Evolution of halogen bonding interactions in a co-crystal system: X-ray diffraction under pressure in lab

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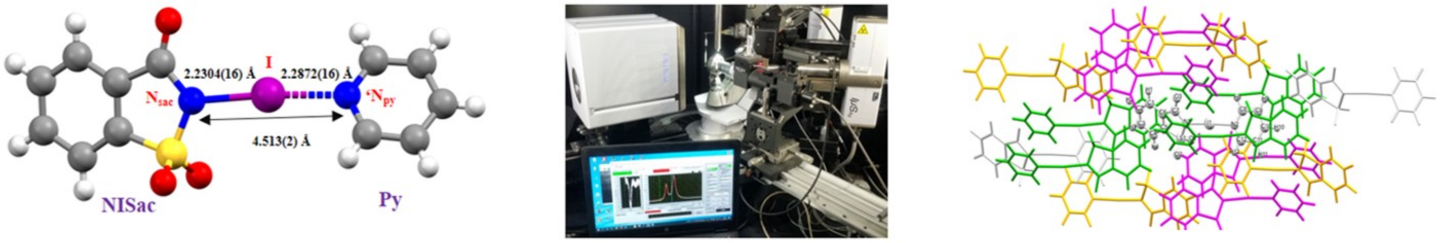
Halogen bonding (XB) interactions are defined as those involving electrophilic sites (σ-holes) associated to a covalently bonded atom of group-17 with nucleophilic sites from either the same or a different molecule[1]. These σ-hole regions are expected to exhibit along the extension of covalent bonds and can be finely tuned by the electronic nature of substituents in the molecule bearing the halogen atom.

In a previous study involving donor-acceptor complexes, we have succeeded to co-crystallize iodine substituted imide derivatives with pyridine derivatives. In these systems, we have pointed out a strong halogen bonding motif where the halogen atom is significantly shifted towards the acceptor moiety. For one of them, which is leading to an ionic crystal rather than a co-crystal[2], an electrostatic secondary interaction of $C{=}O^{\delta-}\cdots I^{\delta+}$ type has been discussed as one of the reasons behind such a halogen atom shift towards the acceptor. In our work, we are actually investigating the evolution of such XB interactions in an organic binary adduct composed of *N-Iodosaccharin* and *Pyridine (NISac.Py)* via X-ray diffraction experiments under pressure. These experiments were undertaken with a Membrane Diamond Anvil Cell (MDAC) under external pressure ranging from 0 GPa to 4.5 GPa, by using an in-house set-up (with the in-situ measurement of pressure from time to time) developed in our laboratory and adapted to the diffractometer (Bruker D8 venture) that was used to collect high-pressure X-ray diffraction data.



(a) (b) (c)

Fig. 1: (a) [Nsac-I···N'py] motif in NISac.Py at ambient conditions (b) MDAC installed in in-house set-up for the in-situ measurement of pressure by ruby luminescence (c) molecular shell generated around the central molecule in a radius of 3.8 Å for analysis of intermolecular interactions at 0 GPa.

Aiming to analyse the influence of the molecular environment on the XB motif of *NISac.Py*, X-ray diffraction studies have permitted to follow the evolving behaviour of the $N_{sac}\text{-}I\cdots N'_{py}$ interactions as a function of pressure, which results in the shifting of the halogen atom position between donor and acceptor moieties. This trend might be linked to a potential change of state from co-crystal to ionic crystal form under pressure. The study also opens up an opportunity to understand the modification of secondary interactions as a function of pressure. Another interesting finding resulting from this work is the occurrence of a mechanical twinning and its behaviour as a function of pressure, which is analysed in detail. Periodic theoretical calculations were also carried out by applying isotropic external pressures. They were followed by the analyses of the Equation of State (EOS), molecular environments and non-covalent interactions, all of them showing good agreements with experimental results. In summary, this work illustrates the possibility of working with pressure as another thermodynamic variable that permits to alter weak intermolecular interactions and therefore to explore phase transformation or polymorphic phases in other donor-acceptor systems formed by similar interactions.

[1] Cavallo, G., Metrangolo, P., Milani, R., Pilati, T., Priimagi, A., Resnati, G. & Terraneo, G. (2016). Chem. Rev. **116**, 2478–2601.

[2] Makhotkina, O., Lieffrig, J., Jeannin, O., Fourmigué, M., Aubert, E. & Espinosa, E. (2015). Cryst. Growth Des. **15**, 3464–3473.

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