) | C9—C10—H10B   | 109.1     |
| C2—C1—Br1  | 118.6 (3) | C11—C10—H10B  | 109.1     |
| C6—C1—Br1  | 118.8 (4) | H10A—C10—H10B | 107.8     |
| C1—C2—C3   | 120.2 (4) | C12—C11—C10   | 110.7 (4) |
| C1—C2—H2   | 119.9     | C12—C11—H11A  | 109.5     |
| C3—C2—H2   | 119.9     | C10—C11—H11A  | 109.5     |
| N2—C3—C2   | 119.5 (4) | C12—C11—H11B  | 109.5     |
| N2—C3—C4   | 123.6 (4) | C10—C11—H11B  | 109.5     |
| C2—C3—C4   | 116.9 (4) | H11A—C11—H11B | 108.1     |
| C5—C4—C3   | 120.9 (4) | C11—C12—C7    | 110.7 (3) |
| C5—C4—S1   | 120.2 (3) | C11—C12—H12A  | 109.5     |
| C3—C4—S1   | 118.8 (3) | C7—C12—H12A   | 109.5     |
| C6—C5—C4   | 121.9 (4) | C11—C12—H12B  | 109.5     |
| C6—C5—H5   | 119.0     | C7—C12—H12B   | 109.5     |
| C4—C5—H5   | 119.0     | H12A—C12—H12B | 108.1     |
| C5—C6—C1   | 117.2 (4) | C9—C13—H13A   | 109.5     |
| C5—C6—H6   | 121.4     | C9—C13—H13B   | 109.5     |
| C1—C6—H6   | 121.4     | H13A—C13—H13B | 109.5     |
| N2—C7—N1   | 107.6 (3) | C9—C13—H13C   | 109.5     |
| N2—C7—C8   | 108.3 (3) | H13A—C13—H13C | 109.5     |
| N1—C7—C8   | 108.0 (3) | H13B—C13—H13C | 109.5     |
| N2—C7—C12  | 110.9 (3) | C9—C14—H14A   | 109.5     |
| N1—C7—C12  | 112.1 (3) | C9—C14—H14B   | 109.5     |
| C8—C7—C12  | 109.8 (3) | H14A—C14—H14B | 109.5     |
| C7—C8—C9   | 117.6 (3) | C9—C14—H14C   | 109.5     |
| C7—C8—H8A  | 107.9     | H14A—C14—H14C | 109.5     |
| C9—C8—H8A  | 107.9     | H14B—C14—H14C | 109.5     |
| C7—C8—H8B  | 107.9     | C7—N1—S1      | 119.0 (3) |
| C9—C8—H8B  | 107.9     | C7—N1—HN1     | 120.5     |
| H8A—C8—H8B | 107.2     | S1—N1—HN1     | 120.5     |
| C13—C9—C14 | 108.7 (4) | C3—N2—C7      | 125.6 (3) |
| C13—C9—C10 | 109.8 (4) | C3—N2—HN2     | 117.2     |
| C14—C9—C10 | 108.2 (4) | C7—N2—HN2     | 117.2     |

|                |            |                |             |
|----------------|------------|----------------|-------------|
| C13—C9—C8      | 112.6 (4)  | O2—S1—O1       | 116.72 (18) |
| C14—C9—C8      | 107.9 (4)  | O2—S1—N1       | 107.04 (18) |
| C10—C9—C8      | 109.6 (4)  | O1—S1—N1       | 109.40 (19) |
| C9—C10—C11     | 112.7 (4)  | O2—S1—C4       | 110.51 (19) |
| C9—C10—H10A    | 109.1      | O1—S1—C4       | 109.26 (18) |
| C11—C10—H10A   | 109.1      | N1—S1—C4       | 103.01 (17) |
|                |            |                |             |
| C6—C1—C2—C3    | 0.2 (7)    | C9—C10—C11—C12 | 58.9 (5)    |
| Br1—C1—C2—C3   | -179.2 (3) | C10—C11—C12—C7 | -60.5 (5)   |
| C1—C2—C3—N2    | -175.4 (4) | N2—C7—C12—C11  | 173.9 (3)   |
| C1—C2—C3—C4    | 3.8 (6)    | N1—C7—C12—C11  | -65.8 (4)   |
| N2—C3—C4—C5    | 173.8 (4)  | C8—C7—C12—C11  | 54.3 (4)    |
| C2—C3—C4—C5    | -5.3 (6)   | N2—C7—N1—S1    | 55.6 (4)    |
| N2—C3—C4—S1    | -3.3 (5)   | C8—C7—N1—S1    | 172.3 (3)   |
| C2—C3—C4—S1    | 177.6 (3)  | C12—C7—N1—S1   | -66.6 (4)   |
| C3—C4—C5—C6    | 2.9 (6)    | C2—C3—N2—C7    | -168.8 (4)  |
| S1—C4—C5—C6    | -180.0 (3) | C4—C3—N2—C7    | 12.1 (6)    |
| C4—C5—C6—C1    | 1.1 (7)    | N1—C7—N2—C3    | -36.3 (5)   |
| C2—C1—C6—C5    | -2.7 (7)   | C8—C7—N2—C3    | -152.8 (4)  |
| Br1—C1—C6—C5   | 176.7 (3)  | C12—C7—N2—C3   | 86.6 (5)    |
| N2—C7—C8—C9    | -170.4 (3) | C7—N1—S1—O2    | -163.1 (3)  |
| N1—C7—C8—C9    | 73.3 (4)   | C7—N1—S1—O1    | 69.6 (3)    |
| C12—C7—C8—C9   | -49.2 (5)  | C7—N1—S1—C4    | -46.5 (3)   |
| C7—C8—C9—C13   | -75.8 (5)  | C5—C4—S1—O2    | -44.6 (4)   |
| C7—C8—C9—C14   | 164.3 (4)  | C3—C4—S1—O2    | 132.5 (3)   |
| C7—C8—C9—C10   | 46.7 (5)   | C5—C4—S1—O1    | 85.1 (4)    |
| C13—C9—C10—C11 | 74.3 (5)   | C3—C4—S1—O1    | -97.7 (3)   |
| C14—C9—C10—C11 | -167.3 (4) | C5—C4—S1—N1    | -158.6 (3)  |
| C8—C9—C10—C11  | -49.9 (5)  | C3—C4—S1—N1    | 18.5 (3)    |

*Hydrogen-bond geometry* ( $\text{\AA}$ ,  $^\circ$ )

Cg is the centroid of the C1—C6 ring.

| <i>D</i> —H $\cdots$ <i>A</i>      | <i>D</i> —H | H $\cdots$ <i>A</i> | <i>D</i> $\cdots$ <i>A</i> | <i>D</i> —H $\cdots$ <i>A</i> |
|------------------------------------|-------------|---------------------|----------------------------|-------------------------------|
| C12—H12A $\cdots$ O1               | 0.97        | 2.40                | 3.066 (5)                  | 126                           |
| N2—HN2 $\cdots$ O1 <sup>i</sup>    | 0.86        | 2.26                | 3.101 (5)                  | 166                           |
| C11—H11A $\cdots$ Cg <sup>ii</sup> | 0.97        | 2.58                | 3.506 (5)                  | 160                           |

Symmetry codes: (i)  $x+1/2, -y+1/2, z-1/2$ ; (ii)  $x+1/2, -y+1/2, z+1/2$ .