THE THERMAL EXPANSION OF A GROSSULARITE GARNET*

By L. G. WILSON†

Introduction

A study of the thermal behaviour of the lattice constant of a grossularite garnet in terms of thermal expansion has been made using a 10·302 cm diameter high temperature back reflection symmetrical processing X-ray camera designed by G. B. Clarke (1951) for the measurement of mineral lattice constants at high temperature.

The measurement of the diffraction patterns obtained in the work was made with a thin steel scale graduated in 0·5 mm. A reproducibility of $\pm 0{\cdot}01$ cm. was obtained in these measurements. This method was adopted in preference to that employing a travelling microscope with unit magnification, which gave a similar reproducibility of measurement. The film measurements were converted to lattice constants using the extrapolation technique of Cohen (1935). $K\alpha_1$ and $K\alpha_2$ reflections always appeared resolved and, since unfiltered radiation was used, $K\beta_1$ reflections frequently occurred. For calculation all reflections observed were reduced to equivalent $K\alpha_1$ reflections.

The behaviour of the camera was tested by making a series of measurements, at various temperatures, of the lattice constant of platinum and comparing the equation relating these values to their corresponding temperatures, with accepted lattice constant-temperature expressions for platinum. The results of this work are given below.

Platinum Lattice Constant Test

Twenty-seven lattice constant determinations were made on a sample of platinum at different temperatures over the range 15–800 °C using cobalt radiation ($K\alpha_1 = 1{\cdot}78529$ kX). Using the least squares method the equation

* Manuscript received May 16, 1956.

† Physics Department, University of Western Australia, Perth ; present address : C.S.I.R.O., East Melbourne.

best relating these lattice constants a to temperature t °C for the experimental values was calculated as

$$a=3\cdot91414+3\cdot80\times10^{-5}t\ (\mathrm{kX}), \quad \ldots\ldots\ldots\ldots\ (1)$$

where the standard error of a is $\pm3\times10^{-4}$ and those for the constants of the equation are $\pm7\times10^{-5}$ and $\pm2\times10^{-7}$ respectively.

A reasonable frequency distribution is shown by the deviations of the values of a, calculated from equation (1) for the experimental temperatures, from the experimental values, only one value exceeding twice the standard error.

The validity of equation (1) as a means of expressing platinum lattice constants at different temperatures was tested by comparing the value of a calculated at 100 °C intervals using equation (1) and the values obtained from two expressions given in the International Critical Tables (1927) together with the lattice constant value of 3·91519 kX at 25 °C given by the Alphabetical and Numerical Indexes of X-ray Diffraction Patterns (American Society for Testing Materials 1953). The two expressions used are

$$a=a_0(1+8\cdot786\times10^{-6}t+3\cdot118\times10^{-9}t^2 +5\cdot2\times10^{-12}t^3+4\cdot095\times10^{-15}t^4), \quad \ldots\ldots\ldots\ (2)$$

and

$$a=a_0(1+9\cdot75\times10^{-6}t). \quad \ldots\ldots\ldots\ldots\ (3)$$

Equation (2) is given as valid over the temperature range from −50 to +600 °C and equation (3) over the range from 0 to 1670 °C.

The comparison shows that equation (1) expresses the lattice constant of platinum to an agreement of $\pm2\times10^{-4}$ kX with other available data, and therefore the apparatus can be regarded as a satisfactory instrument for lattice constant determinations over the range from 15 to 800 °C.

The Thermal Expansion of Grossularite Garnet

The grossularite garnet used for these determinations was originally supplied by the Foote Mineral Company who suggest its origin as Boleo, near Santa Rosalie, Lower California, Mexico. An analysis indicated the specimen to be a normal grossularite garnet and an optical examination shows the material to be uniform in composition. Pure $3CaO.Al_2O_3.3SiO_2$ comprised 93·33 per cent. of the material and iron oxides amounted to 5·61 per cent.

Using iron radiation ($K\alpha_1=1\cdot93207$ kX) 28 lattice constant determinations were made with the specimen held at different temperatures over the range 25–940 °C. The equation best relating these values of lattice constant and temperature estimated by the least squares method is

$$a=11\cdot8368+8\cdot6\times10^{-5}t+2\cdot2\times10^{-8}t^2\ (\mathrm{kX}), \quad \ldots\ldots\ldots\ (4)$$

where a has a standard error of $\pm10^{-3}$ kX and the three constants of the equation have standard errors of $\pm4\times10^{-4}$, $\pm6\times10^{-6}$, and $\pm3\times10^{-9}$ respectively.

As in the case of the platinum results a reasonable frequency distribution is shown by the deviations of the values of a, calculated from equation (4) for

the experimental temperatures, from the experimental values, only two deviations exceeding twice the standard error.

Equation (4) when differentiated with respect to temperature gives an expression for the coefficient of thermal expansion of grossularite garnet, thus

$$\frac{1}{a}\frac{da}{dt}=\frac{1}{a}(8\cdot6\times10^{-5}+4\cdot4\times10^{-8}t). \quad \ldots\ldots\ldots \quad (5)$$

This equation expresses the coefficient to within ±2 per cent. at 25 °C varying proportionately to ±6 per cent. at 940 °C as a result of the standard errors involved in the estimation of the constants in equation (4).

The author wishes to thank Professor C. J. B. Clews for permission to carry out this work at the Physics Department, University of Western Australia. Acknowledgment is also made to Mr. J. Shearer for his valuable advice and guidance.

References

American Society for Testing Materials (1953).—Alphabetical and Numerical Indexes of X-ray Diffraction Patterns. Card No. 4–0787.

Clarke, G. B. (1951).—The measurement of the thermal expansion of grossularite by X-rays. M.Sc. Thesis. University of Western Australia.

Cohen, M. U. (1935).—Precision lattice constants from X-ray powder photographs. *Rev. Sci. Instrum.* **6**: 68–74; **7**: 155.

International Critical Tables (1927).—Vol. 2, pp. 461–2. (McGraw-Hill: New York.)