electronic specific heat constants are too large, and that a value approximately equal to 10 mj/g–at/deg^2 is more reasonable.

Estimated Data. The data given in parentheses for the dilation term A, and the heat capacities $C_v{}^l$ and C_v are the estimated values. If one of the quantities needed to calculate A, $C_v{}^l$, or C_v was estimated, then A, $C_v{}^l$, or C_v is considered to be an estimated value. For the elements white phosphorus, rhombic sulfur, arsenic, antimony, europium, and gadolinium the only estimated quantity was $C_v{}^e$. For scandium and osmium the compressibility was the only estimated quantity. For neptunium both $C_v{}^e$ and the compressibility were estimates. For polonium C_p, $C_v{}^e$, and the compressibility were estimated. For white phosphorus both $C_v{}^e$ and the thermal expansion were estimated. For technetium, actinium, and protactinium, estimated values were used for $C_v{}^e$, C_p, the compressibility, and the thermal expansion. For promethium, francium, and radium all quantities were estimates.

VIII. Debye Temperature

There is little need to dwell on the theory and the background of the Debye temperature, since these are usually well treated in the standard textbooks concerned with solids. More detailed discussions are found in the review papers by Blackman,[93] de Launay,[94] Keesom and Pearlman,[95] Herbstein,[96] and Mitra.[97]

The Debye temperature can be obtained from specific heat measurements, melting points (Lindemann equation), elastic constants, X-ray and neutron diffraction intensity data, electrical resistivities, and thermal-expansion data. Other techniques, which are not as generally applicable as those mentioned above, are of minor importance here. For those who are interested, these other techniques are summarized in some of the above reviews.[93,96,97]

Since the Debye temperatures vary with temperature, one must be careful when comparing the Debye temperature obtained by one method with a Debye temperature obtained by another method. That is, the Debye temperatures should only be compared when both were measured at the same or approximately the same temperature. This is especially

[93] M. Blackman, *in* "Handbuch der Physik" (S. Flügge, ed.), Vol. 7, Part I, p. 325. Springer, Berlin, 1955.

[94] J. de Launay, *Solid State Phys.* **2**, 219 (1956).

[95] P. H. Keesom and N. Pearlman, *in* "Handbuch der Physik" (S. Flügge, ed.), Vol. 14, p. 282. Springer, Berlin, 1956.

[96] F. H. Herbstein, *Advan. Phys.* **10**, 313 (1961).

[97] S. S. Mitra, *J. Sci. Ind. Res. (India)* **21A**, 76 (1962).

important for low-temperature measurements, i.e., temperatures below 50° to 100°K ($-223°$ to $-173°$C). Usually, the Debye temperatures do not show very large temperature variations above this temperature range, although exceptions may be encountered, particularly for those materials which have very large Debye temperatures, i.e., $> 800°$K.

The Debye temperatures as determined by the methods mentioned above are discussed in Sections 16–21 and summarized in Tables XV through XVIII.

16. DEBYE TEMPERATURE FROM SPECIFIC HEAT DATA

The Debye temperature as determined from specific heat measurements is designated as θ^S, and any subscript which may be given indicates the particular temperature (absolute) at which θ^S was evaluated; e.g., $\theta_0{}^S$ indicates the Debye temperature was evaluated from specific heat data at $0°$K ($-273°$C). The Debye theory of the lattice specific heat gives the following expression for the heat capacity of a solid:

$$C_V{}^l = 3R[J(y) - yJ'(y)], \tag{16.1}$$

where R is the gas constant, $y = \theta^S/T$ and $J(y)$ is given by

$$J(y) = \frac{3}{y^3} \int_0^y \frac{y^3 \, dy}{e^y - 1}. \tag{16.2}$$

The integral in Eq. (16.2) has been solved, and tables of $C_v{}^l$ versus θ^S/T may be found in a number of sources.[57,94,98,99] The tables given by de Launay[94] and Zemansky[98] are quite abbreviated compared with those of Simon,[99] and Lewis *et al.* (Appendix 5).[57] At low temperatures when $\theta^S/T \ll 1$, Eq. (16.1) can be written as

$$C_v{}^l = 464.4(T/\theta_0{}^S)^3, \tag{16.3}$$

which is seen to be identical to the last term in Eq. (13.1). It is appropriate to use the subscript 0 with θ^S in Eq. (16.3) since the Debye temperature and electronic specific heat constant, γ, are evaluated from a plot of C_v/T versus T^2, where γ is the intercept at $T = 0°$K and $464.4/(\theta_0{}^S)^3$ is the slope of the straight line.

Debye Temperature at $0°$K. The Debye temperatures $\theta_0{}^S$ are listed in Table XV. The value of $\theta_0{}^S$ varies from a minimum value of $40°$K for

[98] M. W. Zemansky, "Heat and Thermodynamics," 4th ed., p. 266. McGraw-Hill, New York, 1957.

[99] F. Simon, *in* "Handbuch der Physik" (H. Geiger and K. Scheel, eds.), Vol. 10, p. 367. Springer, Berlin, 1962; it should be noted that these tables are based on a value of $R = 1.983$ and, therefore, the values given for $C_v{}^l$ are too low by 0.2%.