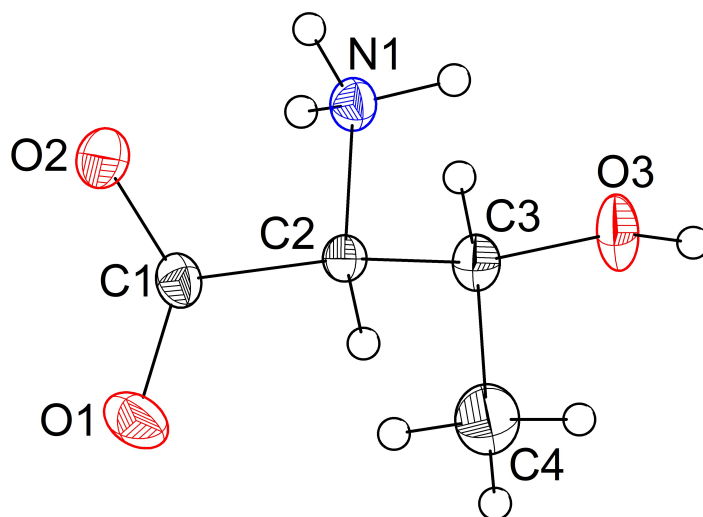


## Comments on the paper “Synthesis, structural and optical properties, ferromagnetic behaviour, cytotoxicity and NLO activity of lithium sulphate doped L-threonine”

Bikshandarkoil R. Srinivasan\*, Megha S. Deshpande, Sudesh M. Morajkar  
School of Chemical Sciences, Goa University, Goa 403206, India Email: [srini@unigoa.ac.in](mailto:srini@unigoa.ac.in)

### Graphical abstract

Slow evaporation of an aqueous solution containing equimolar quantities of L-threonine and lithium sulphate monohydrate results in the fractional crystallization of L-threonine.



### Highlights

- # The title paper is critiqued
- # Crystal growth of lithium sulphate doped L-threonine is reinvestigated
- # Lithium sulphate doped L-threonine is, in fact, L-threonine
- # L-threonine is a diamagnetic solid

Comments on the paper “Synthesis, structural and optical properties, ferromagnetic behaviour, cytotoxicity and NLO activity of lithium sulphate doped L-threonine”

Bikshandarkoil R. Srinivasan, Megha S. Deshpande, Sudesh M. Morajkar  
School of Chemical Sciences, Goa University, Goa 403206, India Email: [srini@unigoa.ac.in](mailto:srini@unigoa.ac.in)

**Abstract**

The authors of the title paper (*Optics and Laser Technology* **83** (2016) 49–54) claim to have grown a ‘lithium sulphate doped L-threonine’ crystal by slow evaporation of an aqueous solution containing equimolar amounts of L-threonine and lithium sulphate. A reinvestigation of the crystal growth reaction reveals that fractional crystallization of L-threonine occurs. In this letter to the Editor, we prove that the so-called lithium sulphate doped L-threonine is a dubious crystal and not a ferromagnetic material.

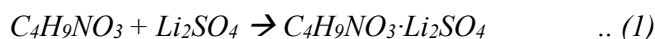
**Keywords:** *L-threonine; lithium sulphate; lithium sulphate doped L-threonine; dubious crystal; ferromagnetic*

Dear editor,

During a literature survey of L-threonine based crystals, we became aware of the title paper [1] published in *Optics and Laser Technology*. This paper attracted our attention in view of a mention of ferromagnetic behaviour in the title. Since the zwitterionic L-threonine and the closed-shell lithium sulphate (or its monohydrate) are well-known diamagnetic materials, we perused the title paper to comprehend the ferromagnetic property of a so-called lithium sulphate doped L-threonine crystal. Unfortunately, we noted that the presentation of the results does not meet scientific standards. The several incorrect claims in the title paper are discussed in this letter to the Editor.

The authors of the title paper [1] report to have grown a so-called lithium sulphate doped L-threonine crystal (**1**)<sup>1</sup> abbreviated as (Li<sub>2</sub>SO<sub>4</sub>-LT) by slow evaporation of an aqueous solution containing equimolar amounts of L-threonine and lithium sulphate. Although no amounts of reagents employed for the crystal growth reaction and the yield of the so-called doped crystal were reported, authors mentioned under the heading ‘material preparation’ the following:

*The following chemical reaction for the synthesis of the material was expected to take place.*



From the above equation in the title paper, it is obvious that the desired compound was a 1:1 adduct of the reagents referred to as L-threonine lithium sulphate. Although it is not clear why two moles of adduct were expected as product, it is noted that authors reported that it was initially impossible for them to confirm the formation of any adduct. Hence they decided to use inductively coupled plasma optical emission spectroscopy (ICP-OES) technique to probe this. Based on the results of this study the authors reported the following ‘.. *only 0.07 mol of lithium sulphate has been incorporated into the crystal lattices of pure L-threonine to influence the surrounding and distort lattice locally which leads to the slight changes in the lattice parameters of the parent system. The remaining 0.93 mol of lithium sulphate goes into the solution.*’ Although the authors declared that the grown material is a so-called lithium sulphate doped L-threonine crystal based on their ICP-OES study, a scrutiny of the reported amounts of lithium and sulphur reveals (See Supplementary material) that the claim of 0.07 mol% doping is inappropriate. For example, the reported value of 0.015 mg of Li in 76.18 mg of the sample taken for analysis is much (41 times) lower than the expected value for a 0.07 mol% doping. Further, authors are unaware that lithium sulphate always crystallizes from aqueous solution as a monohydrate and not in anhydrous form. We explain the presence of a major amount of lithium salt in solution to no chemical reaction between the reagents.

Under the heading “XRD study’ the authors reported that the unit cell dimensions of the title crystal and the space group ( $P2_12_12_1$ ) and compared the values with that of pure L-threonine. Instead of the relevant original reference on the structure of L-threonine [2] or a low temperature structure reported by Janczak et al. [3], an unusual secondary reference was cited for comparison. Authors claimed, “*the slight deviation of the cell parameters of the doped crystal  $Li_2SO_4$ -LT with those of pure LT confirms the incorporation of  $Li_2SO_4$  in the host lattice of LT*”. The above claim can be dismissed because for the so-called doped crystal and pure L-threonine crystal, the authors did not report the temperature of unit cell determination and the errors of the measurements of the cell parameters. In the absence of a CIF file, the reported data cannot be considered as reliable.

Under the heading “Optical property – UV–vis–NIR optical absorption spectrum” authors reported the band gap as 4.92 eV, which is in close agreement with the value of 5.05 eV obtained from a theoretical study of pure L-threonine [4]. The reported infrared (IR) spectrum of the so-called doped crystal appears suspiciously similar to that of L-threonine, indicating the absence of any lithium sulphate in **1**. Many assignments are incorrect. For example, authors reported “*The O-H bend of –COOH group is indicated due to the peak at  $1246\text{ cm}^{-1}$* ” without taking into account that the zwitterionic L-threonine does not contain any –COOH. The vibrations of the sulphate group are not considered. A better explanation of the IR spectrum is that the sample under study does not contain any lithium sulphate whatsoever.

Under the heading ‘Magnetic property –ferromagnetic behaviour’ authors reported that the title crystal **1** exhibits ferromagnetic behaviour and reported its coercivity and retentivity as 550.06 G and  $79.50 \times 10^{-6}$  emu respectively. The authors reasoned as follows: “*Pure L-threonine was found to be a diamagnetic material when it was placed perpendicular to a magnetic field. Due to higher conducting nature of the dopant  $Li_2SO_4$ , the diamagnetic*

*behaviour was surprisingly changed to ferromagnetic behaviour as evident from VSM measurements.*” While authors could correctly report that pure L-threonine is a diamagnetic material, it is unfortunate that they were unaware that lithium sulphate as well as lithium sulphate monohydrate are diamagnetic materials because monovalent  $\text{Li}^+$  ion has a closed-shell electronic configuration and the dianionic sulphate is electron paired. Hence one does not expect an amino acid containing lithium sulphate to exhibit any ferromagnetic property. However, in the literature well-known diamagnetic compounds of Zn(II) and Cd(II) were claimed to be room temperature ferromagnetic and such incorrect claims have been commented and explained due to both incorrect scientific reasoning as well as a lack of expertise to interpret magnetic data [5]. Although it is not clear how the authors determined a remarkable retentivity value (of the order of  $10^{-6}$  emu) we opine that the title paper is yet another example of making an incorrect claim of soft magnetic behaviour, due to being unaware of the errors associated with measurement of magnetic signals, a point well described by Garcia et al [6].

In view of several inconsistent claims, especially the unusual magnetic behaviour and the IR spectrum showing the absence of any lithium sulphate, we decided to determine the exact nature of the so-called ‘lithium sulphate doped L-threonine’ **1** crystal. For this, we performed a crystal growth reaction by taking equimolar amounts of L-threonine (0.596 g, 5 mM) and lithium sulphate monohydrate (0.640 g, 5 mM) in ~50 ml of distilled water. The reaction mixture was stirred well for 12 h and left undisturbed for slow evaporation at room temperature. After a week, crystalline product was obtained. We did not take any special efforts to grow big crystals since the product had several X-ray quality crystals. The crystals were isolated by filtration and washed well with small amounts of ice-cold water and allowed to dry to obtain an yield of ~0.500 g of crystalline material. We labelled the product as compound **1-R** (R for reinvestigated) 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. We performed a flame test using a well washed crystal to determine the presence of any Li in **1-R** [7]. This test indicated the absence of lithium and sulphate in **1-R**. However, a crystal dipped in the mother liquor and subjected to flame test did indicate presence of Li. Hence, we believe that the presence of Li in the ICP-OES study is due to use of unwashed crystals.

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

Empirical formula	C <sub>4</sub> H <sub>9</sub> NO <sub>3</sub>
Formula weight (g mol <sup>-1</sup> )	119.12
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)	5.1473(2)
<i>b</i> (Å)	7.7382(4)
<i>c</i> (Å)	13.6124(6)
$\alpha$ (°)	90
$\beta$ (°)	90
$\gamma$ (°)	90
Volume (Å <sup>3</sup> )	542.19(4)
<i>Z</i>	4
<i>D</i> <sub>calc</sub> (mg/m <sup>3</sup> )	1.459
Absorption coefficient (mm <sup>-1</sup> )	0.124
F(000)	256
Crystal size (mm <sup>3</sup> )	0.347 x 0.220 x 0.164
$\theta$ range for data collection (°)	2.993 to 28.291
Limiting indices	-6 ≤ <i>h</i> ≤ 6, -10 ≤ <i>k</i> ≤ 10, -18 ≤ <i>l</i> ≤ 18
Reflections collected /unique	7738 / 1331 [R(int) = 0.0186]
Completeness $\theta = 27.00^\circ$	97.9 %
Refinement method	Full- matrix least-squares on F <sup>2</sup>
Data / restraints / parameters	1331 / 0 / 77
Goodness of fit on F <sup>2</sup>	1.139
Final R indices [I > 2 $\sigma$ (I)]	R1 = 0.0248, wR2 = 0.0682
R indices (all data)	R1 = 0.0255, wR2 = 0.0689
Largest diff. peak and hole (e Å <sup>-3</sup> )	0.259 and -0.136
CCDC deposit No	2074517

Compound **1-R** crystallizes in the nonpolar 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-threonine molecule in zwitterionic form (Fig. 1) with all

atoms located in general position. Our structure model is in agreement with literature data [2]. Since the structure of L-threonine is well documented in the literature since 1950, we do not discuss it anymore. A checkCIF report for **1-R** is given in Supplementary material.

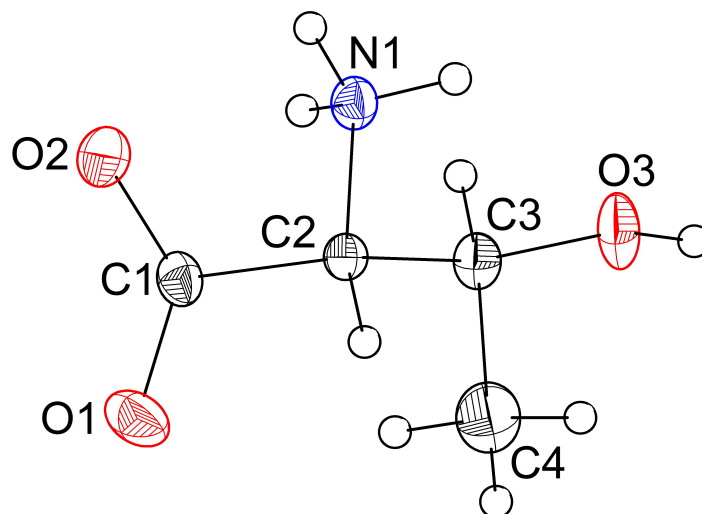
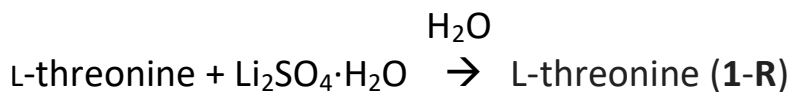


Fig.1 Crystal structure of L-threonine **1-R** showing the atom-labelling Scheme. Thermal ellipsoids are drawn at the 50% probability level for all non-hydrogen atoms.

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



Scheme 1 – Fractional crystallization of L-threonine

The crystallized product after washing well with water does not give a positive test for either Li or  $(\text{SO}_4)^{2-}$  and the fractional crystallization also explains the reported IR spectrum. The above given discussions convincingly prove that a so-called lithium sulphate doped L-

threonine crystal is, in fact, L-threonine. The optical spectra, cytotoxicity and other studies of the so called doped crystal **1** have no scientific merit and hence are not commented. In the literature, several L-threonine based crystals have been proved to be dubious [8-14] and the title compound is a new member of this series (for details see [Table S1](#)).

In summary, we have proved that the title lithium sulphate doped L-threonine is, in fact, L-threonine and not a ferromagnetic material.

**Declaration of conflict of interest:**

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

**Supplementary Material**

Deposition Number 2074517 contains the supplementary crystallographic data of L-threonine **1-R** 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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**Footnote** <sup>1</sup> compound is referred to as **1** to avoid use of an incorrect name and a strange code



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## Supplementary Material for ONLINE version

Abbreviations:

MW – Molecular Weight; L-thronine – L-thr;

Note: Authors consider that their crystal grown from an aqueous medium is a lithium sulphate doped L-thr crystal. However, they did not take into account that when lithium sulphate is crystallized from aqueous solution, the crystal obtained is a monohydrate namely lithium sulphate monohydrate formulated as  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$

L-thr (MW) **119.12** g mol<sup>-1</sup>

$\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  (MW) **127.96** g mol<sup>-1</sup>

Based on ICP-OES analysis authors claim that the so-called lithium sulphate doped L-thr crystal contains 0.07 mol of lithium sulphate ((this should be actually  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$ ))

MW of a sample of 0.93 mol% L-thr (**110.78** g) containing 0.07 mol% of  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  (**8.96** g) having formula  $(\text{L-thr})_{0.93}(\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O})_{0.07}$  is **119.74**

Based on above, **119.74** grams of doped crystal contains **8.96** mg of  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  --- (1)

For the ICP-OES analysis authors an amount of **76.18** mg of the doped crystal was used for analysis.

Based on equation (1) amount of  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  expected to be present in **76.18** mg of doped crystal can be calculated as **5.7** mg.

127.96 g of  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  contains 2Li atoms which is  $2 \times 6.94$  g of Li

Therefore 5.7 mg of  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  is expected to contain **0.618** mg of Li -- (2)

Authors report that from ICP-OES analysis the amount of is found to be **0.015** mg which is not in agreement with the expected value of **0.618** mg based on calculation for 0.07 mol% doping.

Additionally, amount of S (0.039 g) found by ICP-OES is not in agreement with amount of Li (0.015 g) found for the formula  $\text{Li}_2\text{SO}_4 \cdot \text{H}_2\text{O}$  indicating that calculations are all incorrect / questionable.

Table S1 List of L-threonine based dubious crystals

No	Name of reported material	Actual crystal	Reference
1	L-threonine formate	L-threonine	S2, S8
2	L-threonine diformate	L-threonine	S8
3	L-threonine zinc acetate	L-threonine	S7
4	Urea L-threonine	L-threonine	S9
5	L-threonine phosphate	L-threonine	S8
6	L-threoninium sodium fluoride	L-threonine	S10
7	L-threoninium tartrate	L-threonine	S10
8	L-threoninium phosphate	L-threonine	S10
9	L-threonium acetate	L-threonine	S1, S5
10	magnesium sulfate admixed L-threonine	L-threonine	S6
11	L-threonine calcium chloride	L-threonine	S3
12	$\text{Li}_2\text{SO}_4$ doped L-threonine	L-threonine	This work
13	L-threonine phthalate	Phthalic acid	S4, S8

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