of the frequency distribution are then given in terms of elements of the first column of (A7)

$$\mu_{2n}=\frac{a_{n0}}{2(2n-1)\zeta(2n)}\left(\frac{2\pi kT_b}{\hbar}\right)^{2n}. \quad \text{(A9)}$$

The expansions (A4), (A5), and (A6) are valid over a larger range of the inverse temperature than (A1), and in consequence their coefficients can be determined with greater accuracy, and hence, the moments μ_{2n} can be calculated to a higher value of n.

PHYSICAL REVIEW VOLUME 124, NUMBER 3 NOVEMBER 1, 1961

Specific Heat of a Body-Centered Cubic Cr-Fe Alloy between 30° and 110°K*

CHUAN-TSENG WEI
Department of Metallurgical Engineering Michigan State University, East Lansing, Michigan

AND

CHIN-HUAN CHENG
Department of Mining and Metallurgical Engineering University of Illinois, Urbana, Illinois

(Received December 19, 1960; revised manuscript received June 21, 1961)

The specific heat of a body-centered cubic alloy, $Cr_{80.6}Fe_{19.4}$,was determined between 30° and 110°K. The electronic specific heat coefficient γ and the Debye characteristic temperature were evaluated between 40° and 60°K to be $(46\pm5)\times10^{-4}$ cal mole^{-1} deg^{-2} and 472±14°K, respectively. The origin of a sharp peak occurring at 37±2°K is discussed.

THE specific heats of a number of body-centered cubic Cr-Fe alloys between 1.6° and 4.2°K were measured by Wei *et al.*[1] Near 19 at. % Fe there appeared to be a high peak in the coefficient γ of the linear term in temperature. It may be asked whether this high γ peak has its origin in a magnetic transformation. Should the Curie point of such an alloy occur near 4.2°K, the extra heat absorbed in the course of ferro-paramagnetic transition might appear to be linear in T in such a small temperature range. It is the purpose of the present work to investigate the heat capacity of a body-centered cubic alloy, $Cr_{80.6}Fe_{19.4}$, in the temperature range where a possible magnetic transition is likely to occur to see whether the high γ peak may be attributed to a magnetic transition.

The alloy was induction melted, homogenized at 1175°C for three days, and water quenched. X-ray diffraction and microscopic examination indicated that it was a single-phase, body-centered cubic alloy with no more than 1% in the total amount of oxides and foreign materials. Table I gives the chemical analysis of the specimen, which weighed 17.38 g. The calorimetric equipment used in this work was the same as that used for specific heat measurements between 1.6° and 4.2°K.[2] A copper resistence thermometer, which was calibrated at 0°C, 78°K, and 4.2°K against the Dauphinee and Preston-Thomas scale,[3] was used for the temperature measurement. The correction for the heat capacity of the copper body of the heater-thermometer assembly was calculated from Dockerty's heat capacity data[4] for copper.

TABLE I. Chemical analysis of the specimen (weight percent).

Cr	79.00
Fe	20.40
Al	0.01
Si	0.01
Mn	0.01
O_2	0.137
N_2	0.263

The measurement was carried out between 30° and 110°K. The thermal coefficient of the copper thermometer became small below 30°K, making accurate measurements of the specific heat difficult. Above 110°K the thermal relaxation time became long so that the present scheme was not suitable. Figure 1 shows the C_v vs T curve. The λ-shaped portion of the curve resembles that of a Curie type transition. The transition temperature is well defined and is 37±2°K. To check how the heat capacity as a function of temperature deviates from the relationship $C_v=\gamma T+\beta T^3$, a conventional C_v/T vs T^2 plot is shown in Fig. 2. Between 40° and 60°K this relationship still holds approximately. From the straight-line portion of the curve in Fig. 2, γ and β are evaluated to be $\gamma=(46\pm5)\times10^{-4}$ cal mole^{-1} deg^{-2}, $\beta=(0.0440\pm0.0004)\times10^{-4}$ cal mole^{-1} deg^{-4}. The corresponding Debye temperature is 472±14°K which is not unreasonable when compared with $\Theta_{Cr}=418$°K[5] and

* This work was supported by WADC, United States Air Force.

[1] C. T. Wei, C. H. Cheng, and P. A. Beck, Phys. Rev. Letters 2, 95 (1959).

[2] C. T. Wei, C. H. Cheng, and P. A. Beck, Phys. Rev. 112, 696 (1958).

[3] T. M. Dauphinee and H. Preston-Thomas, Rev. Sci. Instr. 25, 884 (1954).

[4] S. M. Dockerty, Can. J. Research 15A, 59 (1937).

[5] S. A. Friedberg, I. Esterman, and J. E. Goldman, Phys. Rev. 85, 375 (1952).

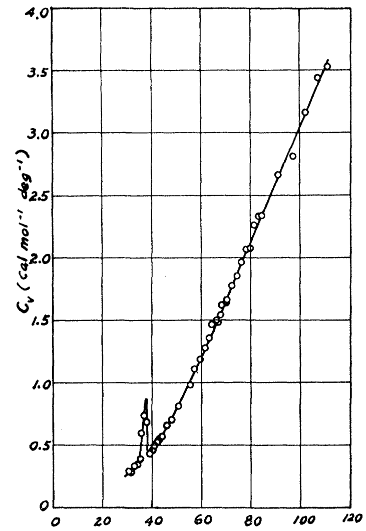

FIG. 1. Specific heat C_v of body-centered cubic alloy, $Cr_{80.6}Fe_{19.4}$, between 30° and 110°K.

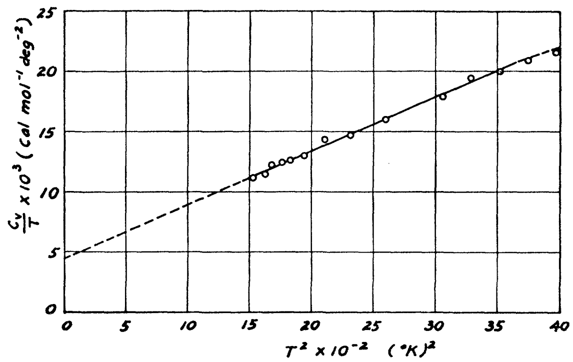

FIG. 2. C_v/T vs T^2 of body-centered cubic alloy, $Cr_{80.6}Fe_{19.4}$.

$\Theta_{Fe}=464$°K.[6] The γ value is consistent with the results in reference 1.

Although the λ-shaped portion of the curve in Fig. 1 resembles that of a Curie-type transition, its exact origin is still obscure. The entropy associated with this transition was estimated by numerical integration to be approximately 0.02 entropy unit which was rather small compared with what one would obtain from the equation: $S=k\log_e[N!/n!(N!-n!)]$ should this transition be in fact the Curie point of this alloy with $N\simeq10^{23}$ and $n\simeq\frac{1}{2}\times10^{23}$ per mole. However, if this transition had its origin in one of the impurity components which were altogether less than one percent, then a mole of this component would have an excess heat capacity at this transition temperature of more than 50 cal deg^{-1} which would be approximately 5 times greater than that of pure iron and seemed unlikely.

Nevitt[7] measured the magnetization of a spherical specimen machined from the very alloy used in the present experiment as a function of temperature and field. By using Arrott's criterion[8] the Curie point could only be set at near 50°K. No specific heat anomaly was observed near that temperature in the present experiment. The nature of this discrepancy is not clearly understood. The fact that a large linear temperature term in the specific heat of this alloy persists above such a transition up to 60°K and its coefficient is consistent with that determined at liquid helium temperature to within experimental accuracy, seems to suggest that the high γ peak in reference 1 is probably not associated with a magnetic transition.

ACKNOWLEDGMENTS

The authors wish to thank Professors P. A. Beck and J. S. Koehler of the University of Illinois, for helpful discussions.

[6] W. H. Keesom and B. Kurrelmeyer, Physics **6**, 663 (1939).

[7] M. V. Nevitt (private communication).

[8] A. Arrott, Phys. Rev. **108**, 1394 (1957).