THE ATOMIC HEATS OF GOLD, PLATINUM AND ANTIMONY AT LIQUID HELIUM TEMPERATURES

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Introduction

The specific heat of platinum was measured in the liquid helium range of temperature by Kok and Keesom as early as 1936 while that of gold was measured only very recently by Corak *et al.* (1955). Apart from these two measurements no other calorimetric data appear to be available for these two metals in the liquid helium range. Therefore, it was decided to obtain fresh measurements with a view to provide an independent check on the earlier data using the new vacuum calorimeter (Ramanathan and Srinivasan, 1955) developed in this laboratory.

Travis Anderson (1930) investigated the temperature variation of the specific heat of antimony in the range 60° to 300° K. Below this range, however, no data appear to be available. So, the investigation of the temperature variation of atomic heat of antimony in the liquid helium range was also carried out with the purest available metal, using our calorimeter.

Experimental Details

The new vacuum calorimeter which is capable of an accuracy of over 3 per cent. in the temperature range 1·2 to 4·2° K. has been fully described in an earlier communication (Ramanathan and Srinivasan, 1955).

The specimens of gold and platinum were supplied by Messrs. Johnson Matthey & Co., Ltd., London, in cylindrical forms with diametrical holes for embedding carbon resistance thermometers. The purity of the gold specimen is 99·97 per cent. and it weighs 67·99 gm. The platinum specimen is 99·99 per cent. pure and weighs 74·88 gm. The antimony specimen of mass 33·92 gm. was cast out of a Johnson Matthey sample of 99·6 per cent. purity.

The resistance thermometer (a $\frac{1}{2}$ watt, 100 ohms resistor manufactured by Speer Resistor Corporation, U.S.A.) was calibrated against the 1948 vapour pressure-temperature scale (Van Dijk and Shoenberg, 1949) and corrected to the 1955 scale (Van Dijk and Durieux, 1955).

RESULTS

Gold and Platinum.—Figures 1 (*a*) and (*b*) show the variation of the atomic heats of gold and platinum respectively in the liquid helium range of temperature.

The atomic heats of these elements can be represented by the equation $C_v = aT + bT^3$, where 'a' and 'b' are the constants corresponding to

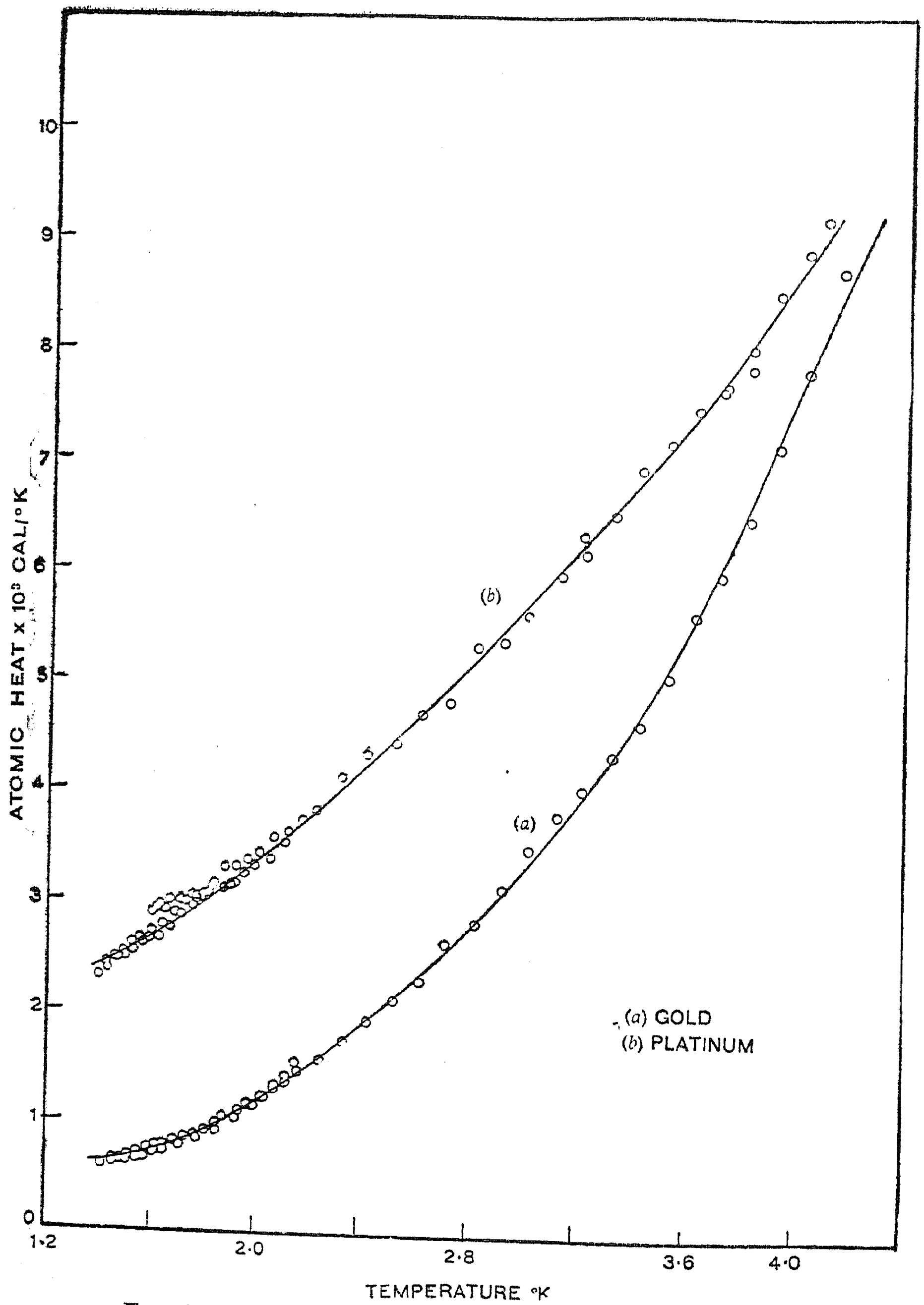

FIG. 1. Variation of atomic heats of gold and platinum.

the electronic and lattice contributions and 'T' is the absolute temperature.

It is noticed from the graphs that the specific heat of the monovalent noble metal gold falls off more rapidly than the specific heat of the transition metal, platinum. This indicates a much larger linear term in the specific heat equation for platinum and is consistent with the supposition of Mott and Jones (1936) that the unfilled '*d*' band contributes appreciably to the electronic specific heats of transition metals.

The atomic heat constants of gold have been calculated by the method of least squares from the results in the range 1·3 to 4·2° K. and are found to be

$$a = (1\cdot825 \pm 0\cdot069)\ 10^{-4}$$
$$b = (1\cdot049 \pm 0\cdot010)\ 10^{-4}$$

The Debye temperature calculated from the 'b' value ($b = 464\cdot4/\theta^3$) is 164·2° K.

Similarly the constants of platinum are found to be

$$a = (15\cdot956 \pm 0\cdot100)\ 10^{-4}$$
$$b = (\ 0\cdot337 \pm 0\cdot014)\ 10^{-4}$$

and

$$\theta = 239\cdot7^\circ\ \text{K}.$$

The results of earlier workers together with ours are given in Table I for comparison.

TABLE I

	Gold			Platinum		
	Purity %	$a \times 10^4$	θ° K.	Purity %	$a \times 10^4$	θ° K.
This work ..	99·97	1·825	164·2	99·99	15·956	239·7
Corak *et al.* ..	99·99	1·777	164·57	..	..	..
Schultz (1954) ..	..	1·48	..	..	..	..
Kok and Keesom (1936)		..	..	99·95	16·07	233·0
Burton (1940) ..	..	..	(S.H.) 170 (Res.) 175	..	..	(S.H.) 225 (Res.) 240

S.H.—Value derived from specific heat data.

Res.—Value derived from electrical resistivity by Gruneisen's formula.

The electronic specific heat constants and the Debye θ values of gold and platinum of earlier workers show general agreement with our values.

Antimony.—Figure 2 (*a*) shows the variation of the atomic heat of antimony with temperature in the range 1·3 to 4·2° K. Figure 2 (*b*) is a plot

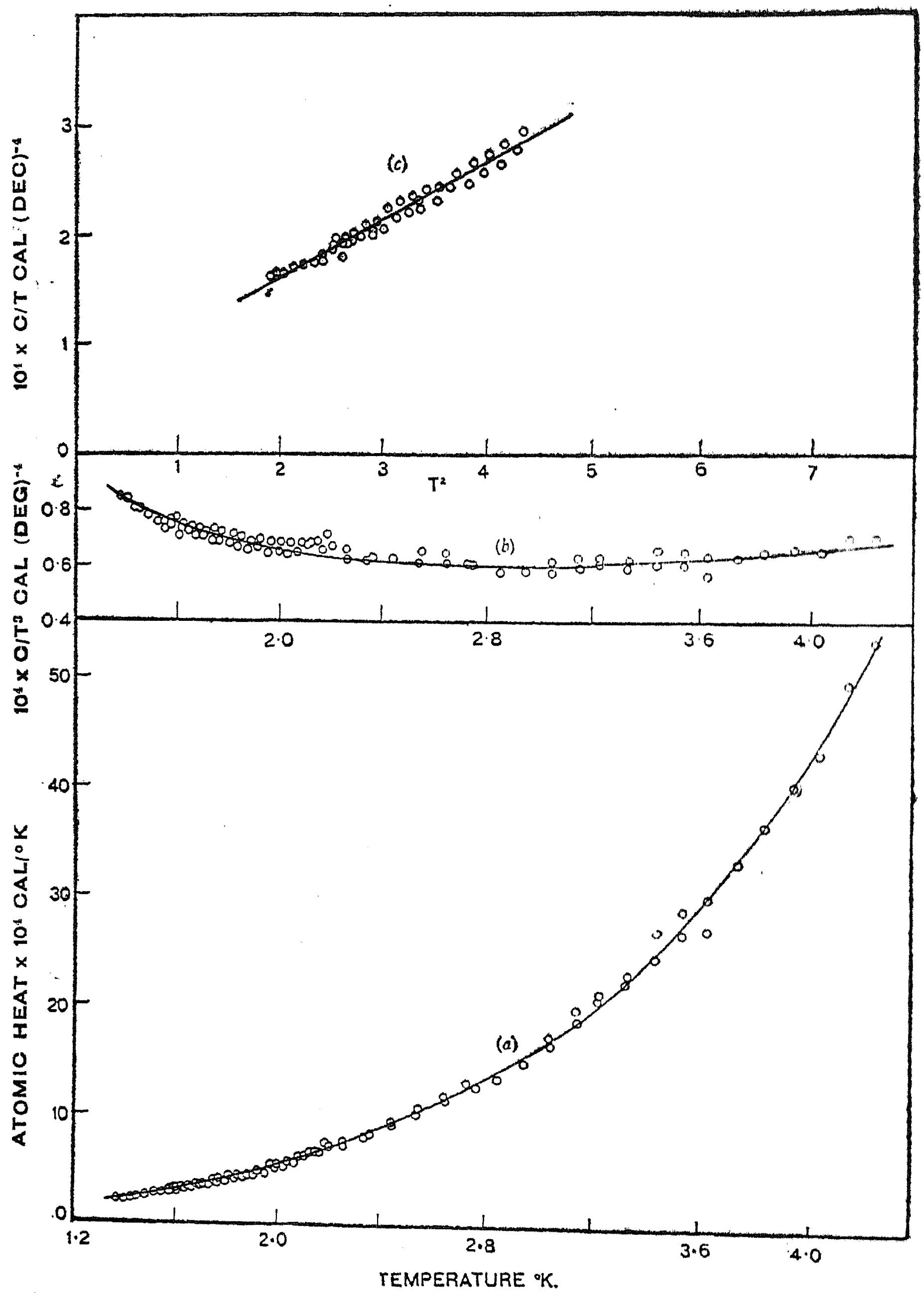

FIG. 2. (*a*) Valuation of atomic heat of antimony in the temperature range 4·1–1·3° K.
(*b*) Variation of C/T^3 with temperature.
(*c*) Plot of C/T against T^2.

of C_v/T^3 against T. The region where the electronic contribution becomes predominant appears below 2° K. Figure 2 (*c*) is a plot of C_v/T *versus* T^2 in this region.

The constants have been calculated by the method of least squares from all the measurements below 2° K. and are found to be

$$a = (0\cdot575 \pm 0\cdot041)\ 10^{-4}$$

$$b = (0\cdot525 \pm 0\cdot013)\ 10^{-4}$$

and

$$\theta = 206\cdot8^\circ \text{ K.}$$

Burton (1940) has calculated θ as 201° K. from the specific heat data of Travis Anderson (1930). This is also in good agreement with our result.

Summary

The variation of atomic heats of gold, platinum and antimony have been investigated in the liquid helium range of temperature (4·2 to 1·3° K.). The atomic heats of these elements can be represented by the formula

$$C_v \text{ (Gold)} = 10^{-4} [(1\cdot825 \pm 0\cdot069)\ T + (1\cdot049 \pm 0\cdot010)\ T^3] \text{ Cal./}^\circ \text{ K.}$$

$$C_v \text{ (Platinum)} = 10^{-4} [(15\cdot956 \pm 0\cdot100)\ T + (0\cdot337 \pm 0\cdot014)\ T^3] \text{ Cal./}^\circ \text{ K.}$$

$$C_v \text{ (Antimony)} = 10^{-4} [(0\cdot575 \pm 0\cdot041)\ T + (0\cdot525 \pm 0\cdot013)\ T^3] \text{ Cal./}^\circ \text{ K.}$$

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References

Burton, E. F., Grayson Smith, H. and Wilhelm, J. O. .. *Phenomena at the Temperature of Liquid Helium* (Reinhold Publishing Corporation, New York), 1940, p. 348.

Corak, W. S. *et al.* .. *Phy. Rev.*, 1955, **98**, 1699.

Kok, J. A. and Keesom, W. H. *Physica*, 1936, **3**, 1035; Leiden Comm. No. 245 (*a*).

Mott, N. F. and Jones, H. .. *The Theory of the Properties of Metals and Alloys* (Oxford University Press), 1936, p. 192.

Ramanathan, K. G. and Srinivasan, T. M. — *Phil. Mag.*, 1955, **46**, 338.

Schulz, L. G. .. *Phy. Rev.*, 1954, **94**, 1422.

Travis Anderson, C. .. *J. Am. Chem. Soc.*, 1930, **52**, 2712.

Van Dijk, H. and Durieux, M. — *Comm. Conference de Physique des Basses Temperatures, Paris*, 1955, p. 595.

—— and Shoenberg, D. .. *Nature*, 1949, **164**, 151.