

# THE THERMAL EXPANSIONS OF THORIA, PERICLASE AND DIAMOND\*

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## ABSTRACT

A central mount, back reflection, *x*-ray powder camera was designed for measuring thermal expansions. The camera is 16 cms. in diameter, has a temperature range from 0° to 1000° C., is inexpensive to construct and is simple to operate.

The linear ( $\alpha_a$ ) and volume ( $\alpha_v$ ) thermal expansion coefficients of ThO<sub>2</sub> are  $\alpha_a = 0.6216 \times 10^{-5} + 3.541 \times 10^{-9}T - 0.1125T^{-2}$  and  $\alpha_v = 1.865 \times 10^{-5} + 10.96 \times 10^{-9}T - 0.3375T^{-2}$  where *T* is the temperature in degrees Kelvin from 298° to 1073° K. For periclase, the coefficients are  $\alpha_v = 1.411 \times 10^{-5} + 1.210 \times 10^{-9}T - 0.5854T^{-2}$  and  $\alpha_a = 4.232 \times 10^{-5} + 3.630 \times 10^{-9}T - 1.756T^{-2}$ , from 298° to 973° K. For commercial diamond dust the coefficients are  $\alpha_v = 0.07667 \times 10^{-5} + 3.672 \times 10^{-9}T - 0.0903T^{-2}$  and  $\alpha_a = 0.2301 \times 10^{-5} + 11.01 \times 10^{-9}T - 0.2708T^{-2}$ , and for a single crystal of South West African diamond,  $\alpha_a = 0.09613 \times 10^{-5} + 3.522 \times 10^{-9}T - 0.0888T^{-2}$  and  $\alpha_v = 0.2884 \times 10^{-5} + 10.57 \times 10^{-9}T - 0.2665T^{-2}$  from 298° to 973° K.

The measured expansions of periclase and diamond are slightly lower than previous measurements made on macroscopic single crystals. The thermal expansion of thoria has not been measured previously.

The unit cell size ( $a_0$ ) and molar volume ( $V_m$ ) at 298.16° K. and 1 atmosphere are, for thoria,  $a_0 = 5.59525 \pm 0.0001$  Å and  $V_m = 26.378 \pm 0.005$  cc./mole; for periclase,  $a_0 = 4.2117 \pm 0.0002$  Å and  $V_m = 11.250 \pm 0.007$  cc./mole; for diamond,  $a_0 = 3.56688 \pm 0.00009$  Å and  $V_m = 3.4168 \pm 0.0001$  cc./mole.

## INSTRUMENTATION

A new high-temperature *x*-ray powder camera has been designed specifically to measure the thermal expansions of minerals from 20° to 1000° C. The camera is a central-mount camera, but only those reflections with Bragg angles greater than 45° are recorded. Diagrams of the camera and its component parts (Figs. 1, 2, 3), are largely self-explanatory.

Essentially the camera consists of a heavy brass plate 20 cms. in diameter with machined recesses to seat the removable film cartridge and the film housing. The brass film cartridge (*a*) has an internal diameter of 16 cms. (film diameter). The cartridge has a  $\frac{3}{4}$  inch slot (*f*) machined in the front surface to allow the passage of the diffracted *x*-ray beams. When in operation the slot is covered with masking paper to make the cartridge light-tight. The top of the film cartridge is sealed by a removable light-tight lid (*d*). Vertical knife edges (*b*), 0.001 inch wide, are attached to the bottom of the film cartridge at approximately  $\theta = 51.141^\circ$ , where  $\theta$  is the effective Bragg angle of the knife edges.

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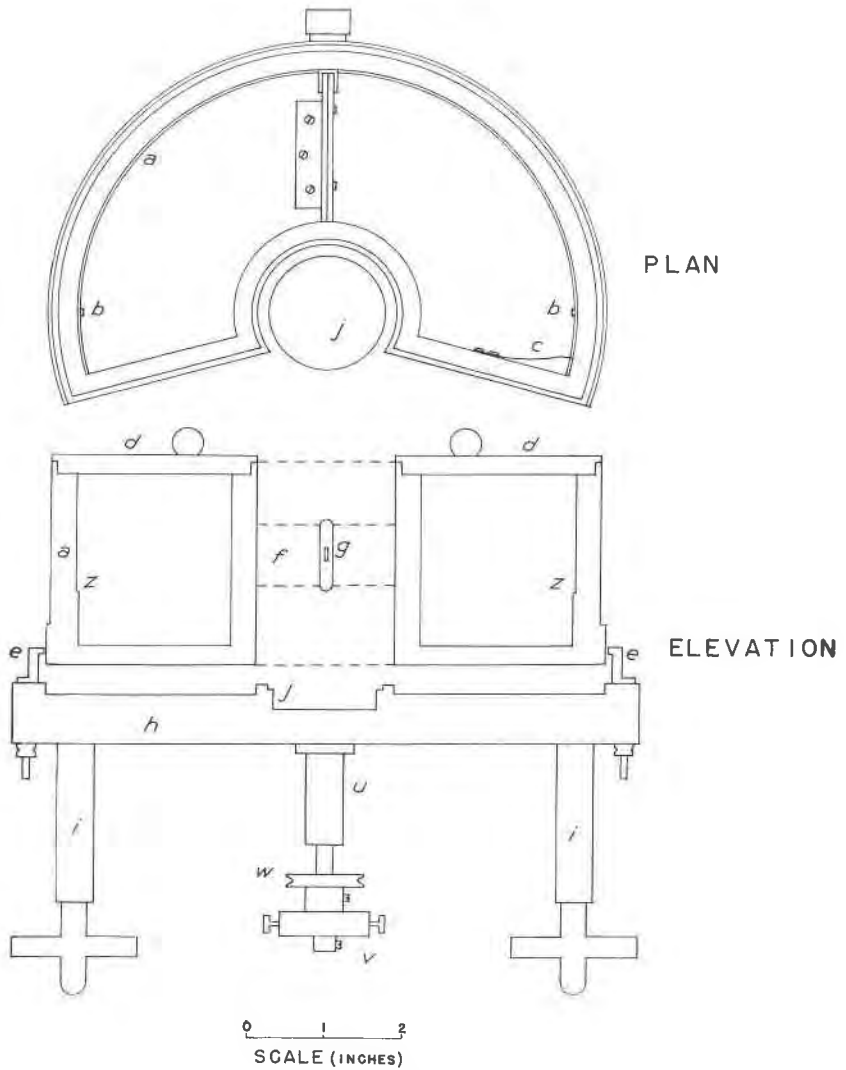


FIG. 1

KEY TO CAMERA PARTS

- (a) Brass film housing.
- (b) Knife edges.
- (c) Spring to hold film tight against seating.
- (d) Removable, light-tight lid.
- (e) Clamps to hold film cartridge steady.
- (f) Slot in cartridge wall covered with black paper.
- (g) Positioning bar for slit system.
- (h) Base plate.
- (i) Adjustable legs.
- (j) Recess for furnace.

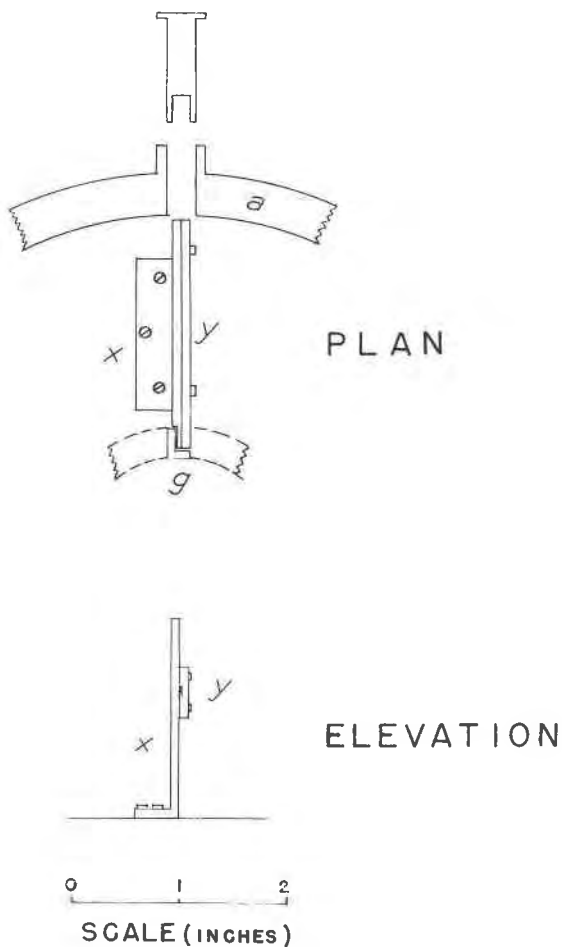


FIG. 2

- (k) Vanes for circulating cooling water.
- (l) Water inlet.
- (m) Water outlet.
- (n) Thermocouple and mechanism for rotating thermocouple around specimen.
- (o) Specimen support and specimen.
- (p) X-ray inlet, and exit for diffracted rays.
- (q) Exit for undiffracted x-ray beam.
- (r) Furnace windings, supported on alundum core.
- (s) Furnace leads.
- (t) Jacket soldered over water-circulating vanes.
- (u) Support for centering system.
- (v) Centering system.
- (w) Drive wheel for rotating specimen in furnace.
- (x) Main support plate for collimating slit, with three positioning screws.
- (y) Plate with slit of desired size machined in it.
- (z) Film seat.

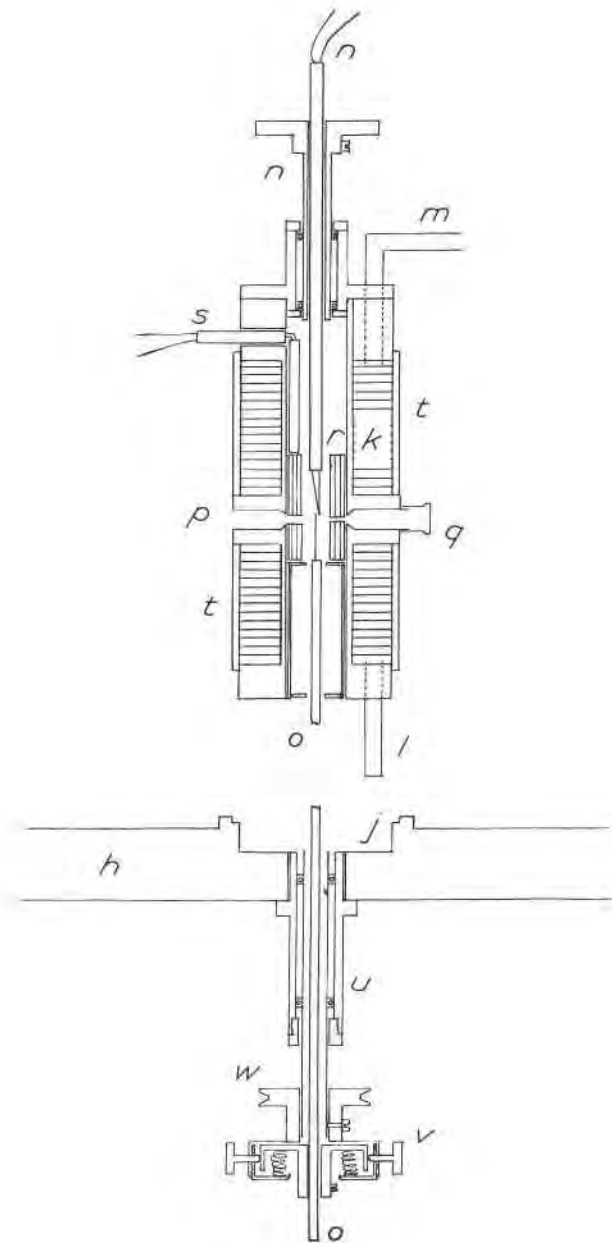


FIG. 3

The specimen under study is mounted in a silica glass capillary tube, approximately 0.2 mm. in diameter, and is then cemented in a 0.25 mm. hole in the top of a  $\frac{1}{8}$  inch stainless steel rod (*o*), Fig. 3. The steel specimen support is clamped into the centering system (*v*).

The collimating slit is milled in a brass strip (*y*), screwed to the supporting plate (*x*). The dimensions of the collimating slit can be adjusted for each substance studied, until suitable line quality with minimal exposure time is obtained.

The furnace has an internal diameter of 0.25 inch and a length of 1 inch. The furnace windings (*r*) are nichrome ribbon  $0.0156 \times 0.005$  inch, supported on an alundum core, and held in place with ceramic cement. Over the furnace core and windings another alundum tube has been fitted, providing some thermal insulation for the furnace. The outer alundum tube fits snugly into the furnace housing and rests directly against the inner wall of the cooling jacket. Since the region  $90^\circ < 2\theta < 180^\circ$ \* is recorded on the film, it is not necessary to have an opening all the way around the furnace for the escape of the diffracted beams. A slot,  $185^\circ$  around the circumference from  $2\theta$  equals  $87.5^\circ$  to  $180^\circ$  on either side of the primary beam, allows the entrance of the primary  $x$ -ray beam and the exit of the diffracted beams. A small circular hole opposite the collimating slit allows the exit of the undiffracted  $x$ -ray beam.

The housing is machined from a single piece of stainless steel stock. Like the furnace, the housing has a  $185^\circ$  slot (*p*) cut in it, with a small exit port (*q*). In operation the slot is covered with masking paper, so that there is no contact with the circulating air outside. The water circulating vanes (*k*) are sealed externally by a stainless steel jacket (*t*). Water is circulated under a pressure of 5 lbs./sq. inch though higher or lower pressures may be used if desired.

The temperature is measured by reading the emf developed in a platinum, platinum-10% rhodium thermocouple (*n*), contained in a  $\frac{1}{8}$  inch silica glass tube. The thermocouple can be raised or lowered and rotated around the specimen, allowing the detection of any temperature inhomogeneities in the furnace. In operation the thermocouple is placed  $\frac{1}{32}$  inch from the specimen in the plane of the incident  $x$ -ray beam. Readings are taken at  $60^\circ$  intervals around the specimen.

The temperature of the furnace is controlled with a variable transformer on the output of a constant voltage transformer. With the furnace insulated from external air currents and the cooling water maintaining a constant flow, the temperature is held constant to  $\pm 1^\circ$  C. at  $400^\circ$  C. for 48 hour test periods.

The knife edges can be located by using any isometric or uniaxial sub-

\*  $\theta$  is the Bragg angle.

stance whose lattice parameters are accurately known. In the present case, the knife edges were located with an accurately measured quartz sample, after the method of Bradley and Jay (1933).

#### METHOD OF MEASUREMENT AND COMPUTATION

In determining thermal expansion the precision of measurement is more important than the absolute accuracy. A constant error in the accuracy of each point, expressed as a percentage, will tend to cancel out in the computation of the thermal expansion coefficient.

All films were measured on a Hilger and Watts Film Measuring Rule #185, ruled to  $1.000 \pm 0.001$  mm., and fitted with a sliding vernier ruled to  $0.050 \pm 0.001$  mm. Individual measurements could be estimated to 0.02 mm. by interpolation. The *x*-ray wavelengths used in all calculations were those recommended by Bragg (1947). The stated precisions of measurements in this paper are the standard deviations.

Measurements of the cell size were made at different temperatures, and from these values both the linear and volume expansions determined. The molar volumes at different temperatures were computed directly from the measured values of  $a_0$  using the formula,

$$V_m = \frac{(a_0)^3 N}{x}$$

where

- $a_0$  is the unit cell edge length in cms.
- $N$  is Avogadro's number (equal to  $(6.02338 \pm 0.00043) \times 10^{23}$  mole<sup>-1</sup>)
- $x$  is the number of formula units in the unit cell
- $V_m$  is the molar volume

Standard values of the unit cell size and the molar volumes at 298.16° K (25° C.) and 1 atmosphere pressure were determined by making several measurements at this temperature. These values have been called  $a_s$  and  $V_{ms}$  respectively. The variation in the coefficients of thermal expansion with temperature have been expressed by functions of the form

$$\alpha_a = \frac{1}{a_s} \left( \frac{\partial a_0}{\partial T} \right)_P = b + cT + dT^{-2}$$

and

$$v = \frac{1}{V_{ms}} \left( \frac{\partial V_m}{\partial T} \right)_P = b_1 + c_1T + d_1T^{-2}$$

where

- $\alpha_a$  and  $\alpha_v$  are the linear and volume coefficients of thermal expansion respectively,
- $a_s$  and  $V_{ms}$  are the unit cell size and molar volume at 298.16° K and 1 atmosphere respectively,
- $T$  is the temperature in degrees Kelvin,
- $b, c, d,$  and  $b_1, c_1, d_1,$  are constants of the equations.

If the equations above are integrated, we get functions of the form

$$\frac{a_0 - a_s}{a_s} = bT + \frac{1}{2}cT^2 - dT^{-1} + I$$

where

$a_0$  is the unit cell size at temperature  $T^\circ$  K

$I$  is the constant of integration.

Since the integrated form is sometimes more useful than the differential form, all the constants  $b$ ,  $c$ ,  $d$ , and  $I$  have been given in Table 8.

### EXPERIMENTAL DATA

#### THORIA

The sample used in the present study was the one used by Frondel (1955) in his accurate determination of the cell size. A spectrographic analysis by the United States Geological Survey showed Si and Mg to be the major impurities (Table 1). The Si and Mg may or may not be dis-

TABLE 1. SPECTROGRAPHIC ANALYSIS OF  $\text{ThO}_2$  SAMPLE

over 10%	Th
5 -10%	—
1 -5%	—
0.5 -1%	—
0.1 -0.5%	Si, Mg
0.05 -0.1%	—
0.01 -0.05%	Fe, B, Al
0.005 -0.01%	—
0.001 -0.005%	Sc, Cu
0.0005-0.0001%	—
0.0001-0.0005%	Be

solved in the  $\text{ThO}_2$ . If all the impurities present were dissolved in the  $\text{ThO}_2$  it is doubtful if they would alter the physical properties significantly.

Previous accurate measurements of the lattice parameter of thoria are limited to Frondel (1955) and Hund and Niessen (1952). Frondel's value of  $5.58415 \pm 0.00005$  kX at  $31.6^\circ$  reduces to  $5.59520 \pm 0.00005$  Å at  $25^\circ$  C. Hund and Niessen's value of  $5.59530$  Å was determined at an unknown 'room temperature.' The value obtained in the present study is  $5.59525 \pm 0.0001$  Å, and this was selected as the standard value of  $a_0$  at  $298.16^\circ$  K. Table 2 shows the unit cell size and molar volume at the various temperatures of measurement. The parameters of the various functions derived from the data in Table 2 are shown in Table 8.

TABLE 2. THORIA

Unit cell edge ( $a_0$ ) and molar volume ( $V_m$ ) at different temperatures

Temp. °C.	$a_0$ Å	$V_m$ cc./mole
8.5	5.59475	26.3707
25.0	5.59525	26.3780
33.0	5.59557	26.3823
34.1	5.59561	26.3830
103.1	5.59812	26.4184
162.0	5.60040	26.4507
256.2	5.60424	26.5052
343.1	5.60802	26.5588
398.2	5.61069	26.5968
403.0	5.61069	26.5968
404.2	5.61090	26.5998
421.3	5.61189	26.6139
446.0	5.61288	26.6279
495.9	5.61542	26.6641
593.9	5.62044	26.7357
700.0	5.62589	26.8136
787.2	5.63050	26.8795

*Best values*

$$a_0 \text{ at } 298.16^\circ \text{ K.} = 5.59525 \pm 0.0001 \text{ \AA}$$

$$V_m \text{ at } 298.16^\circ \text{ K.} = 26.378 \pm 0.005 \text{ cc./mole}$$

$$\rho \text{ at } 298.16^\circ \text{ K.} = 10.013 \pm 0.001 \text{ gm./cc.}$$

$$\alpha_a \text{ at } 298.16^\circ \text{ K.} = 6.00 \times 10^{-6}$$

$$\alpha_v \text{ at } 298.16^\circ \text{ K.} = 18.1 \times 10^{-6}$$

## PERICLASE

The sample of periclase was a colorless single crystal prepared synthetically by the Norton Company. Similar material from the Norton Company was studied by Austin (1931) using the interferometer method and by White (1938) using a mechanical dilatometer. In a recent series of measurements Sharma (1950) measured the linear expansion of periclase by the interferometer method. The measurements of Austin and White show a reasonable agreement, though Austin's measurements are more refined than White's. Sharma's results are in distinct variance with both Austin and White and to the present study.

Previous accurate measurements of the lattice parameter of periclase are limited to Wyckoff (1925) and Jay and Andrews (1945). Wyckoff determined the lattice parameter at an unspecified room temperature as 4.203 kX (4.211<sub>5</sub> Å). Jay and Andrews also made their measurements at an unspecified room temperature. Their value of 4.200 kX (4.209 Å) is



somewhat lower than Wyckoff's value and the present measurement. The best value of  $a_0$  at 298.16° K. has been selected from the present measurements as  $4.2117 \pm 0.0002$  Å. The measured values of the lattice parameter and calculated values of the molar volume at various temperatures are shown in Table 3. The parameters of the various functions derived from the data in Table 3 are given in Table 8.

TABLE 3. PERICLASE  
Unit cell edge ( $a_0$ ) and molar volume ( $V_m$ ) at different temperatures

Temp. °C.	$a_0$ Å	$V_m$ cc./mole
10.5	4.21130	11.2466
21.0	4.21160	11.2492
25.0	4.21168	11.2498
46.5	4.21243	11.2558
76.5	4.21360	11.2652
131.0	4.21595	11.2841
229.5	4.22090	11.3239
320.6	4.22576	11.3630
404.2	4.23047	11.4011
512.0	4.23679	11.4523
601.8	4.24195	11.4942
703.1	4.24812	11.5444

<i>Best values</i>		
$a_0$ at 298.16° K.	=	$4.2117 \pm 0.0002$ Å
$V_m$ at 298.16° K.	=	$11.250 \pm 0.007$ cc./mole
$\rho$ at 298.16° K.	=	$3.593 \pm 0.002$ gm./cc.
$\alpha_a$ at 298.16° K.	=	$7.88 \times 10^{-6}$
$\alpha_v$ at 298.16° K.	=	$23.6 \times 10^{-6}$

Austin's measurements are the most accurate of the previous data. The present work gives slightly lower values than Austin's over most of the temperature range studied (Fig. 4). The curves are sensibly parallel above 423° K. (150° C.) with Austin's values about 3% higher than those of the present work. From 273° to 423° K. the two curves do not have any correspondence. Austin's curve falls away very sharply compared to the more regular decrease found in the present study. The reason for the sudden decrease in Austin's values is not known, but it is believed to be incorrect. The measurements by White have a larger scatter than Austin's, but a curve computed from the data falls between Austin's data and the curve determined in this study (Fig. 4).

Sharma's measurements are at variance with all the other measure-

ments. Except for the region below 373° K. his values are not in serious numerical disagreement. The questionable feature of Sharma's work is the shape of his curve. Sharma found that a positive parabolic function was the one best fitting his data. The other three studies all indicate a

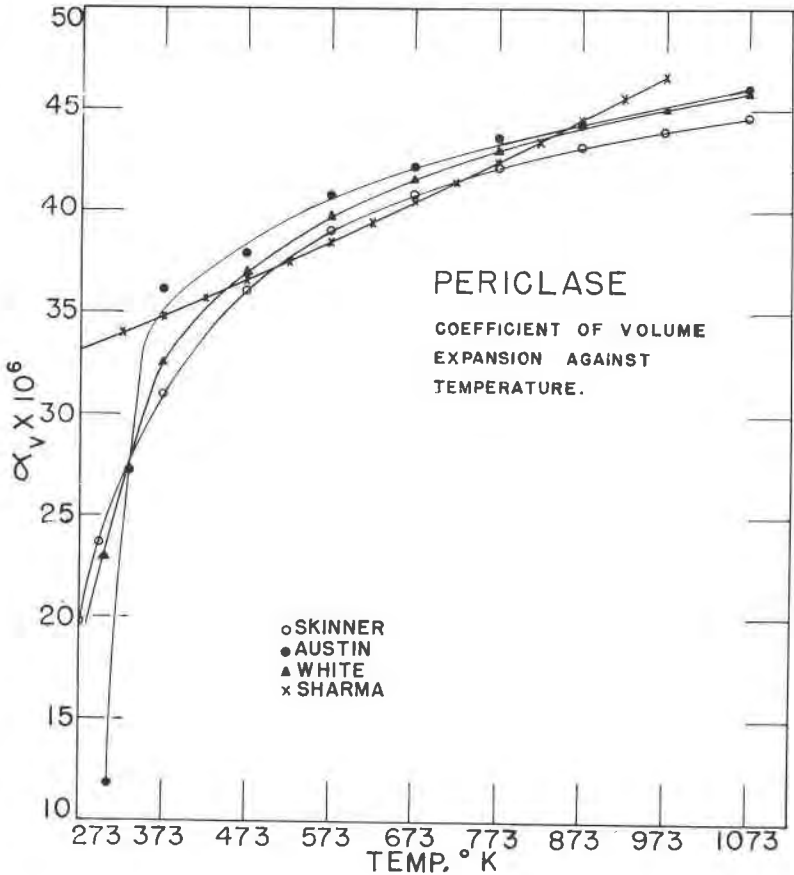


FIG. 4

curve which tends to flatten out at high temperatures and decrease rapidly at low temperatures. Theory predicts a curve of this general shape. It is felt that Sharma's work must contain some unexplained instrumental errors.

#### DIAMOND

A number of investigators have previously determined the unit cell size of diamond. Though a considerable range in values exists, it is

doubtful if the range is due as much to compositional variation, as suggested by Lonsdale (1947), as to experimental errors in the different methods of measurement. In general, the diamonds studied have not been analyzed, and where analyses have been made they must be taken with caution, since investigators generally do not state whether the impurities are present as inclusions or in solid solution. Present knowledge does not support the thesis of compositional variation sufficiently well to explain all variations in the cell size.

In Table 4 all known determinations of the cell size have been gathered.

TABLE 4. THE LATTICE PARAMETER OF DIAMOND AT 25° C. AS DETERMINED BY DIFFERENT INVESTIGATORS USING X-RAY METHODS

Cell size $a_0$ Å	Method used	Investigator
3.56693 ± 0.001*	Single crystal	Ehrenberg (1926)
3.56698 ± 0.00005	Single crystal	Tu (1932)
3.56688 ± 0.00005	Single crystal	Tu (1932)
3.56673 ± 0.0001	Single crystal	Renninger (1937)
3.56676 ± 0.0001	Single crystal	Trzewatowski (1937)
3.56687 ± 0.0001	Powder method on commercial diamond dust	Riley (1944)
3.56726 ± 0.00005	Single crystal divergent beam	Lonsdale (1947)
3.56710 ± 0.00005	Single crystal divergent beam	Lonsdale (1947)
3.56684 ± 0.00005	Single crystal divergent beam	Lonsdale (1947)
3.56668 ± 0.0001	Single crystal divergent beam	Lonsdale (1947)
3.56689 ± 0.00003	Powder, gray bort.	Straumanis and Aka (1951)
3.56681 ± 0.00002	Powder, average of three samples	Straumanis and Aka (1951)
3.56680 ± 0.0001	Powder, commercial diamond dust	Skinner (1954)
3.56685 ± 0.0001	Powder, from a single crystal	Skinner (1954)

\* Precision stated by each investigator.

The measurements have all been reduced to 25° C., and where the work was stated in the old kX units the figures have been changed to Ångstrom units by applying the conversion factor of 1.00202 recommended by Bragg (1947). The average of all determinations, excluding those of the present work, is 3.56688 Å. This value is obtained by giving Straumanis and Aka's value of 3.56681 a weighting of three, since it is the average of numerous measurements on each of three samples. If the two values of the present determinations are included, the average is unchanged. It is felt that the best value for the unit cell size of diamond at 298.16° K. is 3.56688 ± 0.00009 Å. Using this value, the molar volume of diamond at 298.16° K. is 3.41677 ± 0.0001 cc./mole, and the density is 3.5150 ± 0.001 gm./cc., using Wichers' (1952) value of 12.010 for the

atomic weight of carbon. It is felt that the measurements of Lonsdale are given to a greater precision than her method warrants. Her values show the largest spread and include the two highest and the lowest values. It is probable that instrumental errors can account for the large variation in cell size observed by Lonsdale.

The sample of diamond dust used in the present study was a commercial grade with a grain size less than 1.0 micron. It was comprised of chips from a great many diamonds and is the finest fraction obtained from the crushing of many thousands of diamonds from many localities. If the cell size varies with composition, a sample of such a dust containing grains of many different compositions should show a range of cell sizes and the measured cell size should be the average of all the diamonds in the sample. In fact, the measured cell size of diamond dust agrees very closely with the average cell size obtained from all the values reported for single crystal measurements. The only previous measurement of the cell size of commercial diamond dust was that of Riley (1944) and his value of  $3.56687 \pm 0.0001 \text{ \AA}$  agrees very well with the combined average of all the single crystal measurements.

The second diamond studied in the present work was a single colorless fragment from South West Africa. Five independent spectrographic analyses of a portion of the sample (Table 5), by Dr. W. H. Dennen of the Massachusetts Institute of Technology showed it to be exceptionally pure. The only comment by the analyst on the results was that the spotty distribution of impurity content was probably due in part to variations in arcing contents but is in part inherent in the sample. While the major impurity is silicon it is probable that it is present partly as inclusions in the diamond, perhaps in olivine or pyroxene, which might account for the spotty distribution.

The thermal expansions of the two samples studied differ by as much as 10% (Fig. 6). The commercial diamond dust has the lower thermal

TABLE 5. SPECTROGRAPHIC ANALYSIS OF SOUTH WEST AFRICAN DIAMOND SAMPLE  
Range scanned 2,500-10,000  $\text{\AA}$

Plate No.	Impurities in ppm.					
	Mg	Si	Fe	Al	Cu	Ca
1	2	20	1	10	<1	2
2	1	10	1	<10	<1	4
3	15	40	2	<10	<1	<0.5
4	4	<10	<0.5	<10	<1	<0.5
5	2	150	5	<10	<1	<0.5

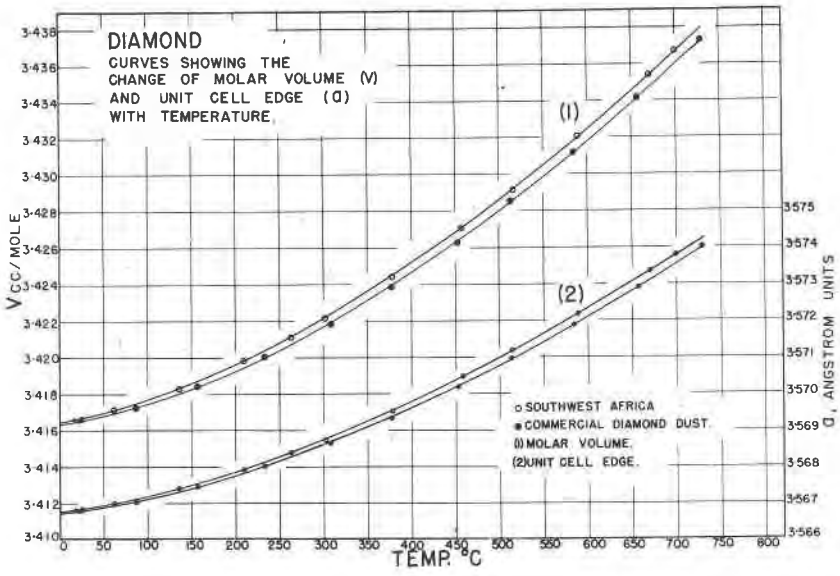


FIG. 5

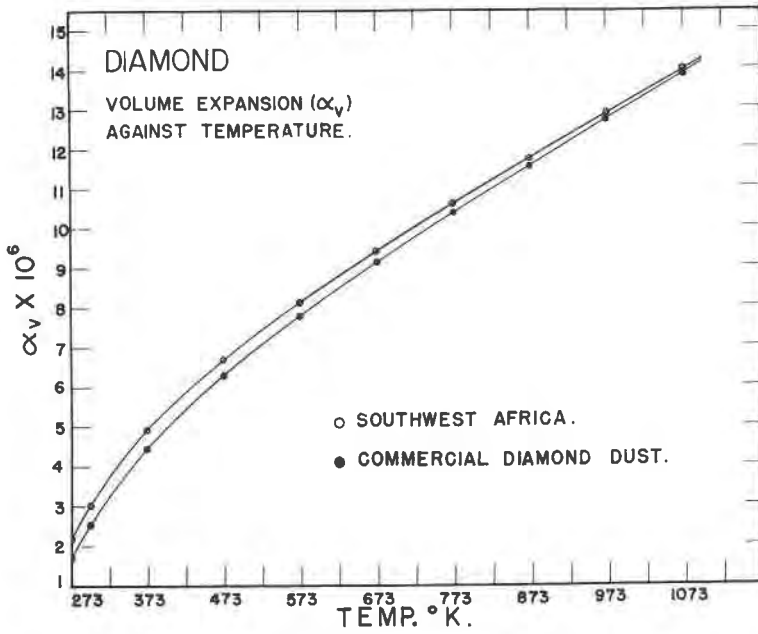


FIG. 6

expansion. At 298.16° K. the molar volumes of the two samples are practically the same and differ by only 0.005%. At 937° K. the molar volume of the South West African diamond is 0.02% larger than the molar volume of the commercial diamond dust (Fig. 5). To assure that experimental errors were not causing the variation in the observed thermal expansions, each sample was separately studied twice. In each case, new specimen mounts were prepared and the thermocouple system rechecked. The curves were completely reversible and reproducible.

The measured values of the unit cell size and the computed values of the molar volumes at different temperatures for the two diamond samples are recorded in Tables 6 and 7. The parameters of the various

TABLE 6. COMMERCIAL DIAMOND DUST  
Unit cell edge  $a_0$ , and molar volume  $V_m$  at different temperatures

Temperature °C.	$a_0$ Å	$V_m$ cc./mole
21.5	3.56679	3.41651
25.0	3.56680	3.41654
87.2	3.56704	3.41723
157.2	3.56745	3.41841
233.1	3.56802	3.42005
308.5	3.56844	3.42183
377.7	3.56934	3.42384
453.0	3.57019	3.42629
513.3	3.57096	3.42851
584.5	3.57187	3.43113
657.7	3.57291	3.34413
729.2	3.57401	3.43730

functions derived from the data in Tables 6 and 7 are given in Table 8.

Several investigators have previously determined the thermal expansion of diamond. The only study comparable to the present one was that of Krishnan (1946). Krishnan used a single-crystal  $x$ -ray method, and measured the expansion of the crystal lattice rather than the expansion of the macroscopic crystal, which is the usual objection to single-crystal measurements. Fizeau (1869) studied the expansion from 0° to 100° C. by the interferometer method. Straumanis and Aka (1951) report an "average" coefficient of linear expansion for the temperature range 10° to 50° C. Their method of handling their data is open to some question, but it gives an estimate of the coefficient at 30° C., as  $\alpha_a = (1.38 \pm 0.12) \times 10^{-6}$ .

The coefficient of linear expansion at 25° C. computed from the data of Fizeau is  $0.96 \times 10^{-6}$ . The values obtained in the present work are

TABLE 7. DIAMOND FROM SOUTH WEST AFRICA  
 Unit cell edge  $a_0$  and molar volume  $V_m$  at different temperatures

Temperature °C.	$a_0$ Å	$V_m$ cc./mole
16.7	3.56683	3.41662
25.0	3.56685	3.41668
62.0	3.56700	3.41712
136.8	3.56741	3.41829
209.0	3.56793	3.41979
263.0	3.56839	3.42111
302.1	3.56874	3.42220
378.3	3.56954	3.42442
457.8	3.57047	3.42709
514.3	3.57118	3.42914
589.1	3.57219	3.43205
670.8	3.57335	3.43539

*Best values*

$a_0$ at 298.16° K. = 3.56688 ± 0.00009 Å
$V_m$ at 298.16° K. = 3.4168 ± 0.0001 cc./mole
$\rho$ at 298.16° K. = 3.5150 ± 0.001 gm./cc.
$\alpha_a$ at 298.16° K. = 1.06 × 10 <sup>-6</sup>
$\alpha_v$ at 298.16° K. = 2.97 × 10 <sup>-6</sup>

TABLE 8. PARAMETERS OF FUNCTIONS GIVING THE LINEAR AND VOLUME COEFFICIENTS OF THERMAL EXPANSION

Substance	Function	Parameters				Accuracy	Temp. range 298° K to
		$b$	$c$	$d$	$I$		
		× 10 <sup>-5</sup>	× 10 <sup>-9</sup>	× 10 <sup>-3</sup>			
Thoria	$\alpha_v$	1.865	10.96	-0.3375	- 7.176	0.5%	1073° K.
	$\alpha_a$	0.6216	3.541	-0.1125	- 2.387	0.2%	1073° K.
Periclase	$\alpha_v$	4.232	3.630	-1.756	-18.66	0.5%	973° K.
	$\alpha_a$	1.411	1.210	-0.5854	- 6.222	0.5%	973° K.
Commercial diamond dust	$\alpha_v$	0.2301	11.01	-0.2708	- 2.083	0.3%	973° K.
	$\alpha_a$	0.07667	3.672	-0.0903	- 0.6947	0.3%	973° K.
South West African diamond	$\alpha_v$	0.2884	10.57	-0.2665	- 2.223	0.3%	973° K.
	$\alpha_a$	0.09613	3.522	-0.0888	- 0.7409	0.3%	973° K.

$1.011 \times 10^{-6}$  for the South West African diamond and  $0.844 \times 10^{-6}$  for the commercial diamond dust. The coefficient at  $25^\circ \text{C}$ . computed from Krishnan's data is  $1.13 \times 10^{-6}$ . It is desirable to decide on an average value of the coefficient of linear thermal expansion for use in reducing accurate measurements of the lattice parameter of diamond to a common temperature for comparison. If all the values quoted above are averaged a figure of  $1.06 \times 10^{-6}$  is obtained, and it is felt that this is the best estimate of the linear coefficient at  $25^\circ \text{C}$ . The thermal expansion of the commercial diamond dust may conceivably be more nearly the "average" expansion of diamond than the value given above, but this suggestion must await further work.

#### ACKNOWLEDGMENTS

Thanks are due to Professors Clifford Frondel and Francis Birch of Harvard University for much material assistance and guidance during the course of the work. E-an Zen has contributed many pertinent discussions and criticisms.

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*Manuscript received May 4, 1956.*