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X-ray studies of purine in a wide range of temperatures

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This paper presents the results of the study of purine by the method of low-temperature x-ray diffraction in the range from 150 to 450 K. The dependence of the unit cell parameters on the temperature for a given compound was first obtained and its coefficients of thermal expansion were calculated. 2D and 3D figures of thermal expansion are constructed, based on this data.
Keywords: *purine, nitrogenous base, low-temperature X-ray diffractometry, thermal expansion*

1. Introduction

The study of polymorphism of compounds is an important field in solid state research and of special importance for the pharmaceutical industry [1, 2].Understanding the processes of phase transition and knowledge of the presence of a specific polymorphic modification, at each stage of processing all components of the pharmaceutical, and most importantly in the final product is an actual problem of the pharmaceutical industry. Purine has not been previously studied at low temperatures.

A purine is an aromatic heterocycle composed of carbon and nitrogen. Purines include adenine and guanine, which participate in DNA and RNA formation. Purines are also constituents of other important biomolecules, such as ATP, GTP, and can serve as cofactors, such as NADH and coenzyme A. [3 - 5].

This work is a continuation of the systematic research of pharmaceutical ingredients. Earlier in articles [6 - 8] we investigated the structural and thermodynamic properties of L-carnitine, hevein, betamethosone valerate. The aim of this work is to study the behavior of purine the low temperature region and to investigate its thermal expansion by means of low-temperature radiography. The method of high- and low-temperature radiography makes it possible to measure the coefficients of thermal expansion along any direction of the crystal structure, along the crystallographic axes (it is more interesting for us), the coefficient of volumetric expansion, the average coefficient of thermal expansion, and so on. [9]. Thermal expansion is one of the thermophysical characteristics of a substance that provides information about it in a wide range of temperatures [10].

2. The experimental part
2.1. Sample

The studied sample of purine (CAS: 120-73-0) was purchased from Sigma-Aldrich (according to the passport for the reagent, the purity of the sample is at least 99.0%). An x-ray diffraction pattern of purine was obtained in the 2θ range from 5 ° to 60 ° on a XRD-6000 X-ray diffractometer from Shimadzu (CuKα radiation, scanning step 0.02 °) to identify the phase (Fig. 1). X-ray data and estimation of the impurity content in the studied substance allowed us to conclude that the researched sample is an individual crystal compound (Pna21, a = 1.555 nm, b = 0.937 nm, c = 0.366 nm) [4].

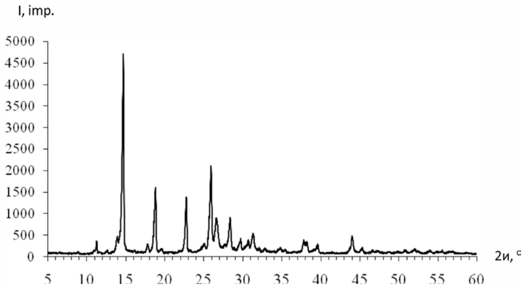

Figure 1. X-ray of purine

Table 1. Unit cell parameters and coefficients of thermal expansion of purine.

T (K)	*a* (nm)	*b* (nm)	*c* (nm)	*V* (nm ^{3})	*ρ* (g·cm^{-3})
150	1.5591(19)	0.9418(13)	0.3648(5)	0.5356(12)	1.489
175	1.5591(19)	0.9421(13)	0.3650(5)	0.5362(12)	1.488
200	1.5606(21)	0.9414(15)	0.3652(6)	0.5365(13)	1.486
225	1.5602(15)	0.9427(11)	0.3652(4)	0.5371(9)	1.485
250	1.5591(18)	0.9415(13)	0.3654(5)	0.5363(11)	1.487
275	1.5596(13)	0.9425(9)	0.3654(4)	0.5370(8)	1.485
300	1.5598(16)	0.9408(12)	0.3655(5)	0.5363(10)	1.487
325	1.5592(14)	0.9412(10)	0.3657(4)	0.5367(9)	1.486
350	1.5610(18)	0.9406(13)	0.3659(5)	0.5372(11)	1.485
375	1.5607(19)	0.9411(13)	0.3657(5)	0.5372(12)	1.485
400	1.5608(16)	0.9413(12)	0.3659(5)	0.5375(10)	1.484
425	1.5595(11)	0.9411(8)	0.3659(3)	0.5370(7)	1.485
450	1.5585(14)	0.9395(10)	0.3659(4)	0.5357(9)	1.489
$\alpha\cdot10^5$ (K^{-1})	0.06	-0.63	1.01	0.43	

Standard uncertainties u are u(T) = 1 K, u(a) = 0.016 Å, u(b) = 0.019 Å, u(c) = 0.04 Å, u(V) = 5 Å3, u(ρ) = 0.003 g·cm-3, ur(p) = ± 1% (level of confidence = 0.68).

2.2. Apparatus and measurement technique

To study the thermal expansion of betamethasone valeratein the temperature range from 150 to 450 K, a powder diffractometer XRD-6000 Shimadzu (CuKα radiation, reflection photography θ-2θ) with a scanning step of 0.02 ° in the range from 5 to 60 ° and a low temperature attachment TTK- 450 Anton Paar were used. The result of the experiment is a series of radiographs obtained at certain temperatures with scanning step 25 K(increments). X-ray diffraction was performed using the XRAY software [11].

The quantitative characteristic of thermal expansion is the coefficient of thermal expansion, calculated as follows:

$$\alpha_a = \left(\frac{1}{a}\right)\cdot\left(\frac{da}{dT}\right)$$

a is the unit cell parameter, T is the temperature.

Calculation of the thermal expansion coefficients was performed in the DTC (Deformation Tensor Computing) software package developed in the St. Petersburg State University [9]. The original data for the calculation are the coefficients of the polynomial equations describing the temperature dependence of the unit cell parameters of the investigated compound. As a result of data processing, the user has a table of thermal expansion coefficients at the required temperatures.The figures of thermal expansion show the character the deformation of the thermal expansion compounds most clearly. These figures make it possible to describe in detail the behavior of the compound in a wide range of temperatures. The length of radius vector drawn from the origin to the boundary of the figure is equal to the value of the coefficient of thermal expansion in a given direction. To construct 2D figures of thermal expansion, the software complex KTR-B2 [8] was used, 3D figures were constructed using the algorithm on Maple 2016 [12] developed at Lobachevsky University [13].

3. Results and discussion

The unit cell parameters and the coefficients of thermal expansion of the investigated sample of purine presented in the table. The temperature dependence of the unit cell parameters is shown in Fig. 2. The dependencies are described by the following polynomials:

$a = 9.011\cdot10^{-7}\cdot T+1.55951428571$ ($150\leq T\leq450$ K)

$b = -59.5604\cdot10^{-7}\cdot T+0.94314065934$ ($150\leq T\leq450$ K)

$c = 36.7033\cdot10^{-7}\cdot T+ 0.36439890110$ ($150\leq T\leq450$ K)

$V = 22.8571\cdot T+ 0.53595274725$ ($150\leq T\leq450$ K).

Thermal expansion of purine is anisotropic, and its coefficient of thermal expansion depends on temperature. The greatest thermal deformations are observed along the crystallographic axis c, which

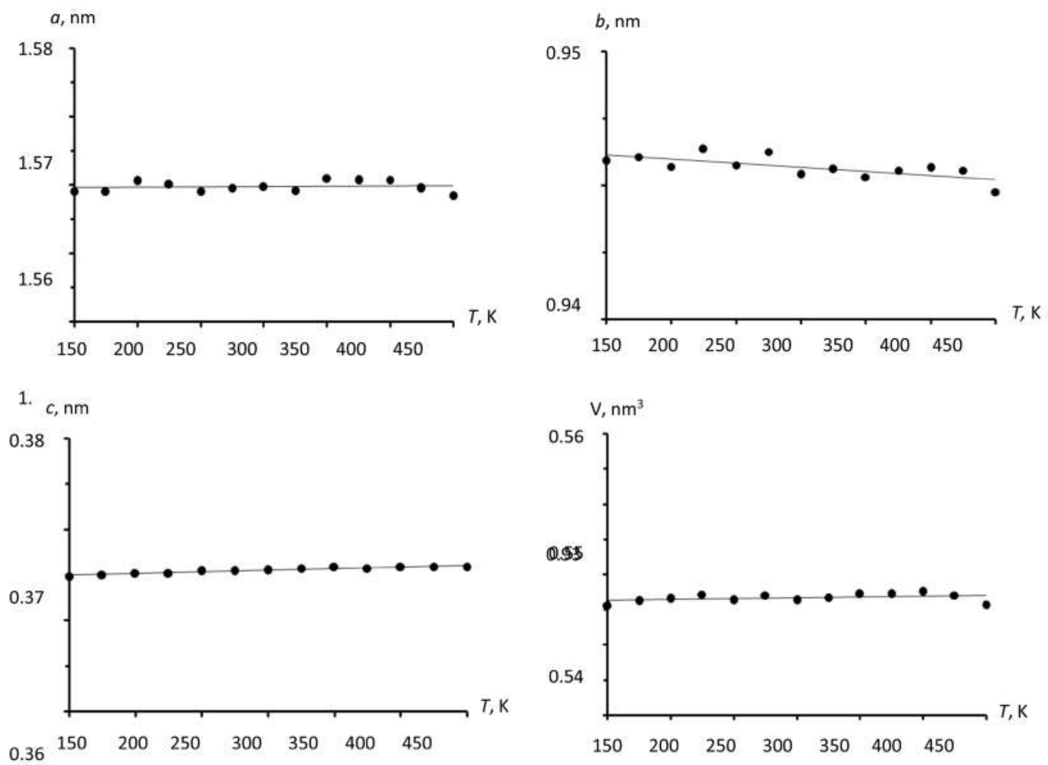

Figure 2. Temperature dependences of the unit cell parameters

is due to the weakest hydrogen bonds along this direction. The anisotropy of thermal expansion is demonstrated most clearly by the 2D and 3D figures of thermal expansion shown in Fig. 3 and 4.

Temperature dependence of the crystal density was calculated using the temperature dependence of the volume of a unit cell of purine. The density of purine (ρ = 1.487 g·cm-3) was previously estimated in [4], our results agree well with this value.

4. Conclusion

The overall aim of this work was to study a purine sample at low temperatures using powder X-ray diffraction for the presence or absence of low-temperature phase transitions, and to study the thermal expansion of this compound and the calculation of its coefficients.

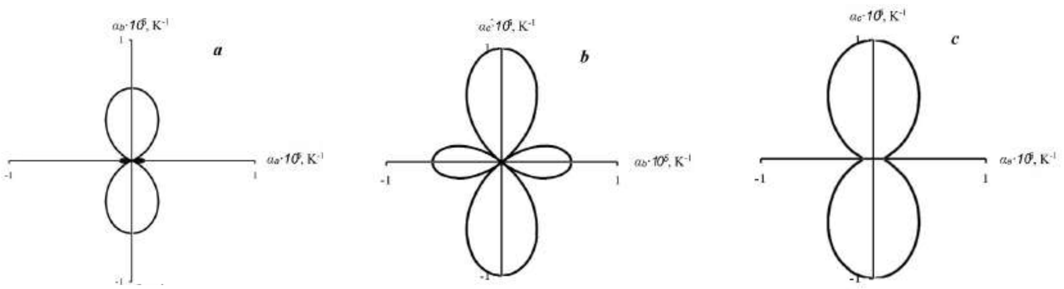

Figure 3. 2D figures of thermal expansion of purine

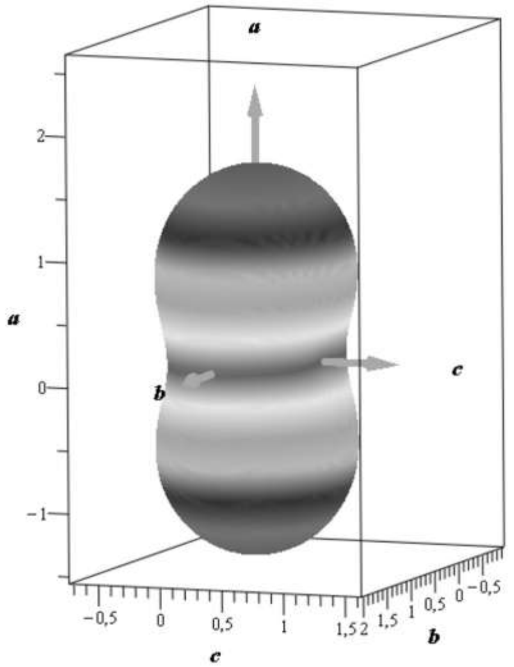

Figure 4. 3D figures of thermal expansion of purine

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