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Anisotropic Thermal Expansion of Arsenic

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The lattice parameters of arsenic have been determined at various temperatures between 28 and 286° C, using 19 cm diameter, high temperature camera. The a-parameter is observed to increase between 28 and 200° C and thereafter it decreases up to 286° C. The c-parameter is found to increase parabolically throughout the range of temperature. The mean values of thermal expansion coefficients along, and perpendicular to, the principal axis between 28 and 200° C are 44.3 $\times$ 10^{-6}/° C and 3.1 $\times$ 10^{-6}/° C respectively.

1. Introduction

Two reports, one Klemm *et al* [1] and the other by Taylor *et al* [2], on the values of the lattice parameters of arsenic at different temperatures are available in the literature. There is, however, some discrepancy in the nature of the temperature variation of the a-parameter as given in these two reports. To resolve this, a redetermination of the lattice parameters and the coefficients of thermal expansion at different temperatures has been undertaken. This note presents the results of the study along with a comparison with earlier data.

2. Experimental and Results

A pure sample supplied by Thomas Tyrer and Co was used to obtain the X-ray powder photographs at the various temperatures. The experimental technique and the method of evaluating the lattice parameters was the same as described earlier [3]. The reflections employed were $(30.6)\alpha_1\alpha_2$, $(31.2)\alpha_1\alpha_2$, $(13.4)\alpha_1\alpha_2$, $(40.2)\alpha_1\alpha_2$ and $(30.9)\alpha_1\alpha_2$. These were recorded at approximate Bragg angles of 56°, 60°, 64°, 73° and 75° respectively with CuKα. In table I the values of the lattice parameters and the axial ratio at different temperatures are given.

The a-t plot given in fig. 1 shows that the a-parameter increases slowly with temperature, reaches a maximum value at about 200° C and then falls gradually. To evaluate the expansion coefficient in this direction, a straight line was drawn using all the experimental points below 200° C and the slope of this line was determined. This gave the average coefficient, $\bar{\alpha}_a = 3.1 \times 10^{-6}$ °C.

TABLE I Values of the lattice parameters of arsenic at different temperatures

Temp. °C	"a" Å	"c" Å	c/a
28	3.7585	10.5564	2.8087
70	3.7591	10.5713	2.8122
155	3.7599	10.6052	2.8206
200	3.7595	10.6368	2.8293
244	3.7601	10.6583	2.8346
286	3.7588	10.6783	2.8409

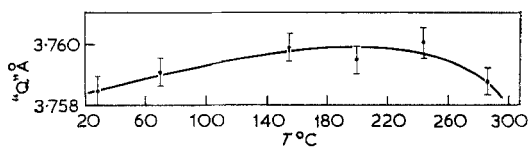

Figure 1 Temperature variation of a-parameter.

The variation of the c-parameter with temperature, shown in fig. 2, is non-linear and hence a quadratic fitted to these points by the method of least-squares gave the following equation.

$$c_t = 10.5522 + 369.93 \times 10^{-6}(t - 20) + 423.30 \times 10^{-9}(t - 20)^2.$$

Here c and t are expressed in Å and °C respectively. The corresponding equation for the

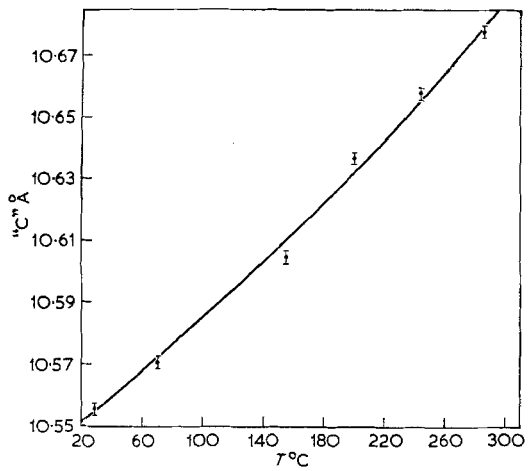

Figure 2 Temperature variation of c-parameter.

coefficient of thermal expansion, obtained by differentiation of c_t with respect to temperature, is

$$\alpha_c = (33.45 \times 10^{-6} + 80.2 \times 10^{-6} t)\ ^\circ\mathrm{C}\,.$$

The error in the coefficients was estimated to be less than 5%.

Bridgman [4] has reported the expansion coefficients along, and perpendicular to, the c-direction at 6° C. The present values of coefficients are extrapolated to the same temperature and compared in table II. Klemm *et al* studied the variation of the lattice parameters with temperature. They also noticed a reversal in the a-parameter plot at about the same temperature (230° C). The mean expansion coefficients evaluated from their graph, compared with the present values in table II are in good agreement.

Recently, Taylor *et al* have studied the lattice parameters of arsenic at different temperatures. The mean expansion coefficient along the c-direction, between 22 and 400° C, as shown in table II, is in good agreement with the present value. However, the coefficient of expansion in the a-direction obtained by them as zero and does not agree with the present result or any of the earlier data as given in table II.

TABLE II Results of the thermal expansion coefficients of arsenic obtained by different workers

Author	$\alpha_a \times 10^6$/°C	$\alpha_c \times 10^6$/°C	Temp. °C
Bridgman	3.0	43.0	At 6
Klemm *et al*	2.6	47.4	Between 0–200
Taylor *et al*	0.0	47.2	Between 20–400
Present work	3.1	33.9	At 6
	3.1	44.3	Between 20–200

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