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Cover Page Footnote

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The purpose of this work is determination of crystal structure and Hirschfeld surface void analysis for many intermolecular interactions in the crystal structure of 1,3-dihydro-2H-benzimidazole-2-iminium-2-hydroxy-5-sulfobenzoate.. For the first time, a new organic salt containing organic benzimidazolium cations and sulfosalicylic anions was synthesized and structurally characterized. Hirshfeld surface analysis confirm that in the crystal shape most remarkable contacts are H···O (38%) and H···H (29.7%) There are some π–π stacking interactions in the crystal shape.

Keywords: benzimidazolium, sulfobenzoate, crystal structure, Hirshfeld surface analysis, void analysis

СИНТЕЗ, КРИСТАЛЛИЧЕСКАЯ СТРУКТУРА, ПОВЕРХНОСТЬ ХИРШФЕЛЬДА И АНАЛИЗ ПУСТОТ 2-ГИДРОКСИБЕНЗОАТА 2-АМИНО-1H-БЕНЗИМИДАЗОЛИЯ

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Целью данной работы является определение кристаллической структуры и анализ поверхностных пустот Хиршфельда для множества межмолекулярных взаимодействий в кристаллической структуре 1,3-дигидро-2H-бензимидазол-2-иминий-2-гидрокси-5-сульфобензоата.. Впервые синтезирована и структурно охарактеризована новая органическая соль, содержащая органические катионы бензимидазолия и сульфосалициловые анионыАнализ поверхности Хиршфельда подтверждает, что в форме кристалла наиболее заметными контактами являются H···O (38%) и H···H (29,7%). В форме кристалла наблюдаются некоторые π-π-стакинг-взаимодействия.

Ключевые слова: бензимидазолий, сульфобензоат, кристальная структура, анализ поверхности Хиршфельда, анализ пустот

2-AMINO-1H-BENZIMIDAZOL 2-GIDROKSIBENZOATNING SINTEZI, KRISTAL TUZILISHI, HIRSHFELD SIRT VA BO'SHLIQ TAHLILI

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Ushbu ishning maqsadi 1,3-dihidro-2H-benzimidazol-2-iminium-2-gidroksi-5-sulfobenzoatning kristal tuzilishidagi molekulalararo o'zaro ta'sirlarning xilma-xilligi uchun kristal tuzilishini aniqlash va sirt Xirshfeld bo'shliqlarini tahlil qilishdir. Organik benzimidazoliy kationlari va sulfosalitsil anionlarini o'z ichiga olgan yangi organik tuz birinchi marta sintezlanadi va strukturaviy xarakterlanadi. Xirshfeld sirt tahlili kristall shaklida eng ko'zga ko'ringan kontaktlar H···O (38%) va H···H (29,7%) ekanligini tasdiqlaydi. Kristal shaklida ba'zi p-p stacking o'zaro ta'sirlari kuzatiladi.

Kalit so'zlar: benzimidazol, sulfosalitsil kislota, kristal tuzilishi, Hirshfeld sirt tahlili, bo'shliq tahlili

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Introduction

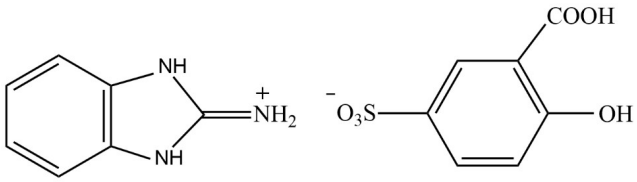
Growing interest to benzimidazole and its derivatives with application in medicine is a vigorous ongoing research subject due to multifunction biological activities [1]. Benzimidazole skeleton presents in several pharmaceutical compounds. Its derivatives are more relevant to biochemistry similar to pyridine or pyrazine derivatives, therefore it also deserves scrutinizing as supramolecular architectures of mixed-ligand metal complexes of the carboxylates and imidazole derivatives [2]. Moreover, some representatives of this chemical compounds have anti-hypertensive anti-allergic, anti-diabetic, anti-inflammatory, mycobacterium, anti-oxidant, anti-protozoal, antiviral and antimicrobial properties [3-5]. Several compounds containing a benzimidazole framework are important chemical classes due to their significant biological activities against several viruses such as HIV, herpes (HSV-1), influenza, Epstein-Barr and Burkitt's lymphoma

promotion [6] and have been studied as antiproliferative chemicals. Additionally, researchers are interested to explore their potential as anticancer agents with efforts to further explore this research area. The mechanism of anticancer action depends on strong metal ligand binding via the nitrogen atoms [7]. The sulfonic acid is a tridentate structure species. Similar proton donors have received significant interest as it may give complex with diverse supramolecular architectures. The sulfonic acid salts have a variety of properties applicable in synthetic and preparation chemistry [8, 9]. Now there is no structural data of the compounds between aromatic sulfonic acids and a biological active benzimidazole moieties.

A search of the Cambridge Structural Database (CSD, version 5.44, update of June 2023) showed 58 hits for cation moieties and 200 hits for 5-sulfosalicylic acid related crystal structures, similar to title compound (1). The first information about molecular structure of sulfosalicylic anion hydrate was reported at the 1975 [10]. Recently, metal organic compounds consisted from benzimidazole and sulfosalicylic units and possessed apart optical properties and charge transfer properties in complexes of organic species useful for developing new drugs [11-14] for glutathione depletion and lipid peroxidation testing and remarkable binding affinities with human serum albumin [15, 16].

The purpose of this work is determination of crystal structure and Hirschfeld surface void analysis for many intermolecular interactions in the crystal structure of 1,3-dihydro-2H-benzimidazole-2-iminium-2-hydroxy-5-sulfobenzoate.

The synthesis, determination of crystal structure, Hirshfeld surface, void analyses of the title organic salt, $C_7H_8N_3^+ \cdot C_7H_5O_5SO^-$, 1,3-dihydro-2H-benzimidazol-2-iminium 2-hydroxy-5-sulfobenzoate, (**I**) related to its nitro analogue [17].



Method and materials

All reagents were commercially available without purification and purchased from Sigma-Aldrich.

The crystals of the title compound, 1,3-dihydro-2H-benzimidazol-2-iminium 2-hydroxy-5-sulfobenzoate, were synthesized and grown as single crystals by slow evaporation method using mixture solutions of 2-aminobenzimidazole with sulfosalicylic acid in the 1:1 M ratio in 5ml of ethanol. The mixture solution was continuously stirred under room temperature 4 hour. The final solution was filtered using filter paper to remove the impurities and kept in dust-free environment for the growth of single crystal at room temperature. After two weeks, the grown crystals were separated and further purified using repeated recrystallization method. The light brown crystal suitable for X-ray diffraction was obtained.

Data collection / cell refinement / data reduction: *CrysAlis Pro* (Rigaku OD, 2020) [18]; program(s) used to solve shape: *SHELXS97* [19]; program(s) used to refine shape: *SHELXL* [20] in *OLEX2 1.3* [21]; molecular visual: *ORTEP-3* for Windows [22], *Mercury* [23]; software used to prepared matter for publication: *OLEX2* [24], *PLATON* [25] and *publCIF* [26]. The main crystallographic data and structure refinement parameters are given in Table 1.

Table 1

Crystallographic data

Parameter	Meaning	Parameter	Meaning
Molecular weight	351.(33)	Temperature/K	293(2)
Crystal system	triclinic	Space group	P- 1
a/ Å	7.5228(3)	Z	2
b/ Å	8.4968(3)	ρcalcg/cm3	1.491
c/Å	12.7128(6)	μ/mm^{-1}	2.192
α/°	79.754(4)	F(000)	364
β/°	80.333(4)	Crystal size/mm3	0.48 × 0.18 × 0.08
γ/°	81.471(3)	Radiation	CuKα (λ=1.54184)
Volume/Å^3	782.72(6)		

Results and Discussion

The asymmetric unit of the title compound (Fig. 1) contains a centrosymmetric benzimidazoliminium cations and sulfobenzoate anions bridging imidazole moieties with oxygens of adjacent anions. In the coordination of organic ions, bond lengths range from 1.308 (3) to 1.465 (4) Å, while bond angles range from 110.15 (3) to 113.57 (2) (Table 2). The lengths and angles in the organic salt show a slight deviation from standard parameters of known crystal structures [13, 17, 27].

The two ring parts of cation almost coplanar, with deviation of 0.81 °, whereas imidazolium ring plane shows deviation from respective CNHH plane with value of 1.77 °. The subjacent benzene-benzene and imidazole-imidazole planes are parallel, with distances of 3.339-3.452 Å and 3.348-3.488 Å, respectively. The anion benzene ring plane shows maximum deviation in respect to its pseudo-ring (C10/C11/O4/H4/O5/C14) with deviation of 1.11 °. The adjacent benzene-benzene planes distances of sulfobenzoate anions are 3.345-3.589 Å, with the sulfur atom lying on former planes. And finally, the crossing of cations and anions planes forms angle of 65.54 °.

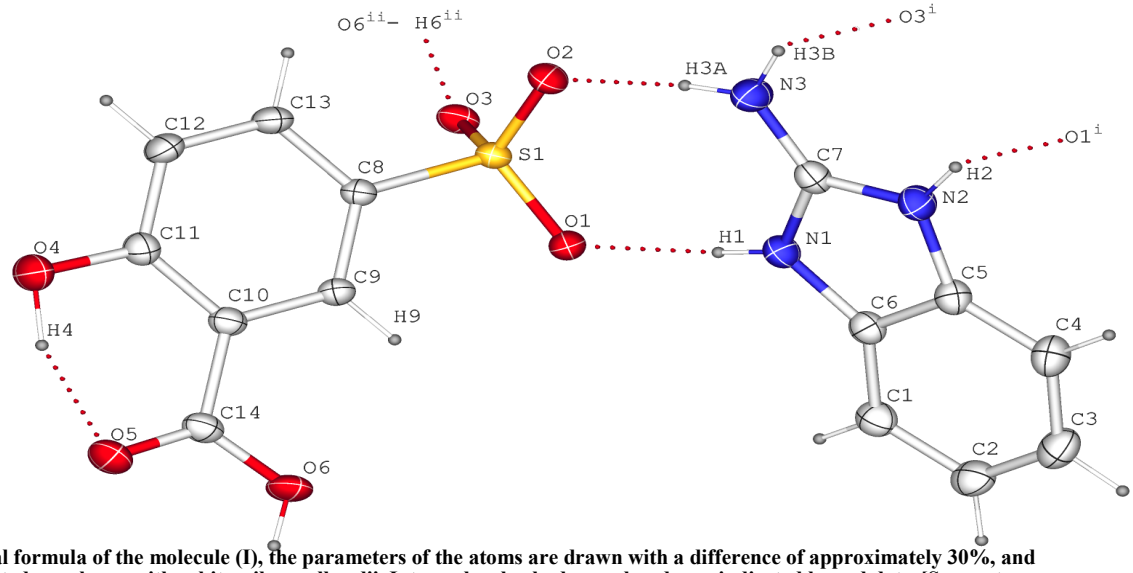


Figure 1. The structural formula of the molecule (I), the parameters of the atoms are drawn with a difference of approximately 30%, and the H atoms are depicted as spheres with arbitrarily small radii. Intermolecular hydrogen bonds are indicated by red dots. [Symmetry codes: (i) x + 1, y, z; (ii) x, y - 1, z.]

Table 2

Selected geometric parameters (Å, °)

N1 – C6	1.395 (3)	S1 – O1	1.4604 (16)
N2 – C5	1.392 (3)	S1 – O2	1.4382 (17)
N1 – C7	1.342 (3)	S1 – O3	1.4650 (16)
N2 – C7	1.350 (3)	O1 – S1 – O2	113.578
N3 – C7	1.307 (3)	O1 – S1 – O3	110.153
S1 – C8	1.757 (2)	O2 – S1 – O3	112.535

In the centrosymmetric structure of organic salt (**I**), the imidazolium N-H groups form strong hydrogen bonds with the sulfate group oxygens of hydroxybenzoate anion (Fig.1, Table 3).

The intersection of OSO planes of two formed pseudo-rings (N1/C7/N3/O2/S1/O1 and $N2^{*}/C7^{*}/N3^{*}$/O3/S1/O1, where * is x+1, y, z) with the HNCNH imidazole planes are equivalent to 6.85 and 45.70 º. The long O4–H4 bond with value of 0.982 Å is disordered and displaced to oxygen atom of carboxyl group, thus forming very strong intramolecular hydrogen bond with value of 1.684 Å. The relative cation-anion hydrogen interaction lead to chains along *a* (*i.e.,* 011). The subjacent cation molecules have head-to-tail shape, whereas bonded to them hydroxybenzoate sulfo-groups are

Table 3

Hydrogen-bond geometry (Å, °). C–H···O are the vdW contacts

D – H···*A*	*D* – H	H···*A*	*D*···*A*	*D* – H···*A*
N1–H1···O1	0.86	1.9900	2.843 (2)	176.00
N2–H2···O1^{i}	0.86	2.0600	2.914 (2)	169.00
N3–H3A···O2	0.86	1.9700	2.815 (3)	168.00
N3–H3B···O3^{i}	0.86	2.0800	2.880 (3)	154.00
O4–H4···O5	0.98 (4)	1.69 (4)	2.604 (3)	154.3
O6^{ii}–H6^{ii} ···O3	0.82 (3)	1.84 (3)	2.647 (2)	169.3
C9–H9···O1	0.93	2.4900	2.881 (3)	106.00
C9–H9···O6	0.93	2.4000	2.713 (3)	100.00

displaced tail-to-tail form with S–S separation of 6.763 Å. The hydrogen bonds lead to the formation of chains parallel to a axis. Such arrangement is strengthened by π···π stacking interactions between neighboring benzimidazolium cations [benzene-benzene centroid = 3.895 (1) Å, imidazole-imidazole centroid = 3.530 (1) Å, with shift planes of 2.006 and 0.542, respectively] and hydroxybenzoate anions [benzene-benzene centroids range from 4.021 to 5.676 Å, with shift planes of 1.815 and 42586, Fig. 2]. The two-dimensional network of (**1**) is assembled from all these intermolecular contacts and interactions (Fig. 3).

In the centrosymmetric structure of organic salt (1), the imidazolium N-H groups form strong hydrogen bonds with oxygens of carboxyl group of hydroxybenzoate anion (Fig.1, Table 3). The $C_7H_8N_3^+ \cdot C_6H_5OCOO^-$ ionic compound is formed via hydrogen bonds N1−H1···· O3[1], N2−H6 ···· O2[2](Fig. 1). In this complex, there are intramolecular and intermolecular hydrogen bonds, and the hydrogen bond lengths are given in Table 3 below. From this we can see that the hydrogen bond lengths between the same atoms are different and the angles between them are also different: N3−O2−C14 128.29(2)° and N2−O3−C14 110.33 (2)°.

A Hirshfeld surface (HS) evaluated using *Crystal Explorer 21.5* [28] in order to explore the non-covalent reciprocities in terms of the Hirshfeld surface and two-dimensional fingerprint plots. The Hirshfeld Surface of a molecule is the region in the crystal where the electron density acceptive to the procrystal [29, 30]. The HS is built by employing

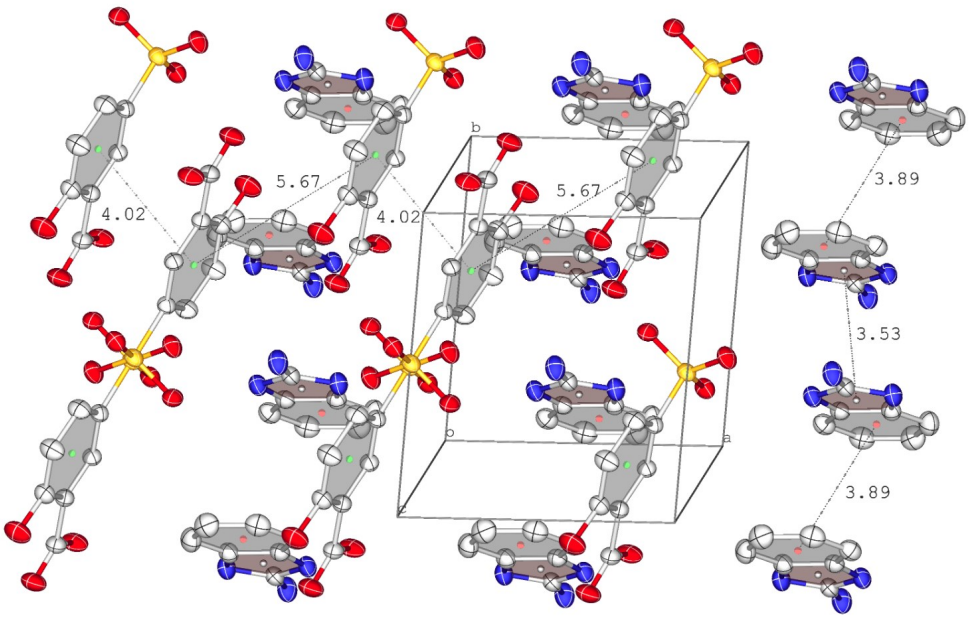


Figure 2. π···π stacking in the crystal structure of (1). Hydrogen atoms and water molecules are omitted for clarity.

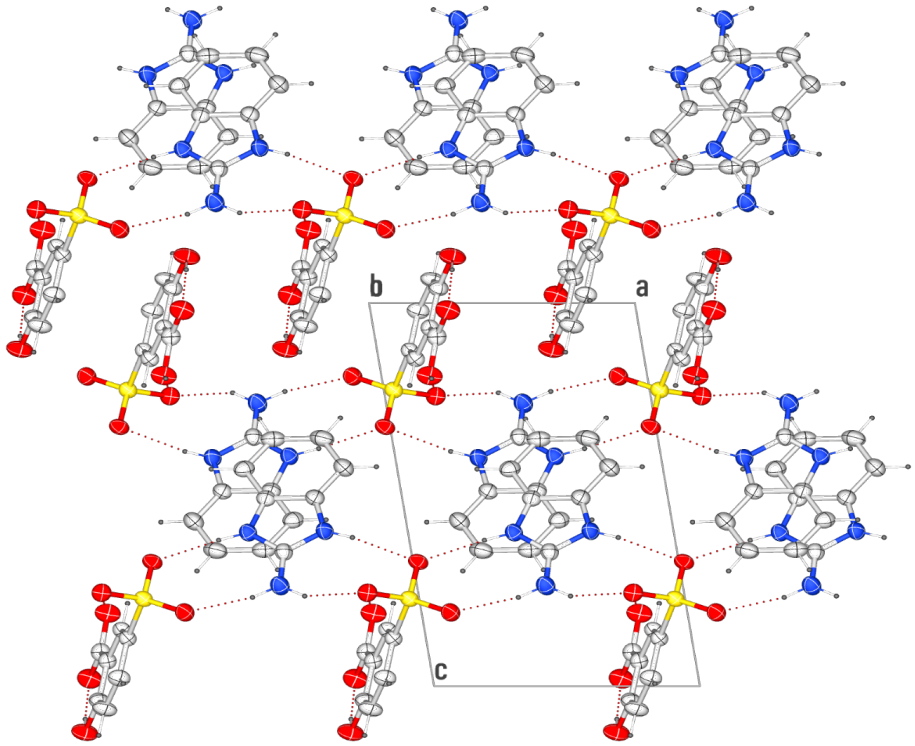


Figure 3. View of the crystal structure of (1) along [010], showing N—H···O and O—H···O hydrogen bonds drawn as red dotted lines.

color encrypt to show the interatomic contacts that are short (red areas), equal to (white areas), or longer than (blue areas) the sum of the Van der Walls radii [32, 33]. The red spots on the analysis showed over d_{norm} (Fig. 4*a*) acted the involvement of atoms in hydrogen-bonding interactions. The Hirshfeld surface showed over shape-index (Fig. 4*b*) is used to check for the presence of correlations such as C−H· · ·π and π-π stacking [32, 33]. The adjacent blue and red triangular regions around the aromatic rings coincide to the presence of π-π stacking correlations in the new compound.

The HS d_{norm} for (Fig. 5) is represented by density weight function of nearest molecules neighbor, when the red spots are due to short interatomic contact in the crystal lattice, associated to strength hydrogen bonds between acceptor-donor groups.

Two-dimensional fingerprint drawings ensure unique report about the non-covalent reciprocity and the crystal packing in terms of the interatomic contacts percentage segment [31-33]. Fig. 6a

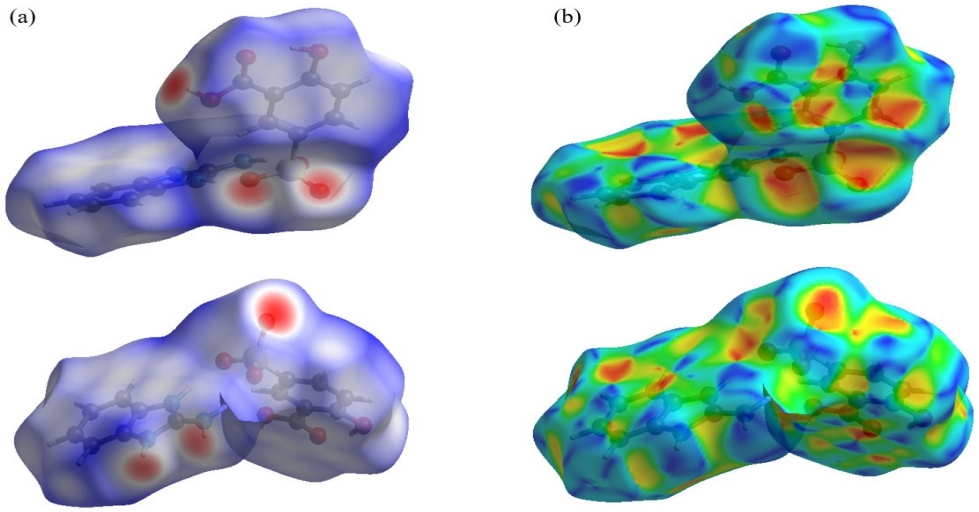
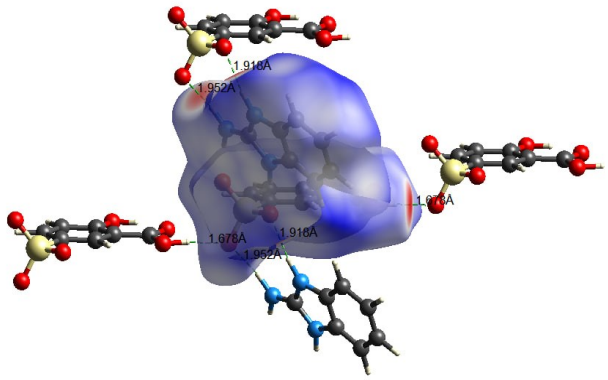


Figure 4. HS plotted over (*a*) d_{norm} in the range – 0.7234 to 1.4221 a.u. and (*b*) shape-index in the range – 1 to 1 a.u.



depicts the fingerprint domain of the total interatomic interactions in the complex, where d_i is the internal and d_e is the external distances. The highest index of interatomic interactions H· · ·O (Fig. 6b) belongs to these atoms and makes up 38% of the crystal packing. The next higher indicators belong to the connections between H· · ·H (29.7%, Fig. 6c) and H· · ·C (13.7%, Fig. 6d). In contrast, others indicator have relatively smaller percentages of the crystal packing and illustrated in Fig. 6e–k. The compound volume in the space of the crystal package is equal 113.51 Å3 (Fig.7).

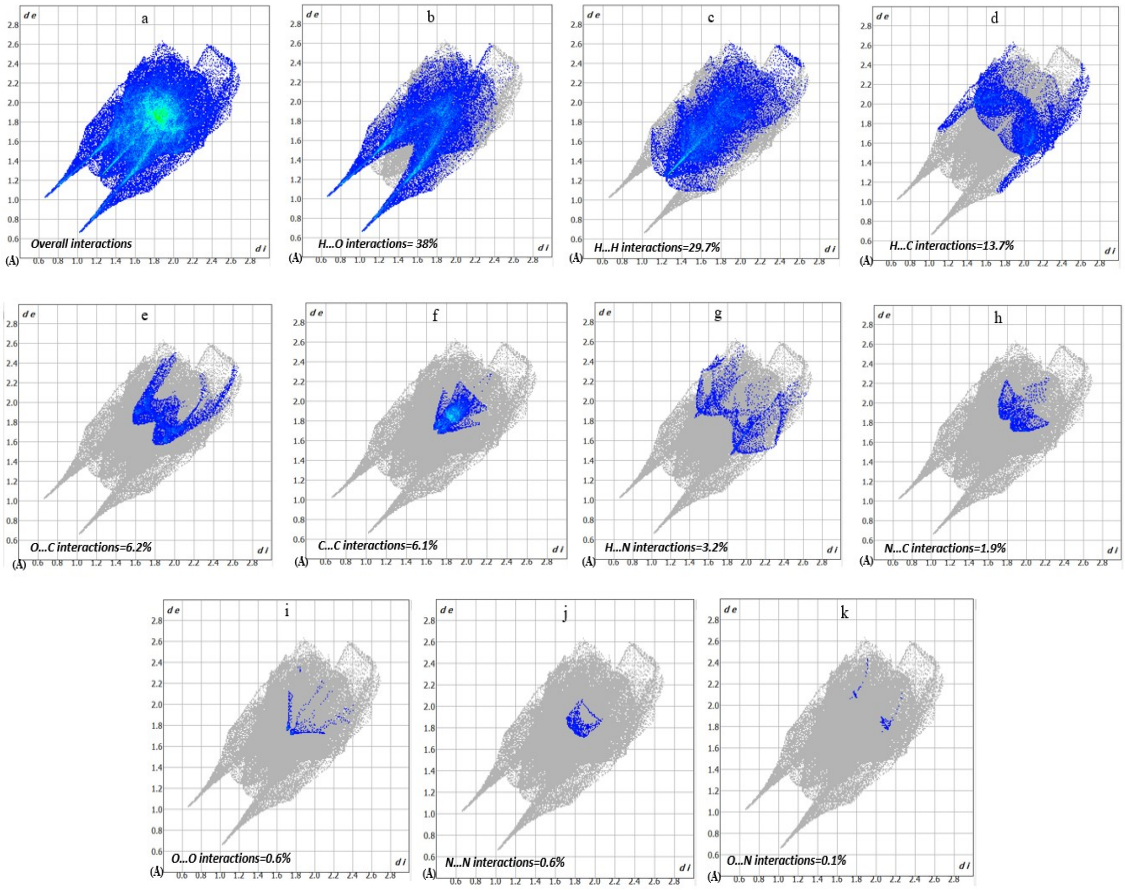


Figure 6. Two-dimensional fingerprint plots of complex for (*a*) all interactions and (*b*)–(*k*) individual interatomic contacts.

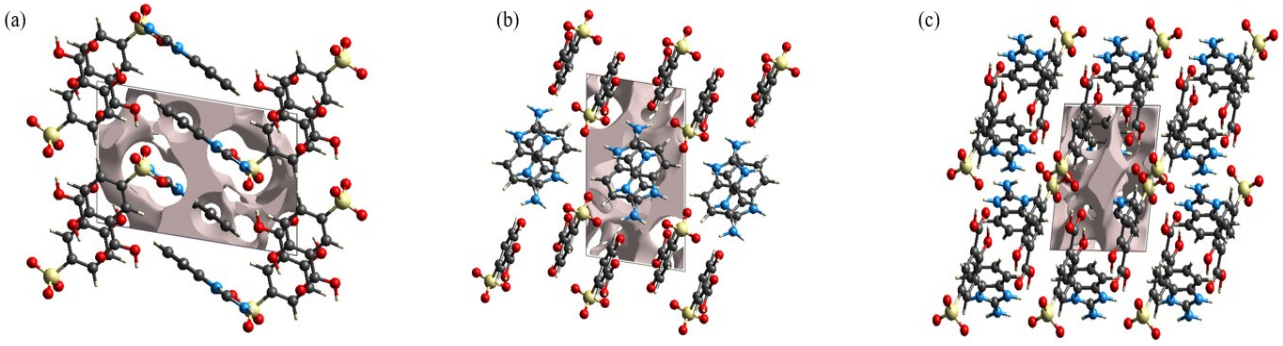


Figure 7. Graphical representations of compound in a view (a) along a axis, (b) along the b axis and (c) along the c axis.

Conclusion

For the first time, a new organic salt containing organic benzimidazolium cations and sulfosalicylic anions was synthesized and structurally characterized. The compound structure is an ion pair which have sulfosalicylate as an organic anion. Hirshfeld surface analysis confirm that in the crystal shape most remarkable contacts are H···O (38%) and H···H (29.7%) There are some π–π stacking interactions in the crystal structure.

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