ЖУРНАЛ СТРУКТУРНОЙ ХИМИИ

2015. Том 56, № 7 *Декабрь* *С. 1449 – 1456*

UDC 547.53:548.73:541.67

MOLECULAR AND CRYSTAL STRUCTURES OF TWO 1,2,4-BENZOTHIADIAZINE DERIVATIVES

P.P.S. Kumar[1], P.A. Suchetan[2], S. Sreenivasa[1], S. Naveen[3], N.K. Lokanath[4], D.B.A. Kumar[1]

[1]*Department of Studies and Research in Chemistry, Tumkur University, India*
E-mail: nirmaldb@rediffmail.com (D.B.A. Kumar)
[2]*Department of Chemistry, University College of Science, Tumkur University, India*
[3]*Institution of Excellence, Vijnana Bhavan, University of Mysore, Manasagangotri, India*
[4]*Department of Studies in Physics, University of Mysore, Manasagangotri, India*

Received September, 26, 2014 *Revised — November, 15, 2014*

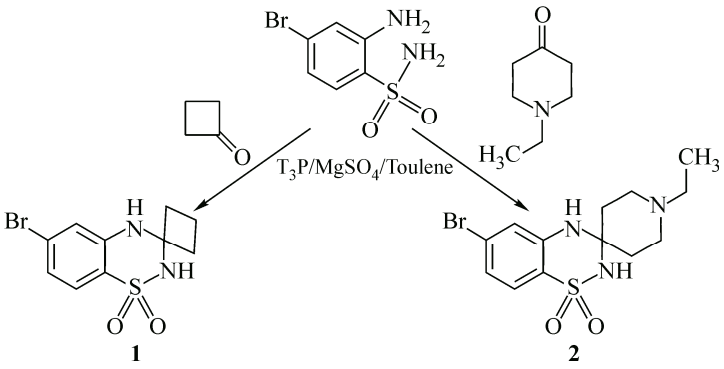
The synthesis of two 1,2,4-benzothiadiazine derivatives, namely, 6-bromo-4*H*-spiro[1,2,4-benzothiadiazine-3,1′-cyclobutane] 1,1-dioxide (**1**) and 6-bromo-1′-ethyl-4*H*-spiro[1,2,4-benzothiadiazine-3,4′-piperidine] 1,1-dioxide (**2**) is described in the present work. The synthesized compounds were studied by IR, ^{1}H and ^{13}C NMR, and single crystal X-ray diffraction to determine their molecular and crystal structure. In both structures the conformation of the 1,2,4-thiadiazinane ring is a twisted *chair* and is stabilized by the intramolecular interaction of the C—H…O type. Compound **1** crystallizes in the monoclinic crystal system and space group $C2/c$ with the unit cell parameters $a = 15.8690(17)$ Å, $b = 12.1453(16)$ Å, $c = 12.0152(15)$ Å, $\beta = 99.686(7)°$, $Z = 8$ and $V = 2282.7(5)$ Å^3. Compound **2** crystallizes in the monoclinic crystal system and space group $P2_1/c$ with the unit cell parameters $a = 14.5748(6)$ Å, $b = 9.3340(5)$ Å, $c = 12.4283(6)$ Å, $\beta = 112.757(2)°$, $Z = 4$ and $V = 1559.14(13)$ Å^3. In the crystal structures different packing motifs are implemented with the formation of supramolecular assemblies of different types due to classical hydrogen bonds such as N—H…O and intermolecular interactions of N—H…Br, N—H…N, C—H…O types and π…π stacking.

DOI: 10.15372/JSC20150721

K e y w o r d s: 1,2,4-benzothiadiazines, IR spectroscopy, X-ray analysis, N—H…O hydrogen bonds, N—H…Br interactions, N—H…N interactions, C—H…O interactions, π…π stacking.

INTRODUCTION

The sulfonamide class of drugs have been used since long back due to its amazing antibacterial and antifungal activities [1, 2]. 1,2,4-Benzothiadiazine 1,1-dioxides are used as antihypertensive, diuretic, anti-diabetic, glutaminergic neuro modulators [3, 4] and K-channel inhibitors [5], yet the ring system has also been known for its anti-microbial and anti-tubercular activities [6, 7]. Additionally, this class of compounds has been proved to inhibit hepatitis C virus (HCV) replication effectively in cell based replication systems with no apparent cytotoxicity [8]. Anticancer agents containing the 1,2,4-benzothiadiazine 1,1-dioxide ring system also exhibit potent antiviral activity. Especially, benzothiadiazine-3-one 1,1-dioxide and its derivatives possess potential activity, including hypoglycemic [9], anticancer, and anti-HIV activities [10—13], and also serve as selective antagonists of CXR2 [14]. 2-Substituted-2*H*-1,2,4-benzothiadiazine-3(4*H*)one 1,1-dioxides showed varying degrees of sedative and hypotensive activities [15]. A number of benzothiadiazine 1,1-dioxide derivatives have recently been reported to display numerous biological activities [16—22]. A literature search reveals



Scheme 1

that 1,2,4-benzothiadiazine 1,1-dioxides are generally synthesized either by condensation of *o*-amino benzene sulfonamides with urea at elevated temperatures [23] or by the reaction of *o*-amino benzene sulfonamide with isocyanates in DMF under reflux [24]. Although various approaches to the preparation of 1,2,4-benzothiadiazine 1,1-dioxide derivatives have been reported [25—31], the development of a simpler method for the synthesis of the 1,2,4-benzothiadiazine 1,1-dioxide moiety is still desirable because of their biological significance.

In search for new class of antibacterial and antifungal agents the present paper describes the synthesis of two important derivatives of 1,2,4-benzothiadiazine. 2-Amino-4-bromobenzene sulfonamide on reaction with different ketones undergoes cyclisation. The cyclisation occurs through condensation and is found to be successful when $T_3P^{®}$ (poly phosphoric acid anhydride) is employed as the coupling agent under reflux, as shown in Scheme 1. Therefore, in view of the above facts compounds **1** and **2** were synthesized and characterized by IR, ^1H and ^{13}C NMR, and LC-MS techniques. The compounds were also subjected to single crystal X-ray diffraction studies to understand their molecular and crystal structures.

EXPERIMENTAL

Materials and methods. Melting points were determined in open capillaries and are uncorrected. Solid state FT-IR spectra were recorded as KBr discs on a Jasco FT-IR spectrometer. ^1H and ^{13}C NMR spectra were recorded in DMSO-d_6 at 399.13 MHz and 75.50 MHz respectively on a Bruker model Avance II instrument. All the chemical shifts were reported in parts per million (ppm) using tetramethyl silane (TMS) as the internal standard. Mass spectral data were obtained on an AGILENT LC-MS column c-18 instrument. The progresses of all the reactions were monitored by thin layer chromatography.

Synthesis

Synthesis of 6-bromo-4H-spiro[1,2,4-benzothiadiazine-3,1′-cyclobutane] 1,1-dioxide (1). To a cooled solution of 2-amino-4-bromo benzene sulfonamide (5.0 g, 19.9 mmol) and anhydrous $MgSO_4$ (3.5 g, 29.88 mmol) in dry toluene (60 ml), cyclobutanone (1.5 g, 22 mmol) was added followed by slow addition of polyphosphoric acid anhydride ($T_3P^{®}$, 19 ml, 29.88 mmol, 50 % solution in ethyl acetate).The reaction mixture was then refluxed in a sealed tube at 120 °C for 6 h. It was cooled to 10 °C and neutralized with a saturated $NaHCO_3$ solution (100 ml). The crude product was extracted with ethyl acetate (100 ml) and was finally washed with a brine solution (50 ml). The organic phase was dried over anhydrous sodium sulfate and concentrated to give a 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 X 2) to give pure titled compound (4.5 g, 75 % yield) as an off-white solid. M.p. 275—278 °C.

Synthesis of 6-bromo-1′-ethyl-4H-spiro[1,2,4-benzothiadiazine-3,4′-piperidine] 1,1-dioxide (2). Compound **2** was prepared following the similar procedure with 1-ethyl-4-piperidone (2.8 g, 22 mmol) to get an off-white solid (3.8 g, 53 % yield). M.p. 265—268 °C.

X-ray diffraction analysis

Colourless prisms of both compounds were obtained from slow evaporation of the solutions of the respective compounds in ethyl acetate.

The data for the two compounds were collected on a Bruker Smart X2S diffractometer using CuK_α (λ = 1.54178) radiation. Image processing and data reduction were performed using SAINT-

Table 1

Crystal data and structure refinement for **1** *and* **2**

Parameter	**1**	**2**
CCDC number	1023519	1023520
Empirical formula	$C_{10}H_{11}BrN_2O_2S$	$C_{13}H_{18}BrN_3O_2S$
Formula weight	303.18	360.27
Temperature, K	296(2)	293(2)
Crystal system	Monoclinic	Monoclinic
Space group	*C*2/*c*	$P2_1/c$
a, *b*, *c*, Å	15.8690(17), 12.1453(16), 12.0152(15)	14.5748(6), 9.3340(5), 12.4283(6)
β, deg.	99.686(7)	112.757(2)
Volume, Å^3	2282.7(5)	1559.14(13)
Z	8	4
ρ_{calc}, mg/mm^3	1.764	1.535
Absorption coefficient	6.529	4.894
F(000)	1216.0	736.0
Crystal size, mm	0.43×0.32×0.18	0.46×0.33×0.19
2θ range for data collection, deg.	9.22 to 128.58	11.54 to 129
Index ranges	$-18 \le h \le 18$, $-14 \le k \le 13$, $-13 \le l \le 13$	$-16 \le h \le 17$, $-10 \le k \le 9$, $-14 \le l \le 14$
Reflections collected / independent	8176 / 1872	15006 / 2569
Data / restraints / parameters	1872 / 0 / 145	2569 / 0 / 182
Goodness-of-fit on F^2	1.085	1.044
Final *R* indexes [$I \ge 2\sigma(I)$]	$R_1 = 0.0430$, $wR_2 = 0.1170$	$R_1 = 0.0513$, $wR_2 = 0.1350$
Final *R* indexes [all data]	$R_1 = 0.0543$, $wR_2 = 0.1346$	$R_1 = 0.0645$, $wR_2 = 0.1442$
Largest diff. peak / hole, e/Å^3	0.62 / –0.63	0.57 / –0.74

Plus and XPREP [32]. The structure was solved by direct methods using SHELXS-97 [33]. The positions and anisotropic displacement parameters of all the atoms (excluding hydrogen) were included in the full-matrix least-square refinement using SHELXL97 [33] and the procedures were carried out for a few cycles until the convergence was reached. The H atoms were placed at the calculated positions in the riding model approximation (aromatic C—H: 0.93 Å; Alkyl C—H: 0.96 Å) with $U_{iso}(H) = 1.5U_{eq}(C)$ for Alkyl H and $U_{iso}(H) = 1.2U_{eq}(C)$ for all other H atoms. The H atom of the NH group was located in a difference map and later refined freely. The non-hydrogen atoms were refined anisotropically. Molecular and packing diagrams were generated using ORTEP [34] and MERCURY [35]. The details of crystal data and structure refinement of **1** and **2** are given in Table 1.

RESULTS AND DISCUSSION

The compounds were synthesized according to Scheme 1 and characterized by IR, ^{1}H and ^{13}C NMR, LC-MS, and single crystal X-ray diffraction techniques.

Spectral analysis. Spectral data of the synthesized compounds are in full agreement with its proposed structure.

The IR spectra of compounds **1** and **2** exhibit strong bands at 1376 cm^{-1} due to asymmetric (S=O) stretching and a band at 1160 cm^{-1} due to symmetric (S=O) stretching. A single band appearing at 3104 cm^{-1} due to the secondary N—H group of sulphonamide and a band at 3305 cm^{-1} confirms the cyclization of sulphonamide through condensation with the ketone. The appearance of a band between 2950—2814 cm^{-1} due to C—H stretching in compounds **1** and **2** confirms the presence of saturated hydrocarbons. Stretching C—N bands have overlapped with the S=O stretching frequencies, hence could not be identified. The ^{1}H NMR spectrum of compound **1** shows peaks at δ, ppm: 7.92 (s, 1H, SO_2NH), 7.76 (s, 1H, Ar—H), 7.36—7.34 (d, 1H, Ar—H, *J* = 8.4 Hz), 6.917—6.912 (d, 1H, Ar—H, *J* = 2.0 Hz), 3.32 (s, 1H, NH), 2.57—2.48 (m, 2H, CH_2), 2.18—2.10 (m, 2H, CH_2), 1.86—1.76 (m,

Table 2

Selected bond lengths (Å) *and angles* (deg.) *for compounds* **1** *and* **2**

Bond lengths		Bond angles		Bond lengths		Bond angles	
Compound **1**				Compound **2**			
C1—Br1	1.893(4)	C2—C1—Br1	117.8(3)	C1—Br1	1.904(4)	C2—C1—Br1	118.2(3)
C3—N1	1.412(5)	C6—C1—Br1	119.5(3)	C3—N2	1.362(4)	C6—C1—Br1	118.9(3)
S1—C4	1.745(4)	C2—C3—N1	118.9(4)	S1—C4	1.745(4)	C2—C3—N2	119.7(3)
N1—C7	1.446(5)	C4—C3—N1	122.7(3)	N1—C7	1.478(4)	C4—C3—N2	122.9(3)
N2—C7	1.475(5)	C3—C4—S1	120.8(3)	N2—C7	1.452(4)	C3—C4—S1	119.7(3)
S1—N2	1.625(3)	C5—C4—S1	118.6(3)	C9—N3	1.471(4)	C5—C4—S1	119.2(3)
S1—O1	1.434(3)	N1—C7—C8	119.0(3)	C10—N3	1.472(4)	N1—C7—C8	112.1(2)
S1—O2	1.430(3)	N1—C7—C10	116.2(3)	C12—N3	1.487(4)	N1—C7—C11	107.9(2)
		N1—C7—N2	108.4(3)	S1—O1	1.426(3)	N2—C7—C8	110.9(3)
		N2—C7—C8	114.3(3)	S1—O2	1.435(2)	N2—C7—C11	108.3(2)
		N2—C7—C10	109.3(3)	S1—N1	1.621(2)	N2—C7—N1	109.4(3)
		C3—N1—C7	118.9(3)			N3—C9—C8	110.0(3)
		C7—N2—S1	116.8(3)			N3—C10—C11	110.7(3)
		N2—S1—C4	102.55(18)			N3—C12—C13	113.5(3)
		O1—S1—C4	110.18(19)			O1—S1—C4	109.61(17)
		O1—S1—N2	107.08(19)			O2—S1—O1	116.80(14)
		O2—S1—C4	108.8(2)			O1—S1—N1	107.42(14)
		O2—S1—N2	109.50(18)			O2—S1—N1	109.67(14)
		O2—S1—O1	117.7(2)			N1—S1—C4	103.19(14)

2H, CH_2). ^{13}C NMR of compound **1** shows peaks at δ, ppm: 144 (C1), 119 (C2), 125 (C3), 126 (C4), 120 (C5), 117 (C6), 71 (C7), 39 (C8), 36 (C9), 13 (C10). The LC-MS spectrum shows the appearance of molecular ion peaks at *m*/*z* 301 and 305, confirming the structure of the compound.

The spectral analysis of compound **2** confirms its structure. The spectral data of the synthesized compounds are in full agreement with its proposed structure. The ^1H NMR spectrum of compound **2** shows peaks at δ, ppm: 7.49—7.47 (d, 1H, Ar—H, J = 8.4 Hz), 7.28 (s, 1H, SO_2NH), 6.98—6.96 (q, 1H, Ar—H, J = 3.3 Hz), 6.897—6.892 (d, 1H, Ar—H, J = 1.64 Hz), 4.58 (s, 1H, NH), 2.71—2.67 (m, 2H, CH_2), 2.59—2.49 (m, 4H, CH_2), 2.37—2.33 (d, 2H, CH_2, J = 16 Hz), 1.94—1.88 (q, 2H, CH_2, J = 2.6 Hz), 1.14—1.11 (t, 3H, CH_3, J = 6 Hz). In the LC-MS spectrum molecular ion peaks at *m*/*z* 361 and 363 of equal intensity confirm the structure of the compound.

Crystallography. The details of the crystal data and structure refinement of the compounds are given in Table 1. The selected bond lengths and bond angles for compounds **1** and **2** are given in Table 2. Table 3 gives the details of the respective hydrogen bonding and weak interactions in **1** and **2**. The

Table 3

Hydrogen bond geometry in **1** *and* **2**(Å, deg.) (D: *donor*; A: *acceptor*; H: *hydrogen*)

Compound **1** Cg represents the centroid of the benzene ring					Compound **2**				
D—H…A	D—H	H…A	D…A	D—H…A	D—H…A	D—H	H…A	D…A	D—H…A
N1—HN1…O2^{i}	0.86	2.60(1)	3.1113(1)	120(1)	N2—HN2…O2^{iv}	0.86	2.10(1)	2.9484(1)	170(1)
N2—HN2…Br1^{ii}	0.86	2.58(1)	3.1708(1)	127(1)	N1—HN1…N3^{v}	0.86	2.50(1)	3.0364(1)	121(1)
C10—H10B…O2^{i}	0.97	2.54(1)	3.2808(1)	133(1)	C10—H10B…O1^{vi}	0.97	2.49(1)	3.2259(1)	132(1)
C8—H8B…O2*	0.97	2.44(1)	3.1374(1)	129(1)	C12—H12B…O1^{vii}	0.97	2.56(1)	3.3775(1)	142(1)
Cg…Cg^{iii}	—	—	3.759(1)	—	C8—H8B…O2*	0.97	2.38(1)	3.0808(1)	129(1)

Symmetry code: ^{i} 1/2–x, 1/2+y, 1/2–z; ^{ii} –1/2+x, –1/2+y, z; ^{iii} 1–x, y, 1/2–z; ^{iv} x, 1/2–y, 1/2+z; ^{v} 1–x, 1/2+y, 1/2–z; ^{vi} 1–x, –1/2+y, 1/2–z; ^{vii} 1–x, 1–y, –z.

* Intra.

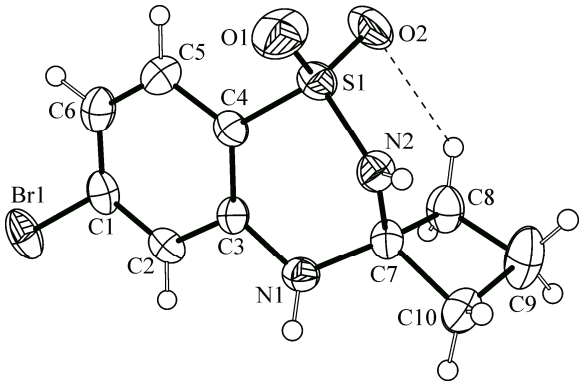


Fig. 1. Molecular structure of compound **1**, showing displacement ellipsoids drawn at the 50 % probability level.
Intramolecular hydrogen bonds are shown as dashed lines

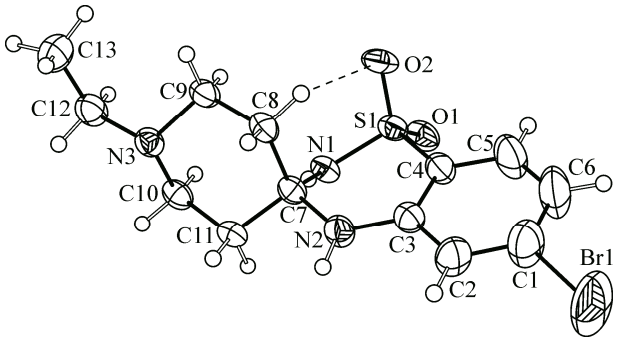


Fig. 2. Molecular structure of compound **2**, showing displacement ellipsoids drawn at the 50 % probability level.
Intramolecular hydrogen bonds are shown as dashed lines

ORTEP diagrams of molecules **1** and **2** with thermal ellipsoids drawn at a 50 % probability are respectively shown in Figs. 1 and 2. Further, the packing diagrams of **1** are shown in Figs. 3 and 4, whereas those of **2** are shown in Figs. 5 and 6.

Molecular structure. Compound **1** crystallizes in the monoclinic crystal system and space group $C2/c$ with the unit cell parameters $a = 15.8690(17)$ Å, $b = 12.1453(16)$ Å, $c = 12.0152(15)$ Å, $\beta = 99.686(7)°$, $Z = 8$ and $V = 2282.7(5)$ Å^3. The conformation of the 1,2,4-thiadiazinane ring in the structure is a twisted *chair* and is stabilized by the intramolecular C8—H8B…O2 interaction (Fig. 1), forming a S(6) graph set motif [36]. The twisted *chair* conformation of the 1,2,4-thiadiazinane ring is obtained from the puckering analysis [37]; puckering amplitude $(Q) = 0.4823$ Å, $\theta = 129.77°$, $\varphi = 277.4155°$. As predicted, the cyclobutyl ring has a puckered conformation. Further, the dihedral angle between the benzene ring and the mean plane (considering non-H atoms) of the cyclobutyl ring is 73.76(1)°, while that between the benzene ring and the mean plane (considering non-H atoms) of the 1,2,4-thiadiazinane ring is 4.72(1)°, and that between the mean plane (considering non-H atoms) of the cyclobutyl ring and the mean plane (considering non-H atoms) of the 1,2,4-thiadiazinane ring is 78.44(1)°.

Compound **2** crystallizes in the monoclinic crystal system and space group $P2_1/c$ with the unit cell parameters $a = 14.5748(6)$ Å, $b = 9.3340(5)$ Å, $c = 12.4283(6)$ Å, $\beta = 112.757(2)°$, $Z = 4$ and $V = 1559.14(13)$ Å^3. Similar to **1**, the conformation of the 1,2,4-thiadiazinane ring in the structure is a twisted *chair* and is stabilized by the intramolecular C8—H8B…O2 interaction (Fig. 2), forming a

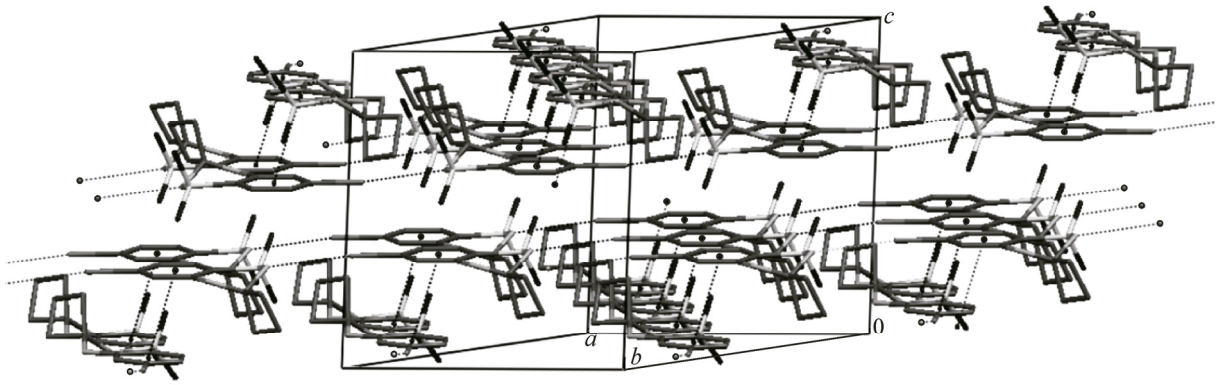


Fig. 3. Crystal Packing in **1** due to N—H…B rand π…π interactions.
H-atoms not involved in H-bonding are omitted for clarity purpose

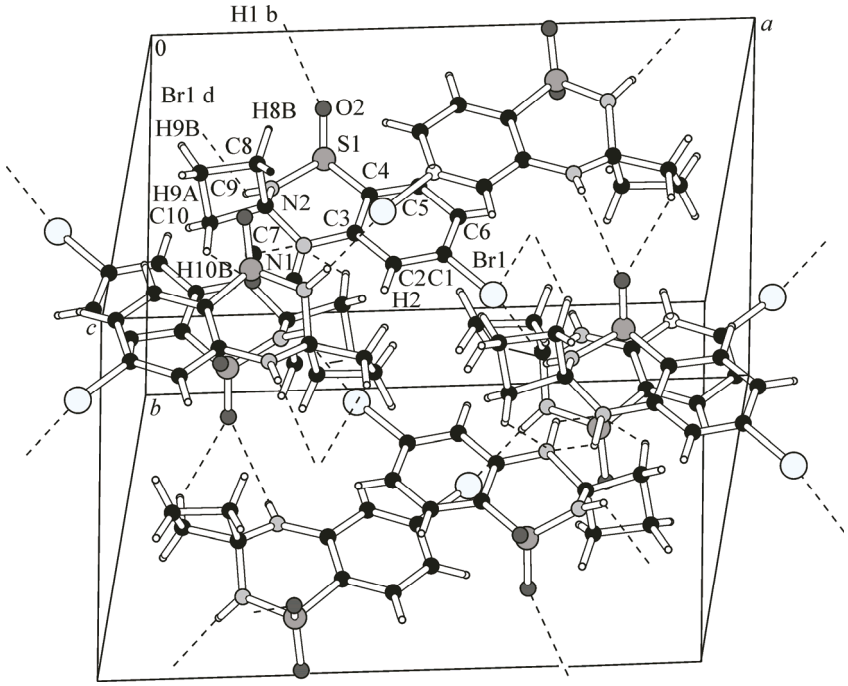


Fig. 4. N—H…O and C—H…O interactions in **1** generating three dimensional architecture

S(6) graph set motif [36]. The twisted *chair* conformation of the 1,2,4-thiadiazinane ring is verified from the puckering analysis [37]; puckering amplitude (Q) = 0.4321 Å, θ = 127.52°, φ = 260.7292°. Further, the piperidine ring in **2** has a *chair* conformation. The dihedral angle between the benzene ring and the mean plane (considering non-H atoms) of the piperidine ring is 73.76(1)°, while that between the benzene ring and the mean plane (considering non-H atoms) of the 1,2,4-thiadiazinane ring is 6.73(1)°, and that between the mean plane (considering non-H atoms) of the piperidine ring and the mean plane (considering non-H atoms) of the 1,2,4-thiadiazinane ring is 73.81(1)°.

Crystal structure. In the crystal structures of **1** and **2** different packing motifs are implemented with the formation of supramolecular assemblies of different types due to classical hydrogen bonds such as N—H…O, intermolecular interactions of the N—H…Br, N—H…N, C—H…O types and weak π…π stacking interactions.

In the crystal structure of **1** there are eight molecules in the unit cell. In the absence of any strong hydrogen bonds, the first stage of packing is controlled by N2—HN2…Br1 interactions. Table 3 gives the details of the contact distance and the symmetry of the intermolecular interaction. Each two molecules in the unit cell are linked to one another by N2—HN2…Br1 interactions forming C(8) chains (Fig. 3). Thus, four such chains pass through each unit cell. In the second stage of packing, the two neighbouring chains are linked to one another by C10—H10B…O2 and N1—HN1…O2 interactions

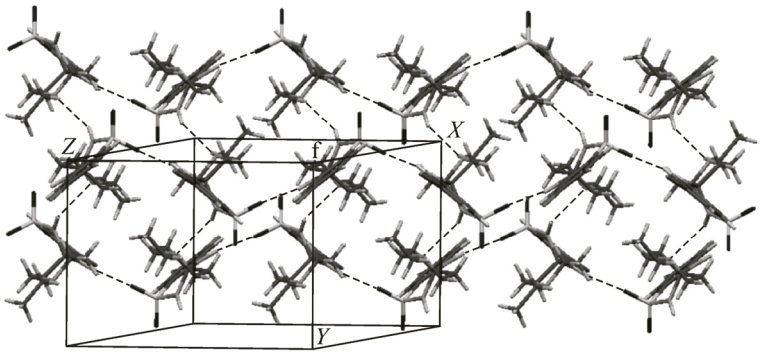


Fig. 5. Crystal packing in **2**, forming C(6) chains via N—H…O hydrogen bonds. Additional *zig-zag* C(6) chains are formed due to the N—H…N interactions

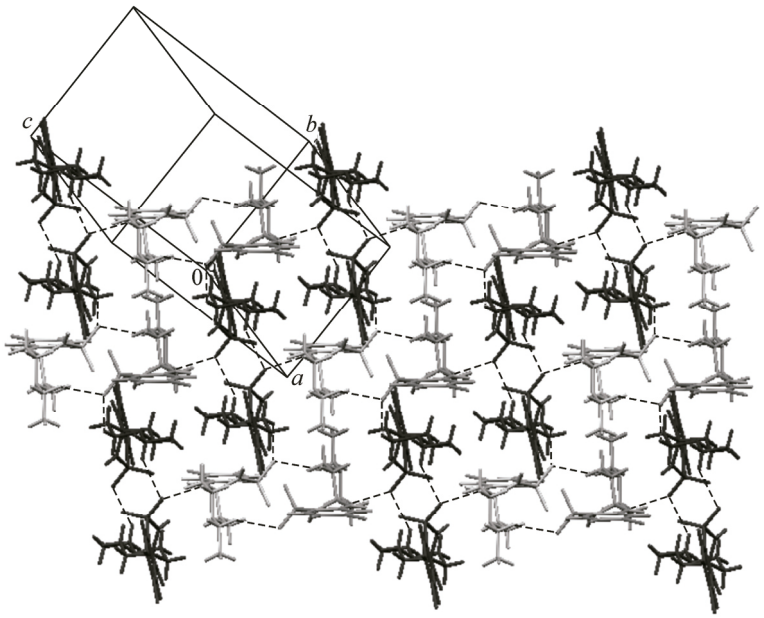


Fig. 6. Two dimensional architecture in **2** as a result of two C—H…O interactions bifurcated at the O atom, forming C(12) chains and $R_2^2(18)$ rings. For clarity purpose, the four molecules in the unit cell are shown with different colours

(Table 3), the interaction being bifurcated at the acceptor O2 atom. The second stage of interactions generate two C(6) chains (Fig. 4). The molecular packing is further strengthened by the π…π stacking interaction (Fig. 3) between the C(8) chains, forming a three dimensional supramolecular architecture.

However, in contrast to **1**, the unit cell in the crystal structure of **2** contains four molecules. These four molecules are interconnected to one another, forming a tetrameric unit via N1—HN1…O2 hydrogen bonds and N1—HN1…N3 intermolecular interactions. Also, in contrast to **1**, the first level of the molecular assembly in **2** is controlled by strong N—H...O hydrogen bonds (Table 3). Molecular pairs (1,2) and (3,4) are linked into C(6) chains through strong N2—HN2…O2 hydrogen bonds (Fig. 5), N2 being the piperidine nitrogen atom. Thus, the piperidine ring plays a significant role in controlling the supramolecular assembly. At the second level these chains are linked to one another via N1—HN1…N3 interactions (Table 3) where the molecular pairs (1,3) and (2,4) are linked via *zigzag* C(6) chains (Fig. 5). It is quite striking to see that **2** does not feature interactions of the N—H…Br type, but instead structure directing N—H…N interactions are observed. The *zigzag* chains are further interconnected to one another via two C—H…O interactions bifurcated at the acceptor O1 atom (Table 3, Fig. 6), namely C10—H10B…O1, forming C(12) chains and C12—H12B…O1 exhibiting the R22(18) ring motif [36]. The supramolecular architecture does not feature any π…π stacking since the distance between the two nearest centroids is 4.979 Å. Therefore, the supramolecular architecture in **2** exhibits a two dimensional architecture.

CONCLUSIONS

The present work describes the synthesis of two 1,2,4-benzothiadiazine derivatives and their characterization by IR, ^{1}H and ^{13}C NMR, and LC-MS techniques. Further, single crystal X-ray diffraction studies were carried out to study the molecular and crystal structures. In the crystal structures different packing motifs are implemented with the formation of supramolecular assemblies of different types due to a difference in the intermolecular and weak interactions. The supramolecular assembly in **1** is due to interactions of the N—H…Br, N—H…O, C—H…O types and a weak π…π interactions, while in **2**, the packing is controlled by strong N—H…O hydrogen bonds and intermolecular interactions of the N—H…N and C—H…O types. **1** exhibits a three dimensional supramolecular architecture, while in **2** it is two dimensional.

The authors are thankful to the X-ray diffractometer facility, University of Mysore, India. P.P. Shinoj, P.A. Suchetan, S. Sreenivasa, and D.B. Aruna Kumar are thankful to Tumkur University, Tumkur for providing the laboratory and instrumental facilities to carry out the work.

CCDC 1023519 & 1023520 contains the supplementary crystallographic data for this paper. These data can be obtained free of charge from the Cambridge Crystallographic Data Center, 12 Union Road, Cambridge CB2 1EZ, UK; fax: (+44) 1223 336 033; or e-mail: deposit@ccdc.cam.ac.uk.

REFERENCES

1. *Truhillo J.I., Kiefer J.R., Huang W. et al.* // Bioorg. Med. Chem. Lett. – 2009. – **19**. – P. 908 – 911.
2. *Lee C.-H., Jiang M., Cowart M. et al.* // J. Med. Chem. – 2001. – **44**. – P. 2133 – 2138.
3. *Cordi A., Spedding M., Serkiz B. et al.* // Chem. Abstr. (US Patent). – 1996. – **124**. – P. 261085.
4. *Sarisky R.T.* // J. Antimicrob. Chemother. – 2004. – **54**. – P. 14.
5. *Di Bella M., Monzani A., Andrisano M.G. et al.* // Farmaco [Sci]. – 1983. – **38**. – P. 466.
6. *Kamal A., Reddy K.S., Ahmed S.K. et al.* // Bioorg. Med. Chem. – 2006. – **14**. – P. 650.
7. *Impagnatiello F., Oberto A., Longone P. et al.* // Proc. Natl. Acad. Sci. U.S.A. – 1997. – **94**. – P. 7053.
8. *Wales J.K., Krees S.V., Grant A.M.J. et al.* // Pharmacol. Exp. Ther. – 1968. – **164**. – P. 421 – 432.
9. *Scozzofava A., Owa T., Mastrolorenzo A. et al.* // Curr. Med. Chem. – 2003. – **10**. – P. 925 – 953.
10. *Casini A., Scozzafava A., Mastrolorenco A. et al.* // Curr. Cancer Drug Targets. – 2002. – **2**. – P. 55 – 75.
11. *Scozzafava A., Casini A., Supuran C.T.* // Curr. Med. Chem. – 2002. – **9**. – P. 1167 – 1185.
12. *Arranz E.M., Díaz J.A., Ingate S.T. et al.* // Bioorg. Med. Chem. – 1999. – **7**. – P. 2811 – 2822.
13. *Wang Y., Busch-Petersen J., Wang F. et al.* // Bioorg. Med. Chem. Lett. – 2007. – **17**. – P. 3864 – 3867.
14. *Hayao S., Stryker W., Phillips B. et al.* // J. Med. Chem. – 1968. – **11**. – P. 1246 – 1248.
15. *Khelili S., Kihal N., Yekhlef M. et al.* // J. Med. Chem. – 2012. – **54**. – P. 873 – 878.
16. *de Tullio P., Servais A.-C., Fillet M. et al.* // J. Med. Chem. – 2011. – **54**. – P. 8353 – 8361.
17. *Francotte P., Goffin E., Fraikin P. et al.* // J. Med. Chem. – 2010. – **53**. – P. 1700 – 1711.
18. *Pirotte B., de Tullio P., Nguyen Q.-A. et al.* // J. Med. Chem. – 2010. – **53**. – P. 147 – 154.
19. *Francotte P., de Tullio P., Goffin E. et al.* // J. Med. Chem. – 2007. – **50**. – P. 3153 – 3157.
20. *Combrink K.D., Gulgeze H.B., Thuring J.W. et al.* // Bioorg. Med. Chem. Lett. – 2007. – **17**. – P. 4784 – 4790.
21. *Boverie S., Antoine M.-H., Somers F. et al.* // J. Med. Chem. – 2005. – **48**. – P. 3492 – 3503.
22. *Girard Y., Atkinson J.G., Rokach J.* // J. Chem. Soc., Perkin Trans. – 1979. – P. 1043 – 1047.
23. *Chern J.-W., Ho C.-P., Wu Y.-H. et al.* // J. Heterocycl. Chem. – 1990. – **27**. – P. 1909 – 1915.
24. *Cherepakha A., Kovtunenko V.O., Tolmachev A., Lukin O.* // Tetrahedron. – 2011. – **67**. – P. 6233 – 6239.
25. *Hirota S., Sakai T., Kitamura N. et al.* // Tetrahedron. – 2010. – **66**. – P. 653 – 662.
26. *Yang D., Liu H., Yang H. et al.* // Adv. Synth. Catal. – 2009. – **351**. – P. 1999 – 2004.
27. *Rolfe A., Hanson P.R.* // Tetrahedron Lett. – 2009. – **50**. – P. 6935 – 6937.
28. *Hirota S., Kato R., Suzuki M. et al.* // Eur. J. Org. Chem. – 2008. – P. 2075 – 2083.
29. *Blackburn C., Achab A., Elder A. et al.* // J. Org. Chem. – 2005. – **70**. – P. 10206 – 10209.
30. *Su W., Cai H., Yang B.J.* // Chem. Res. – 2004. – P. 87 – 88.
31. *Makino S., Nakanishi E., Tsuji T.* // J. Comb. Chem. – 2003. – **5**. – P. 73 – 78.
32. Bruker APEX2, SADABS and SAINT-Plus. Bruker AXS Inc., Madison, Wisconsin, USA, 2009.
33. *Sheldrick G.M.* // Acta Crystallogr. – 2008. – **A64**. – P. 112 – 122
34. *Farrugia L.J.* ORTEP-3 for WINDOWS-A Version of ORTEP-111 with a Graphical User Interface (GUI). // J. Appl. Crystallogr. – 1997. – **30**. – P. 565 – 566.
35. *Macrae C.F., Bruno I.J., Chisholm J.A. et al.* // J. Appl. Crystallogr. – 2008. – **41**. – P. 466 – 470.
36. *Bernstein J., Davis R.E., Shimoni L., Chang N.L.* // Angew. Chem. Int. Ed. Engl. – 1995. – **34**. – P. 1555 – 1573.
37. *Cremer D., Pople J.A.* // J. Am. Chem. Soc. – 1975. – **97**, N 6. – P. 1354 – 1358.