VII. Specific Heat Data

13. Electronic Specific Heat Constant

The electronic specific heat constants were obtained directly from specific heat measurements at very low temperatures, <10°K (−263°C). For most metals at these low temperatures, the specific heat is given by

$$C_p = C_v = \gamma T + 464.4(T/\theta_0^S)^3, \tag{13.1}$$

where C_p is the heat capacity at constant pressure, C_v is the heat capacity at constant volume, γ is the electronic specific heat constant, T is the absolute temperature, and θ_0^S is the Debye temperature.[59] The experimental data are usually plotted in the form C_v/T versus T^2, which yields an intercept equal to γ and a slope equal to $464.4/(\theta_0^S)^3$. Further discussion of θ_0^S is deferred until Section 16. For a few metals, magnetic and nuclear contributions may be equally important, and thus the simple expression given above (Eq. 13.1) then becomes invalid. The onset of superconductivity will also cause some problems, but these are usually solved by carrying out the measurements in a magnetic field that is large enough to destroy superconductivity. Since most of the authors evaluate their specific heat data, and since departures from Eq. (13.1) are taken into account by them, there is no need to discuss such anomalies here.

The electronic specific heat constant is directly proportional to the density of states of the electrons at the Fermi level. Thus it is seen that knowledge of the electronic specific heat constant is very desirable since it is a direct measurement of a fundamental property of a metal. For insulators there is no electronic contribution to the specific heat because all of the bands are completely filled; as a matter of fact, even semiconductors, which usually have a few electrons in an unfilled band (or a few holes in a filled band), generally do not have an electronic contribution.

The electronic specific heat constants are given in Table XIII. These values for γ vary from a minimum value of zero for diamond, germanium, selenium, gray tin, and tellurium to a maximum value of 58 mj/g-at/deg² for α-Ce. The mean value of γ for the elements, for which γ is less than 19 mj/g-at/deg² is 4.1 mj/g-at/deg². All of the estimated values lie between the two extremes cited.

A plot of the electronic specific heat constants of the elements of the fourth, fifth, and sixth periods of the Periodic Table is shown in Fig. 18.

[59] The superscript and subscript after θ indicates that the Debye temperature was obtained from specific heat measurements (S) at zero degrees Kelvin (0). The need for these super- and subscripts will be apparent in Sections 16 to 21, which deal with the Debye temperature.

TABLE XIII. ELECTRONIC SPECIFIC HEAT CONSTANT

Element	γ (mjoules / g-at.deg²)	$\gamma \times 10^4$ (cal / g-at.deg²)	Ref.
3 Li	1.69 ±0.06	4.04	1, 2
4 Be	0.223 ±0.003	0.533	3, 4
5 B	1.26[a]	3.01	5
6 C(g)	0.0138[b]	0.0330	6
6 C(d)	~0	~0	7
11 Na	1.38 ±0.05[a]	3.30	1, 8, 9, 10
12 Mg	1.30 ±0.08	3.11	3, 11, 12, 13
13 Al	1.36 ±0.01[a]	3.25	14, 15, 16
14 Si	0.021	0.050	17, 18
15 P(w, r, b)	(0)[c]	(0)[c]	—
16 S(r, m)	(0)[c]	(0)[c]	—
19 K	2.11 ±0.11	5.04	1, 10, 19
20 Ca	2.90 ±0.18	6.93	20, 21
21 Sc	10.8 ±0.5	25.8	22, 23
22 Ti	3.41 ±0.10	8.15	11, 24, 25, 26
23 V	9.04 ±0.22	21.61	24, 27, 28, 29
24 Cr	1.46 ±0.06[a,d]	3.49	30, 31, 32
25 Mn(α)	8.4[e]	20	33
25 Mn(β)	9.7 ±0.3	23	33, 34
25 Mn(γ)	4.6 ±0.1[a,f]	11	34, 35
25 Mn(δ)	9.42	22.5	34
26 Fe	4.98 ±0.06	11.9	36, 37, 38, 39
27 Co	4.73[a]	11.3	36, 40
28 Ni	7.30 ±0.30[a]	17.4	41, 42, 43
29 Cu	0.693 ±0.007[a]	1.66	16, 21, 25, 44–51
30 Zn	0.643 ±0.012	1.54	3, 52–56
31 Ga	0.598 ±0.004	1.43	56, 57
32 Ge	0.000 ±0.001	0	18, 58, 59
33 As	(0.1)[c]	(0.24)[c]	—
34 Se	0	0	3, 60
37 Rb	2.52 ±0.07	6.02	19, 61
38 Sr	3.64 ±0.18	8.70	20
39 Y	10.1 ±0.1[a]	24.1	22, 62
40 Zr	2.91 ±0.12	6.95	11, 24, 25
41 Nb	7.66 ±0.29[d]	18.3	62, 63, 64
42 Mo	2.10 ±0.14	5.02	24, 62, 65–68
43 Tc	(4.06)[c]	(9.7)[c]	—
44 Ru	3.3	7.9	24
45 Rh	4.6 ±0.4	11.0	24, 69, 70
46 Pd	10.0 ±0.7[a]	23.9	66, 71, 72
47 Ag	0.659 ±0.027	1.58	44, 66, 71, 73–76
48 Cd	0.674 ±0.036	1.61	3, 12, 77
49 In	1.70 ±0.11	4.06	48, 78, 79