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Comments on “Investigation on synthesis, laser damage threshold, and NLO properties of L-asparagine thioacetamide single crystal for photonic device applications” [J Mater Sci: Mater Electron. **31**, 13310-13320 (2020)]

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**Abstract**

The authors of the title paper [J. Mater. Sci. Mater. Electron. **31**, 13310-13320 (2020)] report to have grown a so-called L-asparagine thioacetamide (LATA) single crystal by the slow evaporation of an aqueous solution containing L-asparagine monohydrate and thioacetamide in 1:1 ratio. The same research group has claimed in another paper [J. Mater. Sci. Mater. Electron. **31**, 791–798 (2020)] to have grown a so-called NLO-active potassium hydrogen phthalate fumaric acid crystal (KHPF). In this comment we prove that LATA and KHPF are improperly characterized crystals and both papers are erroneous.

**Keywords:** thioacetamide; L-asparagine thioacetamide; L-asparagine monohydrate; potassium hydrogen phthalate fumaric acid; fumaric acid; improperly characterized crystal

The authors of the title paper [1] claim to have grown a so-called L-asparagine thioacetamide single crystal (LATA) by the slow evaporation of an aqueous solution containing equimolar ratios of L-asparagine monohydrate and thioacetamide. The reaction scheme for the formation of LATA crystal showed the starting amino acid reagent in unionised form, which on reaction with thioacetamide is supposed to have formed a molecular adduct with the oxygens of the carboxylate interacting with the H atoms of the  $-NH_2$  group of thioacetamide. The positive charge on the  $-NH_3$  group of L-asparagine indicates the amino acid to be in zwitter ionic form. However, a negative charge on the amide oxygen appears very unusual.

Although the authors claimed to have characterized the optically colourless crystal with the aid of single crystal structure, powder X-ray diffraction and IR spectroscopy, they did not provide any experimental proof whatsoever in support of the unusual structure of the product. Instead of the single crystal refinement results and a CIF file, only the space group  $P2_12_12_1$  and the unit cell parameters of the so-called LATA crystal were reported. The unit cell was compared with that of L-asparagine monohydrate. Instead of citing the relevant original references [2, 3] for comparison, the authors cited an unusual secondary reference. It is noted that several citations in the paper do not pertain to the subject matter for example L-alanine tetrafluoroborate (L-AIFB). Authors were unaware that two of the references (ref. 10 and 12 in [1]) cited by them for L-AIFB and L-asparagine thiourea monohydrate (LATM) have been proved to be erroneous publications by Petrosyan [4, 5]. Although the authors claimed to have identified the different functional groups of the grown LATA material in the infrared (IR) spectrum no assignment was given for the thiocarbonyl ( $>C=S$ ) group of thioacetamide. Further, the IR spectrum appeared suspiciously similar to that of L-asparagine monohydrate as pointed out in the case of LATM and L-asparagine cadmium chloride monohydrate by Petrosyan [5] and Srinivasan [6]. The characterization data viz. unit cell, powder pattern and IR spectrum gave an indication that no thioacetamide was present in LATA crystal.

In order to determine the exact nature of the so-called LATA crystal, we performed a crystal growth reaction by taking L-asparagine monohydrate (1.0 g, 6.7 mM) and thioacetamide (0.5 g, 6.7 mM) in equimolar ratio in ~50 ml of distilled water. The reaction mixture was continuously stirred for 12 h and filtered. The clear filtrate was left undisturbed for the slow evaporation of water. After a few days, crystalline product was obtained. No special efforts were taken to grow large crystalline blocks since the product (~0.65 g) had several X-ray quality crystals. The crystals were isolated by filtration and washed with a small amount of cold water and allowed to dry. We labelled the product as compound **1** and used a small crystal for single crystal structure determination using a Bruker D8 Quest Eco diffractometer. Details of data collection and refinement results are given in Table 1.

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

Empirical formula	C <sub>4</sub> H <sub>8</sub> N <sub>2</sub> O <sub>3</sub> ·H <sub>2</sub> O
Formula weight (g mol <sup>-1</sup> )	150.14
Temperature (K)	293(2)
Wavelength (Å)	0.71073
Crystal system	orthorhombic
Space group	<i>P</i> 2 <sub>1</sub> 2 <sub>1</sub> 2 <sub>1</sub>
Unit cell dimensions	
<i>a</i> (Å)	5.5802(2)
<i>b</i> (Å)	9.8268(3)
<i>c</i> (Å)	11.7964(4)
$\alpha = \beta = \gamma$	90°
Volume (Å <sup>3</sup> )	646.86(4)
<i>Z</i>	4
<i>D</i> <sub>calc</sub> (mg/m <sup>3</sup> )	1.524
Absorption coefficient (mm <sup>-1</sup> )	0.137
<i>F</i> (000)	320
Crystal size (mm <sup>3</sup> )	0.263 x 0.204 x 0.059
$\theta$ range for data collection (°)	2.698 to 28.289
Limiting indices	-7 ≤ <i>h</i> ≤ 7, -13 ≤ <i>k</i> ≤ 13, -15 ≤ <i>l</i> ≤ 15
Reflections collected /unique	9624 / 1600 [R(int) = 0.0262]
Completeness $\theta = 27.00^\circ$	99.7 %
Absorption correction	Multi scan
Refinement method	Full-matrix least-squares on <i>F</i> <sup>2</sup>
Data / restraints / parameters	1600 / 0 / 100
Goodness of fit on <i>F</i> <sup>2</sup>	1.075
Final <i>R</i> indices [ <i>I</i> > 2 $\sigma$ ( <i>I</i> )]	<i>R</i> 1 = 0.0263, <i>wR</i> 2 = 0.0708
<i>R</i> indices (all data)	<i>R</i> 1 = 0.0294, <i>wR</i> 2 = 0.0738
Absolute structure parameter	-0.5(5)
Largest diff. peak and hole (e Å <sup>-3</sup> )	0.216 and -0.159
CCDC deposit no	2041930

Compound **1** crystallizes in the orthorhombic Sohncke space group *P*2<sub>1</sub>2<sub>1</sub>2<sub>1</sub> and its structure consists of an unique L-asparagine molecule in zwitterionic form and a crystallographically independent lattice water (O4) molecule (Fig. 1) with all atoms located in general positions. The structure model is in good agreement with literature data [2, 3]. Since the structure of L-asparagine monohydrate is well documented in the literature, we do not discuss it anymore.

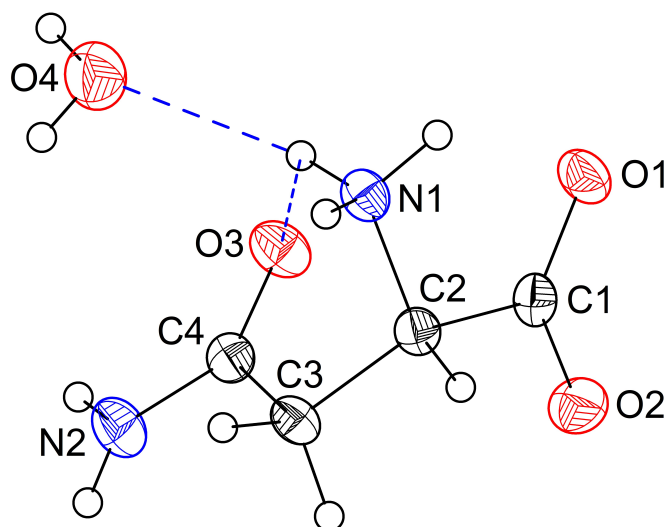
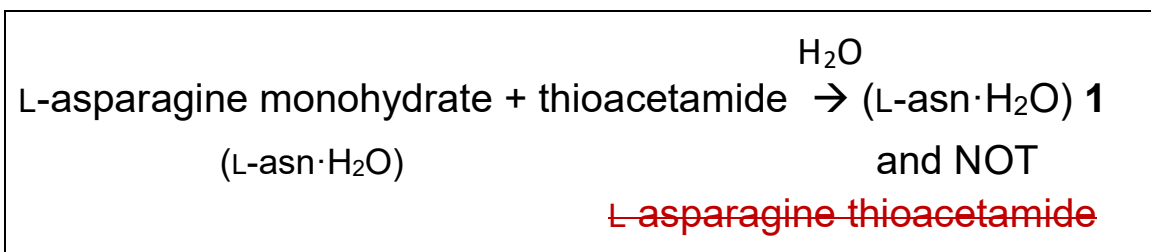


Fig. 1 Crystal structure of L-asparagine monohydrate **1** showing the atom labelling scheme. Thermal ellipsoids are drawn at the 50% probability level for all atoms excepting the hydrogens which are shown as spheres of arbitrary radii. O4 is lattice water. Intramolecular hydrogen bonding is shown in broken lines.

Formation of **1** in good yield from an equimolar reaction of L-asparagine monohydrate and thioacetamide reveals that at room temperature no chemical reaction takes place between the two reagents in water. The less soluble of the two namely L-asparagine fractionally crystallizes as the monohydrate, while the more soluble thioacetamide remains in solution ([Scheme 1](#)).



Scheme 1 – Fractional crystallization of L-asparagine monohydrate

The above given discussions convincingly prove that L-asparagine thioacetamide is an improperly characterized material. The optical studies and other properties of LATA have no scientific merit and hence are not commented.

Another paper published by the corresponding author of [1] is on a so-called potassium hydrogen phthalate fumaric acid crystal (KHPF) [7]. Four different terminologies are used to refer to the KHPF crystal in [7] for example i) potassium hydrogen phthalate fumaric acid in the title ii) fumaric acid potassium hydrogen phthalate in the abstract iii) potassium hydrogen phthalate fumarate in the introduction and in conclusion and iv) dicarboxylic acid (fumaric acid) mixed KHP crystal in the experimental procedure. According to authors, the so-called KHPF crystal was grown by slow evaporation of an aqueous solution containing equimolar ratios of fumaric acid and potassium hydrogen phthalate (KHP). The reaction scheme (*Fig 1 of [7]*) shows that the potassium of KHP is bonded to an oxygen of a fumarate dianion. It is remarkable to see that the fumarate dianion could be generated in an aqueous acidic solution of KHP without addition of any basic reagent. In addition, it is noted that the structure is charge imbalanced because a  $K^+$  cannot account for both the fumarate dianion, and also the hydrogen phthalate anion. Under the heading ‘2.1.1 Reaction scheme’ the formula of KHPF is written as  $\{[(K)^+C_{12}H_9O_7]O^-\}$ . It is not clear why an oxygen is written as a separate unit contradicting the structure in *Fig 1 of [7]*.

The authors claim to have studied the KHPF crystal by single crystal X-ray method but reported only the unit cell parameters without any esd. Although it is not clear if a CIF file of KHPF structure was deposited in the Cambridge Structural Database (CSD) [8], a search of CSD reveals no hit for the cell reported in [7]. The triclinic unit cell ( $402 \text{ \AA}^3$ ) in [7] was compared with the orthorhombic unit cell ( $828.83 \text{ \AA}^3$ ) of potassium hydrogen phthalate. As mentioned earlier for LATA crystal, the reference cited for comparison is an incorrect secondary reference and not the original report of Okaya [9] or any of the papers reporting this structure which are archived in the CSD [10]. For the reduction in cell volume by a half, authors reasoned as follows, “*From the Table the changes in the lattice parameters values are observed which confirms the addition of fumaric acid in pure KHP. The chemical structure is drawn using ‘CHEMDRAW’ software and shown as Fig. 1. The ORTEP diagram also drawn and shown in Fig. 3. From this, it is understood that the KHPF crystal contains two benzene rings and one potassium (K) ion and oxygen ion. The K (potassium) ion bonds with fumaric acid and hydrogen*

atom. The potassium ion bonds with O–H of aromatic ring as intermolecular charge transfer. Hydroxyl group hydrogen atom is responsible for this intermolecular charge transfer (CT) in the crystal system.” In the absence of a CIF file the above explanation is unacceptable and the last two sentences on intermolecular charge transfer can only be termed as inappropriate. It is not clear as to how the authors could draw their ORTEP diagram. It is noted that the other characterization data are highly questionable for example the infrared (IR) spectrum which coincides with the IR spectrum of KHP. In a recent report [11] on the crystal structure of KHP, we have shown that the  $\mu_4$ -heptadentate binding mode of the unique hydrogen phthalate ligand organizes the  $K^+$  ions into a layer resulting in a two-dimensional (2D) coordination polymer. In addition, we have also shown that the structure cannot accommodate other organic molecules viz. thiourea. Hence we were quite surprised to read that a fumaric acid or a fumarate was incorporated into the crystal structure of KHP. In view of this, we reinvestigated the growth of KHPF, so as to determine the exact nature of the KHPF crystal.

A crystal growth reaction was performed by dissolving fumaric acid (0.58 g, 5.0 mM) and potassium hydrogen phthalate (1.021 g, 5.0 mM) in ~100 ml of distilled water to obtain a clear solution. The clear reaction mixture was continuously stirred for 8 h as mentioned in [7]. At the end of 8h we noticed powdery material in the reaction. Hence we set aside the reaction mixture and filtered to separate the white powder. A chemical test of the powder revealed that it does not contain any  $K^+$  but contains –COOH functional group. An IR spectrum revealed that the white powder is actually fumaric acid, which could also be confirmed by the amount of white powder obtained (575 mg). The separation of fumaric acid in near quantitative yield from the reaction medium can be explained to its less solubility in water (4.9 g per litre) as compared to that of KHP (80.0 g per litre) which remains in solution. In the experimental details authors did mention about filtration as follows: “*The solutions were stirred using a mechanical stirrer about 8 h to get a homogeneous mixing solution and the final solution was filtered in dry Petri dish using filter paper of micron pore size and it was kept in room temperature for crystallization*” but did not realise of having separated a less soluble product which was one of the starting reagents. The clear filtrate when left aside for ~ 2 days afforded crystals of

KHP in 90% yield as could be confirmed by its infrared spectrum which coincides with the spectrum of pure KHP [11]. The triclinic unit cell reported by the authors is neither that of the orthorhombic KHP nor that of fumaric acid (Refcode FUMAAC) [12]. In this context we wish to mention that in the absence of a CIF file the reported unit cell in [7] cannot be considered reliable. However, we do note that the IR spectrum in [7] coincides with that of KHP. Thus our reinvestigation explains the occurrence of fractional crystallization in the crystal growth of KHPF as in the case of the LATA crystal [1]. The only difference is that the less soluble fumaric acid was filtered off to obtain potassium hydrogen phthalate. The formation of any fumarate containing product as claimed by the authors of [7] can be ruled out by the acidic nature of the medium.

Our critique once again highlights the importance of single crystal structure refinement data and not unit cell parameters for compound characterization. In this context, we wish to suggest that leading international journals should make submission of CIF file to a database a prerequisite for publication of new crystals.

In summary, we have proved that the so-called L-asparagine thioacetamide (LATA) and potassium hydrogen phthalate fumarate (KHPF) are **improperly characterized** crystals.

### **Conflict of interest**

The authors declare NO conflict of interest.

### **Supplementary Material**

Deposition Number 2041930 contains the supplementary crystallographic data of L-asparagine monohydrate **1** reported in this paper. These data are provided free of charge by the joint Cambridge Crystallographic Data Centre and Fachinformationszentrum Karlsruhe Access Structures service [www.ccdc.cam.ac.uk/structures](http://www.ccdc.cam.ac.uk/structures).

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