

Cocrystal vs. Salt: Effect of crystal environment on molecular interactions

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The distinction between cocrystals and salts is usually investigated in hydrogen-bonded systems as $A-H\cdots B \rightleftharpoons [A]^- \cdots [H-B]^+$, where the position of the hydrogen atom actually defines the ionicity of the complex. The same distinction, but in halogen-bonded systems, is addressed here, in complexes formed out of N-iodoimide derivatives as halogen bond donors, and pyridines as halogen-bond acceptors, anticipating that the position of the iodine atom in these $A-I\cdots B \rightleftharpoons [A]^- \cdots [I-B]^+$ systems will also define their degree of ionicity. We show that the crystalline halogen-bonded complexes of N-iodosuccinimide (NIS) with pyridine, 4-methylpyridine, and 4-dimethylaminopyridine can be described as "close-to-neutral" cocrystals while the crystalline halogen-bonded complex of N-iodosaccharin (NISac) with 4-dimethylaminopyridine (DMAP) adopts a "close-to-ionic" structure [1].

With this aim, theoretical calculations were performed (i) in gas phase on isolated $NIS\cdots Py-NMe_2$ and $NISac\cdots Py-NMe_2$ complexes, and (ii) on the periodic crystal phases, combined with the topological analysis of the electron density distribution $\rho(r)$. The iodine position in the complex $NISac\cdots Py-NMe_2$ was optimized upon the influence of external electric fields ϵ oriented along the $N\cdots N'$ direction ($-3 < \epsilon < +5$ GV/m), showing that this atom behaves as a positive charge following the applied ϵ . Accordingly, an external homogeneous electric field ϵ applied to the $NISac\cdots Py-NMe_2$ complex (all atoms frozen at the crystalline geometry, except iodine) in either gas phase ($\epsilon = 3.7$ GV/m) or periodic pseudo-isolated configuration ($\epsilon = 2.8$ GV/m) is able to shift the iodine atom at the crystal geometry, miming the polarization effect induced by the crystalline electric field, while the linear dependence of the $N(\text{donor})\cdots I$ distance with ϵ is clearly established [1]. The crystal environment actually plays a crucial role in the stabilization of the "close-to-ionic" structure of the $NISac\cdots Py-NMe_2$ complex. The strong influence of the crystalline environment on the iodine position is demonstrated by using plane wave DFT periodic calculations on optimized $NIS\cdots Py-NMe_2$ and $NISac\cdots Py-NMe_2$ crystal structures, as well as by applying this formalism to a hypothetical solid where the halogen bonded complexes are pushed apart from each other within a periodic system [1].

In addition, to evaluate the role of the halogen atom, we have also investigated the nature of the NISac and N-bromosaccharin (NBSac) adducts with 4-picoline (NISac•Pic and NBSac•Pic) by a combination of single crystal X-ray structure determinations, gas phase and periodic DFT calculations (with electric field effects), followed by the topological analyses of $\rho(r)$ and its negative laplacian [2]. We show that the replacement of iodine by bromine favors the displacement of the halogen atom toward the picoline to give a more ionic structure, or in other words that, in these adducts, the halogen bonding interactions are indeed stronger with bromine than with iodine, in spite stronger halogen bonds are recurrently observed with iodine rather than with bromine atoms. This feature is brought close to the very strong halogen bonds found in $[Py-X-Py]^+$ halonium cations [3], where the reduction ratio for the $Br\cdots N$ bonds (0.63) is actually smaller than for the $I\cdots N$ bonds (0.65).

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[2] Aubert, E., Espinosa, E., Nicolas, I., Jeannin, O. & Fourmigué, M. (2017), Faraday Discuss. Chem. Soc., 00, 000-000.

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