Quantitative investigation of intermolecular interactions in dimorphs of 3-Chloro-*N*-(2-fluorophenyl)benzamide and 2-Iodo-*N*-(4-bromophenyl)benzamide

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Abstract. In this study, we have analyzed the role of different intermolecular interactions in the polymorphic modifications of 3-chloro-*N*-(2-fluorophenyl)benzamide (**I**) and 2-iodo-*N*-(4-bromophenyl)benzamide (**II**). The crystals were obtained *via* slow evaporation method with the alteration of solvents for crystallization. The already reported form [*Cryst. Growth Des.* (2011) 11:1578] crystallizes in $P2_1/c$ with $Z'=2$ [Form **IA**], while the new form crystallizes in $Pna2_1$ with $Z'=1$ [Form **IB**]. The latter compound crystallizes in $P2_1/n$ with $Z'=1$ [Form **IIA**] and in $Pbca$ with $Z'=1$ [Form **IIB**]. Weak $\text{Cl} \cdots \text{Cl}$ and $\text{C-H} \cdots \text{F}$ interactions in the former (**IA**, **IB**) and weak $\text{I} \cdots \text{I}$ and $\text{C-H} \cdots \pi$ interactions in the latter (**IIA**, **IIB**) play a vital role in the formation of different polymorphic modifications leading to the observation of conformational and packing polymorphs, respectively. PIXEL calculations show that most of the interactions present in the crystal structures are dispersive in nature. 2D Fingerprint plots revealed that the relative contribution of different intermolecular interactions in different polymorphic forms was different.

Keywords. Halogen; benzamides; intermolecular interactions; dispersion; polymorphs.

1. Introduction

Polymorphism is the existence of more than one distinct crystalline phase having different arrangement of molecules in the crystal lattice which may result in different properties.¹⁻⁴ The commonly observed polymorph is either conformational or packing polymorph form. Conformational polymorph is the existence of crystal forms of the same molecule in different conformers,⁵⁻¹⁰ whereas the packing polymorphs are observed on account of different arrangements of the molecule in the crystal lattice.^{11,12} A recent statistical review on polymorphism concluded that one in two compounds displays polymorphism when screened for its existence.¹³ However, polymorphism is an unpredictable phenomenon and it is very difficult to truly

understand the occurrences of polymorphism in a given molecule.¹⁴⁻¹⁸ Also, polymorphic transitions may directly affect the presence of weak intermolecular interactions present in a crystal structure while strong interactions largely remain unaffected. Further, presence of halogens creates a direct competition between the contribution of hydrogen and halogen bonding in the crystal packing of a given molecule and hence quantitative analysis of various interactions in different polymorphs is of interest.^{19,20}

The benzamide moiety is found in a wide range of biologically active molecules and substituted benzamides have been used as insecticides, antiviral, and anti-inflammatory agents.²¹⁻²⁵ These compounds with variability in conformation are influenced by both electronic and structural effects.^{26,27} A systematic study on halogen substituted benzamide has revealed that strong $\text{N-H} \cdots \text{O}=\text{C}$ interactions largely remain preserved in

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Scheme 1. Molecular diagram of 3-chloro-N-(2-fluorophenyl)benzamide (**I**) (Form **IA**, **IB**) and 2-iodo-N-(4-bromophenyl)benzamide (**II**) (Form **IIA**, **IIB**) with the numbering scheme.

the crystal structures while the contribution of different weak interactions such as C-H $\cdots$ O, C-H $\cdots$ X, X $\cdots$ X and interactions involving π systems may differ depending on the molecular conformation and packing.^{28–35} In this regard, we present here, the observation of polymorphic modifications of two compounds, namely, 3-chloro-N-(2-fluorophenyl)benzamide (**I**) [Forms **IA**, **IB**] and 2-iodo-N-(4-bromophenyl)benzamide (**II**) [Forms **IIA**, **IIB**] (Scheme 1). Form **IA** was already reported in our previous study,³¹ and is utilized in this work for detailed comparison between the polymorphs. The aim of this work was to quantitatively study the formation of polymorph in terms of contribution of different intermolecular interactions towards the crystal packing of different polymorphs.

2. Experimental

2.1 Synthesis of the compound and experiments on crystallization

The compounds **I** and **II** (Scheme 1) were synthesized by the reaction of 3-chlorobenzoyl chloride with 2-fluoroaniline and 2-iodobenzoyl chloride with 4-bromoaniline, respectively.^{30–32} Small amounts of the compounds were taken in several 5 mL beakers and dissolved in different solvents and combination of solvents separately. The crystals were grown by slow evaporation method at $\sim 25^\circ\text{C}$. It was observed that crystals of different morphologies were obtained in both examples. The new form of Compound **I** forms plate (**IB**) from methanol and acetonitrile (2:1, v/v) solvents. Compound **II** forms needle shaped crystals (**IIA**) from ethyl acetate and block-shaped crystals (**IIB**) from acetonitrile (Figure 1).

Figure 1. Morphological changes observed on crystallization from different solvents, plates for (**IB**) and needles and blocks for (**IIA**, **IIB**), respectively.

2.2 X-ray data collection

As stated earlier, the single crystal diffraction data for Form **IA** of 3-chloro-N-(2-fluorophenyl)benzamide (**I**) has already been reported.³¹ A suitable single crystal of **IB** was selected and data were collected on a Bruker AXS SMART APEX CCD diffractometer.³⁶ The X-ray generator was operated at 50 kV and 35 mA using MoK α radiation ($\lambda = 0.71073 \text{ \AA}$). Data were collected with ω scan width of 0.3° . A total of 606 frames were collected in three different settings of φ (0° , 90° , 180°) keeping the sample to detector distance fixed at 6.03 cm and the 2θ value fixed at -25° . The data were reduced using SAINTPLUS and an empirical absorption correction was applied using the package SADABS.³⁶ The crystals [**IIA**, **IIB**] were recollected in CrysAlis CCD, Oxford Diffraction with X-ray generator at 49.30 kV and 0.980 mA, using MoK α radiation ($\lambda = 0.7107 \text{ \AA}$). The cell refinement and the data reduction were done in CrysAlis RED.³⁷ The structures were solved by direct methods using SHELXL97,³⁸ present in the program suite WinGX (version 1.70.01).³⁹ The molecular diagrams and the packing diagrams were generated using CSD Mercury.⁴⁰ Geometrical calculations were done using PARST95,⁴¹ and PLATON.⁴² The non-hydrogen atoms are refined anisotropically and hydrogen atoms bonded to C and N atoms were positioned geometrically and refined using a riding model with distance restraints of N-H = $0.86 \text{ \AA}$, aromatic C-H = $0.93 \text{ \AA}$ and with Uiso(H) = 1.2 Ueq(N,C) . Table 1 lists all the crystallographic details. Selected torsion angles and dihedral angles are listed in Table S1 (in Supplementary Information). Intramolecular interactions are listed in Table S2 (in SI) and intermolecular interactions along with interaction energies are listed in Table S3 (in Supplementary Information).

2.3 Theoretical calculations

PIXEL method,^{43–45} present in the CLP module was utilized to evaluate the lattice energies of different polymorphs and the strength of different intermolecular interactions participating in crystal packing. PIXEL is a computationally inexpensive method for a quantitative investigation of intermolecular interactions and has been utilized extensively in similar studies.^{46–48} Another advantage is that it provides

Table 1. Crystallographic Information.

	IB	IIA	IIB
Formula	C ₁₃ H ₉ NOFCI	C ₁₃ H ₉ NOIBr	C ₁₃ H ₉ NOIBr
Formula weight	249.7	402.0	402.0
Temperature (K)	292(2)	292(2)	292(2)
Crystal system	Orthorhombic	Monoclinic	Orthorhombic
Crystallized from solvents	Methanol & Acetonitrile	Ethyl acetate	Acetonitrile
Morphology	Plate	Needle	Block
Size of crystals (mm)	0.24x0.18x0.12	0.25x0.14x0.05	0.32x0.28x0.25
CCDC No.	751295	751296	751297
Space group	<i>Pna</i> 2 ₁	<i>P</i> 2 ₁ / <i>n</i>	<i>Pbca</i>
<i>a</i> (Å), <i>b</i> (Å), <i>c</i> (Å)	9.605(3), 24.774(7), 4.886(1)	12.397(5), 5.197(5), 20.471(5)	9.480(6), 13.742(7), 20.205(9)
β (°)	90	93.623(5)	90
Volume (Å ³)	1162.9(6)	1316.2(1)	2632.3(2)
<i>Z</i>	4	4	8
Density (g cm ⁻³)	1.43	2.03	2.029
μ (mm ⁻¹)	0.322	5.451	5.451
<i>F</i> (000)	511.9	759.9	1519.8
$\theta_{\min, \max}$ (°)	1.6, 25.0	3.3, 26.0	3.1, 25.0
<i>h</i> _{min, max} ; <i>k</i> _{min, max} ; <i>l</i> _{min, max}	−11, 11; −29, 29; −5, 5	−15, 15; −6, 6; −25, 25	−11, 11; −16, 16; −24, 24
Reflections measured	10685	34747	23666
Unique reflections	1157	2589	2314
No. of parameters	154	154	155
<i>R</i> _{all} , <i>R</i> _{obs}	0.046, 0.042	0.059, 0.029	0.059, 0.036
<i>wR</i> _{2_all} , <i>wR</i> _{2_obs}	0.099, 0.097	0.067, 0.062	0.082, 0.078
$\Delta \rho_{\min, \max}$ (eÅ ⁻³)	0.254, −0.126	0.649, −0.502	0.699, −0.578
G.o.F	1.236	0.889	0.937

*The crystal data of Form (IA) is already reported in reference 28.

total interaction energies partitioned into coulombic, polarization, dispersion and repulsive energy components which help in gaining deeper insights into the nature and characteristics of intermolecular interactions. All the calculations were performed at the default MP2 level utilizing 6-31G** basis set for all atom except for Iodine atom. For Iodine, 6-311G** basis set was used. The basis set for the iodine atom was obtained from EMSL basis set library.^{49,50} 2D Fingerprint plot,^{51,52} was plotted using the software program Crystal Explorer 3.1.⁵³

Table 2. Lattice Energy (kJ/mol) partitioned into Coulombic, Polarization, Dispersion, and Repulsion Contributions by Atom–Atom CLP Method.

	<i>E</i> _{elec}	<i>E</i> _{pol}	<i>E</i> _{disp}	<i>E</i> _{rep}	<i>E</i> _{tot}
IA	−47.7	−22.1	−134.8	81.6	−123.0
IB	−59.0	−26.2	−131.3	88.4	−129.0
IIA	−63.9	−33.7	−156.1	120.0	−133.7
IIB	−72.7	−32.5	−156.7	123.2	−138.8

3. Results and Discussion

3.1 Crystal structure analysis of I

Form (IA) crystallizes in the space group with *P*2₁/*c* with two symmetry independent molecules (*Z*'=2).²⁸ The torsion around the amide bond in the two symmetry independent molecules (A and B) are −175.8(3)° and 172.0(3)°, respectively (Figure S1(a) in SI). The lattice energy of Form (I) was calculated to be −123.0 kJ/mol (Table 2). An intramolecular C–H ··· O interaction in both the molecules of the asymmetric unit restricts the molecular conformation (Figure 2, Table S2). Table S3 (in Supplementary Information) contains

the list of different intermolecular interactions present in Form (IA) along with their geometrical parameters and interaction energies. The two molecules in the asymmetric unit are connected *via* two C–H ··· π interactions (involving highly acidic H2' and H12') with a stabilization energy of −24.2 kJ/mol (motif V, Figure 3). The most stabilized molecular pair in Form (IA) consists of strong N–H ··· O=C interaction which forms a molecular chain along *b*-axis (Figure 4(a)). The molecular pairs are further stabilized by the presence of a unique C–F ··· O interaction in addition to multiple π ··· π interactions involving the carbon atoms of aromatic ring Cg1 and Cg2 (Cg1: C1–C6; Cg2: C8–C13)

Figure 2. (a) Form **IB**, (b) Form **IIA**, and (c) Form **IIB** are drawn with 50% ellipsoidal probability with the atom numbering scheme. Dotted lines indicate the presence of different intramolecular interactions in the asymmetric unit.

Figure 3. Molecular pairs **I - XII** of Form (**IA**) arranged with decreasing interaction energies.

Figure 4. Packing diagram of Form (**IA**) showing the utilization of different molecular motifs.

rings [motif **I**]. The second molecule in the asymmetric unit also forms a molecular chain along the *b*-axis due to the presence of strong $\text{N-H} \cdots \text{O}=\text{C}$ interaction in addition to the $\pi \cdots \pi$ interactions involving the atoms of Cg3 and Cg4 rings (Cg3: C1'-C6'; Cg4: C8'-C13')

(motif **II**, Figure 4(a)). Both motifs **I** and **II** have similar interaction energy of -44.2 kJ/mol and -42.3 kJ/mol, respectively (Table S3 in SI). It is worth noting that in both the motifs, the percentage contribution of dispersion energy [motif **I**: $\sim 48\%$; motif **II**: $\sim 51\%$] towards

Figure 5. Molecular pairs I - VII of Form (**IB**) arranged with decreasing interaction energies.

Figure 6. Packing diagram of Form (**IB**) showing the utilization of different molecular motifs.

stabilization was similar to the percentage contribution from the sum of electrostatic and polarization components [motif **I**: ~52%; motif **II**: ~49%]. The molecular chains formed by motif **I** is interconnected to another similar chain *via* the formation of a C-H $\cdots$ Cl interaction involving highly acidic H4 atom [Motif **VII**, - 11.4 kJ/mol]. A dimeric C-H $\cdots$ Cl interaction (involving highly acidic H4') [Motif **IX**, - 8.5 kJ/mol] interconnects the molecular chains formed by motif **II**. C-H $\cdots$ Cl interactions were dispersive in nature with at least 65% contribution towards stabilization. Packing down the *ab*-plane is also stabilized by the presence of highly dispersive molecular pairs [motif **X**, - 7.2 kJ/mol and motif **XI**, - 5.9 kJ/mol] which provide additional stability to the molecular packing. The molecular packing of Form (**I**) was further governed by the formation of similarly stabilized molecular motifs **IV** (- 25.1 kJ/mol) and **V** (- 24.2 kJ/mol). Both the motifs are governed by presence of directional C-H $\cdots$ π interactions (Table S3, Figure 4(b)). The organic fluorine attached to the aromatic carbon also contributes significantly towards the molecular packing (Figure 4(a),(b)). In motif **III**, the nucleophilic fluorine interacts with the electrophilic

carbonyl group and forms a highly stabilized molecular with additional stability provided by presence of $\pi \cdots \pi$ stacking interaction [- 30.2 kJ/mol]. Organic fluorine is also involved in the formation of two short and directional C-H $\cdots$ F-C interaction (motif **VI**, Table S3), the interaction energy is - 15.9 kJ/mol, the electrostatic contribution being ~33%. The high electrostatic contribution can be attributed to the involvement of the most acidic hydrogen H10 in the formation of one of the C-H $\cdots$ F-C interaction in motif **VI**. The packing is further supported by presence of a C-H $\cdots$ π interaction [motif **VIII**, - 8.8 kJ/mol] and a type I Cl $\cdots$ Cl interaction [3.332Å; 166°, 164°] down the *ab*-plane (motif **XII**, Figure 4(c)).

Form (**IB**) crystallizes as plates in the non-centrosymmetric space group *Pna*2₁ with *Z*'=1 [Table 1]. The torsion angle around the amide (C1-C7-N1-C8) bond is 172.6(2)° (Figure S1(a)). The intra-molecular C-H $\cdots$ O found in Form (**IA**) is absent in this structure (Figure 2). The lattice energy of Form (**IB**) was calculated to be - 129.0 kJ/mol which is 6 kJ/mol greater than that of Form (**IA**) (Table 2). Figure 5 contains the different molecular pair in the crystal structure and

Figure 7. Molecular pairs I - VIII of Form (IIA) arranged with decreasing interaction energies.

Figure 6 shows the utilization of these molecular pairs in crystal packing. The most stabilized molecular pair in Form (IB) consists of a strong $\text{N}-\text{H}\cdots\text{O}=\text{C}$ interaction along with $\text{C}=\text{O}\cdots\pi$, short and directional $\text{C}-\text{H}\cdots\text{F}-\text{C}$ (involving highly acidic H2) and $\text{C}-\text{H}\cdots\pi$ interaction (Figure 5) resulting in an overall interaction energy of -44.1 kJ/mol [motif I] with $\sim 43\%$ contribution from the dispersion energy towards stabilization (Table S3). Motif I forms a molecular chain along the *a*-axis [Figure 6(a)] and such a molecular chain are interconnected via $\text{C}-\text{H}\cdots\text{Cl}$ interactions [motif V (-7.6 kJ/mol), motif VI (-6.6 kJ/mol) and $\text{C}-\text{H}\cdots\pi$ interactions [motif VII, -6.2 kJ/mol] along the *b*-axis. Along the *c*-axis, molecular packing is governed by presence of $\text{C}-\text{H}\cdots\text{O}$ and $\text{C}-\text{H}\cdots\pi$ interactions [Motif III, -18.8 kJ/mol] which results in the formation of a molecular chain (Figure 6(b)). Such chains are interconnected to each other via motif IV which consists of $\text{C}-\text{H}\cdots\pi$ and $\text{C}-\text{F}(lp)\cdots\pi$ interaction and have a interaction energy of -8.0 kJ/mol (Table S3). The presence of a short and highly directional $\text{C}-\text{H}\cdots\text{F}-\text{C}$ interaction along with $\pi\cdots\pi$ stacking interactions involving the atoms of Cg1 and Cg2 rings results in formation of a highly stabilized molecular pair [motif II, -26.4 kJ/mol] along the *c*-axis.

3.2 Crystal structures of polymorphs of II

The Form (IIA) crystallizes as needle-shaped crystals in the monoclinic centrosymmetric space group $P2_1/n$, with one symmetry independent molecule ($Z'=1$) with the torsion around the amide (C1-C7-N1-C8) bond being $179.8(2)^\circ$ (Figure S1(b)). The lattice energy of

Form (IIA) was calculated to be -133.7 kJ/mol. The molecular conformation is stabilized by the formation of an intramolecular $\text{C}-\text{H}\cdots\text{O}$ and $\text{C}-\text{I}\cdots\text{O}=\text{C}$ intramolecular interaction (Figure 2, Table S2). Different molecular pairs along with the molecular packing have been shown in Figures 7 and 8, respectively. Motif I comprises of strong $\text{N}-\text{H}\cdots\text{O}=\text{C}$ interaction along with $\text{C}-\text{H}\cdots\text{O}$ and $\text{C}-\text{H}\cdots\pi$ interactions resulting in formation of a molecular chain along *a*-axis (Figure 8(a)) and have a stabilization energy of -50.4 kJ/mol with $\sim 50\%$ contribution from dispersion towards stabilization (Table S3). Similar chains are interconnected via presence of $\text{C}-\text{H}\cdots\text{Br}$ (involving highly acidic H3) and $\text{C}-\text{H}\cdots\pi$ interaction [motif II, -25.1 kJ/mol]. Further stability along *b*-axis is provided by presence of a unique $\text{C}-\text{I}\cdots\text{O}=\text{C}$ interaction [motif V, -7.7 kJ/mol]. The bromine atom attached to the aromatic ring is further involved in formation of another $\text{C}-\text{H}\cdots\text{Br}$ interaction [motif VIII, -5.0 kJ/mol] and a highly dispersive inter-halogen $\text{C}-\text{Br}\cdots\text{I}-\text{C}$ interaction [motif VI, -7.6 kJ/mol]. The contribution of dispersion in motif VI was calculated to be 86% . Down the *bc*-plane, the packing is governed by the presence of a centrosymmetric $\text{C}-\text{Br}\cdots\text{I}-\text{C}$ interaction along with $\pi\cdots\pi$ stacking interactions involving atoms of Cg2 rings [motif III, -25.1 kJ/mol] (Figure 7). Motif III is interconnected to another similar motif via the formation of a $\text{C}-\text{H}\cdots\text{Br}$ interaction involving [motif IV, -8.6 kJ/mol] along *b*-axis (involving highly acidic H12) and via dimeric $\pi\cdots\pi$ interaction [motif VII, -7.0 kJ/mol] along the *c*-axis (Figure 8(c)).

Form (IIB) crystallizes as block-shaped crystals in the orthorhombic centrosymmetric space group $Pbca$, with $Z'=1$. The torsion around the amide (C1-C7-N1-C8)

Figure 8. Packing diagram of Form (IIA) showing the utilization of different molecular motifs.

Figure 9. Pairs of molecules I-VII of Form (IIB) arranged with decreasing interaction energies.

bond is $176.2(2)^\circ$ (Figure S1(b)) and the molecular conformation is stabilized by C-H $\cdots$ O and I $\cdots$ O intramolecular interactions (Table S2). The lattice energy of Form (IIB) was calculated to be 5 kJ/mole greater than that of Form (IIA). The different molecular pairs present and their participation in molecular packing has been shown in Figures 9 and 10, respectively. A strong N-H $\cdots$ O=C bond along with C-H $\cdots$ I, C-H $\cdots$ O and displaced $\pi\cdots\pi$ stacking interaction results in the formation of a molecular chain along *b*-axis with an interaction energy of -52.3 kJ/mol (motif I, Figure 10). These chain are interconnected via two different type of C-H $\cdots\pi$ interactions with a binding energy of -33.0 kJ/mol (motif II, Figure 9) and 29.2 kJ/mol [motif III, Figure 9], respectively. These C-H $\cdots\pi$ interactions were highly dispersive in nature with $\sim 65\%$ percent contribution towards the stabilization of the molecular pair. Along the *a*-axis, the packing is governed by the presence of an offset $\pi\cdots\pi$ stacking interaction with an interaction energy of -7.9

kJ/mol (motif V, Figure 10). Iodine is also involved in formation of two halogen-halogen interactions. It forms a type II I $\cdots$ I interaction [3.973 Å; 163° , 97°] whose interaction energy was calculated to be -7.5 kJ/mol (motif VI, Figure 9). It is also involved in the formation of Br $\cdots$ I interaction down the *ac*- plane [motif VIII, -4.4 kJ/mol]. Packing down the *ac*-plane is further supported by presence of motif IV [-18.4 kJ/mol] which consists of C-H $\cdots$ Br (involving highly acidic H10) and C-H $\cdots\pi$ interactions in addition to motif VII [-7.0 kJ/mol] which consists of C-Br $\cdots\pi$ interactions.

3.3 2D fingerprint plots

2D Fingerprint plots have been proved to be very useful in analysing the contribution of different intermolecular contacts in different polymorphic structures [3, 54].^{3,54} Figure 11 represents the 2D fingerprint plot for IA and IB and it clearly depicts the difference between the two

Figure 10. Packing diagram of Form (IIB) showing the utilization of different molecular motifs.

Figure 11. 2D Fingerprint plots for (a) Form(IA), (b) Form(IB), (c) Form(IIA), and (d) Form(IIB).

polymorphs. The tails depicting the regions of $\text{H} \cdots \text{H}$ and $\text{H} \cdots \text{C}$ contacts ($\text{C}-\text{H} \cdots \pi$ interactions) are broader in case of Form (IA) as compared to Form (IB). Also, the region of $\text{H} \cdots \text{F}$ contact is evident in case of Form (IA) while it is merged within the region of $\text{O} \cdots \text{H}$

interaction in Form (IB). The major difference between the two polymorphs was the presence of Type I $\text{Cl} \cdots \text{Cl}$ interaction exclusively in Form (IA) and this difference was clearly evident from the fingerprint plot. The contribution of $\text{Cl} \cdots \text{Cl}$ was obtained to be 3.7% in Form

Figure 12. Comparison of contribution of different intermolecular interactions in (a) Form (IA) and Form (IB); (b) Form (IIA) and Form (IIB).

(IA) as compared to 0.1% in Form (IB) (Figure 12, Figures S2 and S3). Consequently, this resulted in higher contribution of H...Cl interaction in Form (IB) [19.2%] as compared to Form (IA) [14.0%]. The contribution of H...O interaction was 10.3% in Form (IB) as compared to 8.2% in Form (IA) owing to the presence of C-H...O interaction in Form (IA). The contribution of H...H interaction was greater in case of Form (IA) while the contribution of H...C interaction was greater in case of Form (IB) (Figure 12). C-H...F interactions played a very important role in packing of both the polymorphs with a contribution of 9.1% and 9.8% in Form (IA) and Form (IB), respectively.

Difference in the 2D Fingerprint plots for Form (IIA) and Form (IIB) was also clearly evident (Figure 11). The major difference between the two polymorphs was the presence of Type II I...I contact in Form (IIB) which resulted in 5.3% contribution in fingerprint plot as compared to 0.7% in Form (IIA) (Figure 12, Figures S4 and S5 in Supplementary Information). The contribution of

I...O interaction was 1.5% in Form (IIA) as compared to 0.0% in Form (IIB) owing the presence of I...O interaction exclusively in the case of Form (IIA) (Figures S4 and S5). The presence of a C-H...O interaction in addition to N-H...O interaction in Form (IIB) resulted in 10.1% contribution of H...O interaction in the fingerprint plot as compared to 6.9% in case of Form (IIA). The presence of multiple C-H... π interaction resulted in 25.8% contribution towards the fingerprint plot for Form (IIB) as compared to 20.7% in Form (IIA). The presence of a directional H...I interactions specifically in Form (IIA) resulted in 9.5% contribution (Figures S4 and S5).

4. Conclusions

A detailed investigation on the role of intermolecular interactions in the polymorphs of 3-chloro-*N*-(2-fluorophenyl)benzamide [Form (IA) and Form (IB)] and 2-iodo-*N*-(4-bromophenyl)benzamide [Form (IIA) and

Form (IIB)] has been performed. Both C-H... π and C-H...F interaction play a very important role in the crystal packing of Form (IA) and Form (IB). The major difference between two polymorphs is largely due to the different contribution of the Cl...Cl and C-H...Cl interaction towards the molecular packing. The polymorphic modification in case of Form (IIA) and Form (IIB) is mainly driven by the intermolecular interactions involving iodine. 2D Fingerprint clearly reveals the difference in the contribution of iodine-bonded interactions for the two polymorphic forms. Energy calculations revealed that the intermolecular interactions present in all the four crystal structures are largely of dispersive nature.

Supplementary Information (SI)

Overlay diagram of the polymorphs, 2D Fingerprint plots for all the Forms (Figures S1–S5) and Tables (S1–S3) of torsional and dihedral angles, intramolecular interactions, intermolecular interactions along with interaction energies and geometrical parameters are given in Supplementary Information. CIF files are available with CCDC No. 751295, 751296, 751297. Supplementary Information is available at www.ias.ac.in/chemsci.

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Conflict of interest

The authors declare that there is no conflict of interest.

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