4e. Heat Capacities

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In both Tables 4e-1 and 4e-2, temperatures are given in kelvins (K).[1] The formula weights accompanying the symbols of the elements are based on the International Atomic Weights of 1961 ($C^{12} = 12.0000$). The heat capacity is given in calories per kelvin per gram-formula-weight (1 cal = 4.1840 joules). Except for separate listings for allotropic modifications of a few elements, the heat capacity is given only for the physical state in which the element is stable at one atmosphere pressure and at the temperature in question. (For condensed gases of Table 4e-1, the values are given for the saturation pressures.) This state of the element (crystalline, liquid, or gaseous) is indicated in parentheses by the appropriate letters, except that when two or more crystalline forms of an element are known, these are distinguished as α, β, γ, etc. In Table 4e-1 the values given are for the crystalline phase unless indicated otherwise; changes in phase are identified. The asterisks (*) indicate that the values given are in the region of sharp transitions or "heat effects," and the parentheses enclose values that were obtained by extrapolation or interpolation over a broad temperature range. These values may contain large errors. No attempt was made to resolve the discrepancies in the existing data for the few elements where Tables 4e-1 and 4e-2 disagree at the temperature 298.15 K.

In the preparation of Table 4e-1, the results of an unpublished critical analysis of elemental substances being conducted as a part of the National Standard Reference Data System have largely been used. Wherever data more recent than the above analysis were known to have been published, they were examined for any major changes. When the authors tabulated smoothed values at even temperatures, their values were freely used with minor adjustments whenever needed. The following compilations were also used in the preparation of the table: K. K. Kelley, Contributions to the Data on Theoretical Metallurgy: XIV, Entropies of the Elements and Inorganic Compounds, *U.S. Bur. Mines Bull.* 592, 1961; and R. Hultgren, R. L. Orr, P. D. Anderson, and K. K. Kelley, "Selected Values of Thermodynamic Properties of Metals and Alloys," John Wiley & Sons, Inc., New York, 1963.

In Table 4e-2, the values cover, in general, only the temperature range of experimental measurements (or of statistical-thermodynamic calculation in the case of the

[1] The name of the unit of thermodynamic temperature was changed from degree Kelvin (symbol: °K) to kelvin (symbol: K); and kelvin is now defined as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water [*NBS Tech. News Bull.* **52**, 10 (1968)]. The temperatures and temperature intervals used in the experimental measurements of heat capacity are taken to be consistent with the above definition within the accuracy of the values of heat capacity given in Table 4e-1 and 4e-2.

TABLE 4c-1. MOLAR HEAT CAPACITY AT CONSTANT PRESSURE OF ELEMENTAL SUBSTANCES AT LOW TEMPERATURES, CAL/MOLE · K
As revised December, 1967

Element	10	15	20	25	30	50	70	100	150	200	250	298.15
Aluminum Al 26.9815	0.0098	0.026	0.054	0.11	0.20	0.91	1.85	3.12	4.43	5.16	5.56	5.82
Antimony Sb 121.75	0.10	0.36	0.74	1.17	1.59	3.09	4.10	4.92	5.55	5.32	5.95	6.03
Argon A 39.948	0.90	1.89	2.82	3.70	4.39	5.93	6.96(c)	4.97(g)	4.97	4.97	4.97	4.97
Arsenic As 74.9216	(0.03)	0.12	0.27	0.50	0.78	1.90	2.88	3.98	4.94	5.13	5.75	5.89
Barium Ba 137.34	0.44	1.11	1.90	.....	.....	.....	.....	.....	.....	.....	.....	(6.30)
Beryllium Be 9.0122	0.0006	0.002	0.003	0.006	0.009	0.04	0.12	0.43	1.36	2.41	3.30	3.93
Bismuth Bi 208.980	0.51	1.21	1.80	2.32	2.86	4.29	4.99	5.52	5.85	5.99	6.11	6.19
Boron (crystalline) B 10.811	.....	.....	0.006	0.009	0.006	0.02	0.08	0.26	0.77	1.45	2.11	2.65
Boron (amorphous) B 10.811	.....	.....	0.02	0.01	0.01	0.04	0.12	0.33	0.86	1.55	2.22	2.86
Bromine Br_2 159.818	(0.55)	1.72	3.04	4.30	5.36	7.97	9.23	10.42	11.75	12.85	14.16(c)	18.08(l)
Cadmium Cd 112.40	0.22	0.69	1.23	1.79	2.30	3.80	4.34	5.28	5.74	5.94	6.08	6.22
Calcium Ca 40.08	0.05	0.15	0.35	0.62	0.97	2.60	3.54	4.66	5.49	5.91	(6.12)	(6.30)
Carbon (graphite) C 12.01115	0.004	0.01	0.02	0.03	0.04	0.12	0.23	0.40	0.77	1.18	1.63	2.04
Carbon (diamond) C 12.01115	0.0001	0.0002	0.0003	0.0007	0.001	0.005	0.016	0.059	0.24	0.56	0.99	1.46
Cerium Ce 140.12	1.05*	1.14*	1.76	2.46	3.08	3.10	5.83	6.46	6.71*	(6.90)	.....	(6.44)
Cesium Cs 132.905	2.64	3.91	4.67	5.08	5.36	5.80	5.97	6.16	6.41*	6.59*	6.94	7.67*
Chlorine Cl_2 70.906	(0.30)	0.89	1.85	2.89	3.99	6.90	8.68	10.10	12.20(c)	15.95(l)	15.95(l)	8.11(g)
Chromium Cr 51.996	(0.006)	0.014	0.026	0.054	0.095	0.45	1.20	2.39	3.94	4.81	5.30	5.56
Cobalt Co 58.9332	0.014	0.037	0.071	0.14	0.24	0.98	2.05	3.34	4.65	5.33	5.75	5.95
Copper Cu 63.54	0.013	0.044	0.110	0.230	0.405	1.47	2.60	3.82	4.90	5.41	5.68	5.84
Dysprosium Dy 162.50	(0.18)	0.60	1.34	2.20	3.04	5.52	6.97*	8.32*	10.88*	6.96	6.73	6.73
Erbium Er 167.26	(0.47)	1.60	5.02*	3.73	4.60	6.78*	7.35*	5.87	6.21	6.46	6.59	6.72
Europium Eu 151.96	0.93	2.08	2.38	3.31	.....	.....	.....	.....	.....	.....	.....	(6.48)
Fluorine F_2 37.9968	.....	1.75	3.10	4.61	6.03(c_1)	11.79(c_2)	13.56(l)	6.96(g)	6.99	7.10	7.28	7.49
Gadolinium Gd 157.25	0.18	0.46	1.06	1.77	2.44	4.64	5.40	6.91	7.81	8.64	9.95*	8.86*
Gallium Ga 69.72	0.058	0.25	0.54	0.84	1.19	2.45	3.47	4.43	5.26	5.69	5.95	6.24
Germanium Ge 72.59	0.014	0.077	0.22	0.41	0.63	1.48	2.27	3.30	4.44	5.03	5.37	5.59
Gold Au 196.967	0.103	0.352	0.762	1.25	1.76	3.41	4.38	5.12	5.64	5.84	5.97	6.08
Hafnium Hf 178.49	0.04	0.16	0.41	0.77	1.20	2.90	4.00	4.92	5.55	5.83	6.01	6.15
Helium He 4.0026	4.97(g)	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97	4.97
Holmium Ho 164.930	0.64	1.57*	2.29*	2.98	3.67	5.86	7.41	9.39	6.34	6.33	6.42	6.49
n-Hydrogen H_2 2.01594	0.47(c)	3.32(l)	4.55	6.22	10.10(l)	4.98(g)	5.06	5.39	6.07	6.52	6.77	6.89
	<---------- 99.8 % para ---------->											
n-Deuterium D_2 4.02820	0.54(c)	1.64(c)	5.49(l)	.....	.....	5.06(g)	5.95	6.89	7.19	7.03	6.98	6.98	6.98
	<---------- 97.8 % ortho---->											
Indium In 114.82	0.43	1.01	1.67	2.36	2.98	4.41	5.08	5.58	5.99	6.17	6.31	6.38
Iodine I_2 253.8088	0.96	2.45	3.87	5.14	6.16	8.57	9.96	10.96	11.86	12.32	12.73	13.01
Iridium Ir 192.2	(0.014)	0.038	0.094	0.22	0.43	1.75	2.98	4.15	5.17	5.58	5.87	(6.12)
Iron Fe 55.847	0.017	0.034	0.061	0.11	0.18	0.73	1.61	2.88	4.33	5.13	5.63	5.99
Krypton Kr 83.80	1.46	2.90	3.67	4.43	5.01	6.01	6.57	7.55(c)	4.97(g)	4.97	4.97	4.97
Lanthanum La 138.91	0.26	0.80	1.48	2.20	2.83	4.41	5.12	5.64	6.04	.....	.....	(6.65)
Lead Pb 207.19	0.66	1.68	2.58	3.37	3.94	5.12	5.57	5.85	6.04	6.17	6.27	6.36
Lithium Li 6.939	0.015	0.043	0.095	0.17	0.23	0.97	1.86	3.19*	4.48*	5.15	5.60	5.91
Lutetium Lu 174.97	(0.12)	0.40	0.88	1.46	2.02	3.79	4.72	5.40	5.91	6.16	6.31	6.42
Magnesium Mg 24.312	0.010	0.034	0.086	0.18	0.33	1.36	2.51	3.77	4.90	5.43	5.75	5.95
Manganese (α) Mn 54.9380	0.04	0.068	0.12	0.19	0.33	1.16	2.24	3.52*	4.79	5.51	5.97	6.29

Mercury Hg 200.59	1.12	1.85	2.52	3.04	3.53	4.76	5.36	5.80	6.19	6.52(c)	6.78(l)	6.69
Molybdenum Mo 95.94	0.010	0.024	0.050	0.099	0.18	0.90	1.92	3.21	4.52	5.15	5.50	5.68
Neodymium Nd 144.24	1.26	1.79	2.45*	2.85	3.39	5.16	(5.99)	(6.36)	(6.77)	.....	.....	(6.57)
Neon Ne 20.183	1.25	2.85	4.37(c)	8.44(l)	.....	.....	.....	4.97(g)	4.97	4.97	4.97	4.97
Neptunium Np (237)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(7.0)
Nickel Ni 58.71	0.024	0.043	0.077	0.14	0.23	0.96	1.97	3.28	4.62	5.37	5.83	6.23
Niobium (columbium) Nb(Cb) 92.906	0.050	0.12	0.24	0.42	0.65	1.88	3.02	4.17	5.10	5.52	5.77	5.90
Nitrogen N_2 28.0134	(1.06)	2.87	4.50	6.50	8.25(c_1)	9.92(c_2)	13.4(l)	6.96(g)	6.96	6.96	6.96	6.96
Osmium Os 190.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(5.90)
Oxygen O_2 31.9988	(0.60)	1.59	3.27(c_1)	5.30(c_2)	11.0(c_3)	12.7(l)	6.96(g)	6.96	6.96	6.96	6.98	7.02
Palladium Pd 106.4	0.050	0.12	0.24	0.41	0.67	1.96	3.10	4.26	5.30	5.79	6.06	6.21
Phosphorus (red) P 30.9738	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	4.98
Phosphorus (white) P 30.9738	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	5.63
Platinum Pt 195.09	0.06	0.17	0.36	0.65	1.03	2.56	3.68	4.65	5.47	5.83	6.05	6.19
Plutonium Pu (239)	.....	.....	.....	.....	.....	.....	.....	4.56*	5.50*	5.34*	7.06*	7.65*
Polonium Po (210)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(6.30)
Potassium K 39.102	0.66	1.51	2.34	3.08	3.70	5.01	5.52	5.89	6.22	6.44	6.70	7.06
Praseodymium Pr 140.907	0.99	2.02	3.18	4.36	5.07	6.18*	6.30*	6.22	6.42	(6.51)	(6.56)	(6.59)
Rhenium Re 186.2	.....	.....	0.15	0.32	0.54	1.89	3.08	4.31	5.33	5.80	6.08	6.14
Rhodium Rh 102.905	0.016	0.033	0.067	0.14	0.26	1.20	2.32	3.61	4.82	5.41	5.75	5.97
Rubidium Rb 85.47	1.73	2.95	3.83	4.49	4.90	5.60	5.88	6.10	6.34	6.56	6.85	7.39
Ruthenium Ru 101.07	(0.010)	0.022	0.042	0.084	0.17	0.89	1.92	3.23	4.52	5.17	5.54	5.80
Samarium Sm 150.35	0.63*	1.35*	1.77	2.40	3.11	5.39	7.01	9.08*	6.28	6.47	6.74	7.06
Scandium Sc 44.956	(0.038)	(0.087)	(0.17)	(0.29)	(0.47)	1.54	2.70	3.92	5.05	5.59	5.89	6.12
Selenium Se 78.96	(0.18)	0.45	0.83	1.17	1.51	2.62	3.42	4.34	5.18	5.58	5.80	6.07
Silicon Si 28.086	0.0018	0.0073	0.0023	0.057	0.12	0.53	1.02	1.74	2.86	3.74	4.36	4.78
Silver Ag 107.870	0.044	0.160	0.394	0.733	1.14	2.79	3.90	4.80	5.47	5.77	5.95	6.06
Sodium Na 22.9898	0.14	0.42	0.88	1.44	2.00	3.70	4.65	5.36	5.91	6.20	6.45	6.74
Strontium Sr 87.62	0.17	0.57	1.14	.....	.....	.....	.....	.....	.....	.....	.....	(6.30)
Sulfur (monoclinic) S 32.064	(0.10)	(0.31)	(0.61)	(0.86)	(1.08)	1.77	2.36	3.10	4.06	4.80	5.29	5.64
Sulfur (rhombic) S 32.064	(0.10)	0.31	0.61	0.86	1.08	1.77	2.35	3.06	3.96	4.64	5.08	5.42
Tantalum Ta 180.948	0.050	0.15	0.34	0.62	1.00	2.60	3.75	1.74	5.45	5.76	5.94	6.05
Technetium Tc (99)	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	(5.80)
Tellurium Te 127.60	(0.21)	0.62	1.09	1.57	2.00	3.55	4.47	5.09	5.69	5.91	6.07	6.15
Terbium Tb 158.924	(0.12)	0.47	1.07	1.85	2.64	5.10	5.46	7.56	8.90	11.20	7.55	6.91
Thallium Tl 204.37	(0.81)	1.59	2.40	3.18	3.80	5.01	5.60	5.48	6.06	6.15	6.23	6.29
Thorium Th 232.038	0.16	0.52	1.11	1.80	2.40	4.05	4.88	5.48	5.97	6.22	6.39	6.53
Thulium Tm 168.934	0.47	1.32	2.54	3.93*	5.27*	9.12*	5.84*	6.04*	6.20*	6.34*	6.39	6.46
Tin (gray) Sn 118.69	(0.16)	0.50	0.89	1.24	1.58	2.69	3.70	4.67	5.44	5.81	6.02	6.16
Tin (white) 118.69	0.22	0.64	1.11	1.65	2.20	3.68	4.53	5.35	5.85	6.08	6.20	6.30
Titanium Ti 47.90	0.015	0.036	0.079	0.15	0.27	1.13	2.17	3.43	4.68	5.32	5.72	5.97
Tungsten W 183.80	0.011	0.032	0.077	0.17	0.32	1.39	2.57	3.83	4.90	5.37	5.66	5.81
Uranium U 238.03	0.084	0.31	0.73	1.31	1.93	3.75	4.59	5.32	5.87	6.17	6.40	6.61
Vanadium V 50.942	0.028	0.052	0.087	0.13	0.23	0.89	1.83	3.07	4.41	5.16	5.64	5.97
Xenon Xe 131.30	1.94	3.24	4.00	4.73	5.19	5.99	6.32	6.75	8.04(c)	4.97(g)	4.97	4.97
Ytterbium Yb 173.04	0.35	1.05	1.89	2.70	3.34	4.78	5.36	5.74	6.00	6.14	6.25	6.39
Yttrium Y 88.905	(0.055)	0.19	0.45	0.70	1.26	2.91	4.02	4.95	5.64	6.00	6.20	6.34
Zinc Zn 65.37	0.039	0.17	0.42	0.77	1.16	2.65	3.67	4.61	5.43	5.74	5.94	6.07
Zirconium Zr 91.22	0.03	0.10	0.25	0.45	0.75	2.18	3.37	4.49	5.30	5.74	5.97	6.08

TABLE 4e-2. MOLAR HEAT CAPACITY AT CONSTANT PRESSURE OF THE CHEMICAL ELEMENTS AT HIGHER THAN ROOM TEMPERATURE, CAL/MOLE · K

As revised December, 1967

Element	298.15	400	500	600	700	800	1000	1200	1500	2000	2500	3000
Aluminum Al 26.9815	5.81(c)	6.16	6.45	6.72	7.00	7.37(c)	7.59(l)	7.59(l)	.....	.....	.....	4.971(g)
Antimony Sb 121.75	6.03(c)	6.22	6.38	6.56	6.88	7.15(c)	7.50(l)	7.50(l)				
Argon Ar 39.948	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968(g)
Arsenic As 74.9216	5.89(α)	6.15	6.32	6.50	6.74	7.02(α)						
Beryllium Be 9.0122	3.93(c)	4.73	5.20	5.54	5.82	6.06	6.54(c)	.....	.....	.....	.....	5.020(g)
Bismuth Bi 208.980	6.20(c)	6.45	6.69(c)	7.6(l)	7.6	7.6(l)						
Boron (crystalline) B 10.811	2.65(c)	3.72	4.49	4.99	5.32	5.56	5.95	6.26	6.67	7.12(c)		
Boron (amorphous) B 10.811	2.86(c)	3.78	4.40	4.88	5.26	5.57	6.05	6.39	6.75	7.07(c)		
Bromine Br_2 159.818	18.09(l)	8.78(g)	8.86	8.91	8.94	8.97	9.01(g)					
Cadmium Cd 112.40	6.20(c)	6.49	6.78(c)	7.10(l)	7.10	7.10	7.10(l)	4.968(g)	4.968	4.968	4.968	4.969(g)
Calcium Ca 40.08	6.26(α)	6.62	7.03	7.45	7.87(α)	7.86(β)	9.32(β)	7.4(l)	.....	5.008(g)	5.219	5.796(g)
Carbon (graphite) C 12.01115	2.04(c)	2.85	3.50	4.04	4.44	4.74	5.15	5.43	5.67	5.86	5.97	6.06(c)
Carbon (diamond) C 12.0115	1.46(c)	2.45	3.24	3.85	4.31	4.66	5.16	5.60(c)				
Cerium Ce 140.12	6.44(β)	6.76	7.10	7.46	7.84	8.25	9.14(β)	9.35(l)				
Chlorine Cl_2 70.906	8.11(g)	8.44	8.62	8.74	8.82	8.88	8.96	9.01(g)				
Chromium Cr 51.996	5.58(c)	6.02	6.41	6.73	7.00	7.22	7.66	8.48	9.68(c)	.....	.....	7.358(g)
Cobalt Co 58.9332	5.93(α)	6.34	6.74	7.09	7.42(α)	7.75(β)	8.84	10.33	9.50(β)			
Copper Cu 63.54	5.84(c)	6.08	6.25	6.39	6.52	6.62	6.82	7.00(c)	7.5(l)	.....	.....	6.010(g)
Erbium Er 167.26	6.71(c)	6.79	6.87	6.97	7.11	7.27	7.67	8.18	9.14(c)			
Europium Eu 151.96	6.48(c)	6.68	*	7.24	7.52	7.88	9.09(c)	9.11(l)	.....	5.10(g)	5.61	6.74(g)
Fluorine F_2 37.9968	7.49(g)	7.90	8.21	8.43	8.59	8.71(g)						
Germanium Ge 72.59	5.58(c)	5.85	5.95	6.03	6.10	6.19	6.50	6.86(c)	6.60(l)			
Gold Au 196.967	6.06(c)	6.17	6.29	6.40	6.51	6.65	6.89	7.13(c)	7.0(l)			
Hafnium Hf 178.49	6.15(α)	6.34	6.52	6.70	6.88	7.06	7.43	7.79(α)				
Helium He 4.0026	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968(g)
Holmium Ho 164.930	6.49(α)	6.65	6.74	6.76	6.80	6.95	7.61	8.58	10.69(α)			
n-Hydrogen H_2 2.01594	6.892(g)	6.975	6.993	7.008	7.035	7.078	7.215	7.401	7.706	8.162(g)		
n-Deuterium D_2 4.02820	6.978(g)	6.989	7.018	7.078	7.171	7.288	7.557	7.824	8.164	8.568(g)		
Indium In 114.82	6.39(c)	6.93(c)	7.03(l)	6.99	6.96	6.93(l)	.....	.....	.....	.....	5.709(g)	5.509(g)
Iodine I_2 253.8088	13.01(c)	19.28(l)	8.95(g)	8.98	9.00	9.02(g)						
Iridium Ir 192.2	6.00(c)	6.14	6.27	6.41	6.55	6.69	6.96	7.24	7.65(c)			
Iron Fe 55.847	5.97(α)	6.54	7.10	7.66	8.27	9.07	13.01(α)	8.13(γ)	8.73(γ)			
Krypton Kr 83.80	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968(g)
Lanthanum La 138.91	6.65(β)	6.81	6.97	7.13	7.29	7.45(β)						
Lead Pb 207.19	6.52(c)	6.56	6.79	7.02(c)	7.25(l)	7.17	7.03	6.88(l)	.....	.....	6.951(g)	7.925(g)
Lithium Li 6.939	5.78(c)	6.62(c)	7.20(l)	7.06	6.93	6.92	6.89	6.87(l)				
Lutetium Lu 174.97	6.40(c)	6.42	6.46	6.50	6.61	6.79	7.24	7.85	9.09(c)			
Magnesium Mg 24.312	5.095(c)	6.24	6.52	6.80	7.08	7.36(c)	7.8(l)	7.8(l)	4.968(g)	4.969	4.977	5.022(g)

Manganese Mn 54.9380	6.28(c)	6.76	7.21	7.63	8.01	8.35(α)	9.01(β)	9.21(β)	10.99(δ)	.....	5.039(g)	5.252(g)
Mercury Hg 200.59	6.69(l)	6.54	6.48	6.48(l)	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.968	4.968(g)
Molybdenum Mo 95.94	5.73(c)	6.05	6.25	6.38	6.48	6.55	6.70	6.93	7.47	8.53	10.46(c)	
Neodymium Nd 144.24	6.55(α)	6.88	7.24	7.66	8.14	8.71	10.03(α)	10.65(γ)				
Neon Ne 20.183	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968(g)
Nickel Ni 58.71	6.23(c)	6.80	7.37	8.31	7.37	7.44	7.88	8.34	8.65(c)	10.30(l)		
Niobium (columbium) Nb(Cb) 92.906	5.88(c)	6.09	6.18	6.28	6.38	6.48	6.68	6.88(c)				
Nitrogen N_2 28.0134	6.96(g)	6.99	7.07	7.20	7.35	7.51	7.82	8.06	8.33	8.60	8.76	8.86(g)
Osmium Os 190.2	5.90(c)	5.99	6.09	6.18	6.27	6.63	6.54	6.72	7.00(c)			
Oxygen O_2 31.9988	7.02(g)	7.20	7.43	7.67	7.88	8.06	8.34	8.53	8.74	9.03(g)		
Ozone O_3 47.9982	9.38(g)	10.46	11.30	11.92	12.37	12.70	13.15	13.43	13.68(g)			
Palladium Pd 106.4	6.21(c)	6.35	6.49	6.62	6.76	6.90	7.17	7.44	7.86(c)			
Phosphorus (red, triclinic) P 30.9738	5.07(c)	5.51	5.85	6.16	6.50(c)							
Phosphorus (white) P 30.9738	5.70(β)	6.29(l)	6.29(l)									
Platinum Pt 195.09	6.18(c)	6.31	6.44	6.57	6.70	6.82	7.08	7.34	7.72	8.37(c)		
Plutonium Pu[239]	7.64(α)	8.03(β)	8.53(γ)	9.00(δ)	9.00(δ)	8.40(ε)						
Potassium K 39.102	0.70(c)	7.53(l)	7.34	7.20	7.13	7.11	7.26(l)					
Radon Rn [222]	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4.968	4 968	4.968	4.968(g)
Rhenium Re 186.2	6.16(c)	6.22	6.32	6.43	6.56	6.69	6.95	7.22(c)				
Rhodium Rh 102.905	5.97(c)	6.21	6.45	6.69	6.93	7.17	7.65(c)					
Ruthenium Ru 101.07	5.75(c)	5.82	5.91	6.04	6.23	6.42	6.75	7.11	7.24(c)			
Samarium Sm 150.35	7.06(α)	7.93	8.94	9.75	10.19	10.52	10.82(α)	11.22(β)	.....	.....	6.06(g)	6.08(g)
Scandium Sc 44.956	6.10(α)	6.29	6.41	6.57	6.75	6.96	7.46	8.06	9.14(α)			
Selenium (metallic) Se 78.96	6.06(c)	6.65(c)	8.40(l)	8.40(l)								
Silicon Si 28.086	4.78(c)	5.30	5.61	5.82	5.99	6.13	6.35	6.49	6.66(c)			
Silver Ag 107.870	6.07(c)	6.18	6.30	6.42	6.56	6.72	7.15	7.62(c)	.....	.....	4.968(g)	4.969(g)
Sodium Na 22.9898	6.72(c)	7.53(l)	7.30	7.12	7.00	6.92	6.92(l)					
Sulfur S 32.064	5.40(rh)	7.73(l)	9.08	8.20	7.80(l)							
Tantalum Ta 180.948	6.06(c)	6.22	6.30	6.33	6.39	6.45	6.57	6.69	6.87	7.17	7.46(c)	
Tellurium Te 127.60	6.14(c)	6.68	7.21	7.73	8.26(c)	9.00(l)	9.00(l)					
Thallium Tl 204.37	6.29(α)	6.57	7.03(α)	7.2(l)	.....	.....	.....	.....	.....	5.420(g)	5.830	6.173(g)
Thorium Th 232.038	6.53(α)	6.85	7.15	7.45	7.76	8.06	8.67	9.23(α)				
Thulium Tm 168.934	6.46(c)	6.49	6.51	6.59	6.76	7.08	7.52	7.89	8.43(c)	.....	5.20(g)	5.32(g)
Tin (white) Sn 118.69	6.45(c)	6.89	7.32(c)	6.87(l)	6.85	6.85(l)	.....	.....	.....	.....	.....	6.266(g)
Titanium Ti 47.90	5.98(α)	6.31	6.53	6.77	7.01	7.25	7.73(α)	7.10(β)	7.85(β)			
Tungsten (wolfram) W 183.85	5.81(c)	5.96	6.06	6.16	6.27	6.37	6.59	6.80	7.14	7.71	8.30	9.80(c)
Uranium U 238.03	6.61(α)	7.10	7.65	8.31	9.08	9.99(α)	10.26(β)	9.15(γ)	11.45(l)			
Vanadium V 50.942	5.95(c)	6.27	6.44	6.57	6.70	6.85	7.27	7.85	8.69(c)			
Xenon Xe 130.30	4.968(g)	4.968	4.968	4.968	4.968	4.968	4.963	4.958	4.968	4.968	4.968	4.968(g)
Ytterbium Yb 173.04	6.39(α)	6.60	7.41	7.13	7.25	7.37	7.64(α)	8.79(l)	4.97(g)	4.97	5.01	5.16(g)
Yttrium Y 8.905	6.34(α)	6.49	6.65	6.82	7.00	7.18	7.53	7.90	8.43(α)			
Zinc Zn 65.37	6.07(c)	6.31	6.55	6.79(c)	7.5(l)	7.5	7.5(l)	4.968(g)	4.968	4.968	4.968	4.969(g)
Zirconium Zr 91.22	6.06(α)	6.54	6.78	7.01	7.23	7.45	7.90(α)	7.50(β)	7.50(β)			

gases). With the exception of B (amorphous), C (diamond), Se, Te, and the gases H_2, D_2, Eu, Sm, Tm, and Yb, the tabulated values are based on (1) R. Hultgren, R. L. Orr, P. D. Anderson, and K. K. Kelley, "Selected Values of Thermodynamic Properties of Metals and Alloys," John Wiley & Sons, Inc., New York, 1963 (and later looseleaf supplements); (2) JANAF Thermochemical Tables, Clearinghouse, U.S. Department of Commerce, Springfield, Va. (*PB Rept.* 168370, 1965; *PB Rept.* 168-370-1, 1966) (and later looseleaf supplements); and (3) J. Hilsenrath, C. G. Messina, and W. H. Evans, Ideal Gas Thermodynamic Functions for 73 Atoms and Their First and Second Ions to 10,000 K, *Air Force Weapons Lab. Rept.* TDR-64-44, Kirtland Air Force Base, N.Mex., 1964.

TABLE 4e-3. HEAT CAPACITY OF WATER
(Osborne, Stimson, and Ginnings, National Bureau of Standards)

Temp, °C	$\frac{J}{g \cdot K}$	Temp., °C	$\frac{J}{g \cdot K}$
0	4.2177	50	4.1807
5	4.2022	55	4.1824
10	4.1922	60	4.1844
15	4.1858	65	4.1868
20	4.1819	70	4.1896
25	4.1796	75	4.1928
30	4.1785	80	4.1964
35	4.1782	85	4.2005
40	4.1786	90	4.2051
45	4.1795	95	4.2103
50	4.1807	100	4.2160

As a first approximation in explaining the temperature dependence of the heat capacity of solids, Einstein made the assumption that all oscillators in the lattice vibrated with the same frequency ν_0. If h is Planck's constant and k is Boltzmann's constant, let

$$\Theta_E = \frac{h\nu_0}{k} \qquad x = \frac{\Theta_E}{T}$$

and denote the zero-point energy per mole by U_0. Then the Einstein theory of specific heat yields for the molar energy U at the temperature T

$$\text{(Einstein)} \quad \frac{U - U_0}{3RT} = \frac{x}{e^x - 1} \tag{4e-1}$$

where R is the universal gas constant. The Einstein molar heat capacity at constant volume is given by $C_V = dU/dT$, or

$$\text{(Einstein)} \quad \frac{C_V}{3R} = \frac{x^2 e^x}{(e^x - 1)^2} \tag{4e-2}$$

The molar entropy S is equal to $\int (C_V/T)\, dT$, whence

$$\text{(Einstein)} \quad \frac{S}{3R} = \frac{x}{e^x - 1} - \ln (1 - e^{-x}) \tag{4e-3}$$

Numerical values of the quantities in Eqs. (4e-1), (4e-2), and (4e-3) are given in Tables 4e-4, 4e-5 and 4e-6, taken from "Contributions to the Thermodynamic Functions by a Planck-Einstein Oscillator in One Degree of Freedom," prepared by Herrick L. Johnston, Lydia Savedoff, and Jack Belzer, of the Cryogenic Laboratory of the

TABLE 4e-4. $\frac{U - U_0}{3RT}$ (EINSTEIN)

$\frac{\Theta_E}{T}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1.00000	0.95083	0.90333	0.85749	0.81330	0.77075	0.72982	0.69050	0.65277	0.61661
1	0.58198	0.54886	0.51722	0.48702	0.45824	0.43083	0.40475	0.37998	0.35646	0.33416
2	0.31304	0.29304	0.27414	0.25629	0.23945	0.22356	0.20861	0.19453	0.18129	0.16886
3	0.15719	0.14624	0.13598	0.12638	0.11739	0.10898	0.10113	0.09380	0.08695	0.08057
4	0.07463	0.06909	0.06394	0.05915	0.05469	0.05055	0.04671	0.04314	0.03983	0.03676
5	0.03392	0.03128	0.02885	0.02658	0.02450	0.02257	0.02079	0.01914	0.01761	0.01621
6	0.01491	0.01371	0.01261	0.01159	0.01065	0.00979	0.00899	0.00826	0.00758	0.00696
7	0.00639	0.00586	0.00538	0.00494	0.00453	0.00415	0.00381	0.00349	0.00320	0.00293
8	0.00269	0.00246	0.00225	0.00206	0.00189	0.00173	0.00158	0.00145	0.00133	0.00121
9	0.00111	0.00102	0.00093	0.00085	0.00078	0.00071	0.00065	0.00059	0.00054	0.00050
10	0.00045	0.00042	0.00038	0.00035	0.00032	0.00029	0.00026	0.00024	0.00022	0.00020
11	0.00018	0.00017	0.00015	0.00014	0.00013	0.00012	0.00011	0.00010	0.00009	0.00008
12	0.00007	0.00007	0.00006	0.00006	0.00005	0.00005	0.00004	0.00004	0.00004	0.00003
13	0.00003	0.00003	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00001	0.00001
14	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001

TABLE 4e-5. $\frac{C_v}{3R}$ (EINSTEIN)

$\frac{\Theta_E}{T}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1.00000	0.99917	0.99667	0.99253	0.98677	0.97942	0.97053	0.96015	0.94833	0.93515
1	0.92067	0.90499	0.88817	0.87031	0.85151	0.83185	0.81143	0.79035	0.76869	0.74657
2	0.72406	0.70127	0.67827	0.65515	0.63200	0.60889	0.58589	0.56307	0.54049	0.51820
3	0.49627	0.47473	0.45363	0.43301	0.41289	0.39331	0.37429	0.35584	0.33799	0.32073
4	0.30409	0.28806	0.27264	0.25783	0.24363	0.23004	0.21704	0.20462	0.19277	0.18149
5	0.17074	0.16053	0.15083	0.14162	0.13290	0.12464	0.11683	0.10944	0.10247	0.09588
6	0.08968	0.08383	0.07833	0.07315	0.06828	0.06371	0.05942	0.05539	0.05162	0.04808
7	0.04476	0.04166	0.03876	0.03605	0.03351	0.03115	0.02894	0.02687	0.02495	0.02316
8	0.02148	0.01993	0.01848	0.01713	0.01587	0.01471	0.01362	0.01261	0.01168	0.01081
9	0.01000	0.00925	0 00855	0.00791	0.00731	0.00676	0.00624	0.00577	0.00533	0.00492
10	0.00454	0 00419	0 00387	0.00357	0.00329	0.00304	0.00280	0.00258	0.00238	0.00219
11	0.00202	0.00186	0.00172	0.00158	0.00145	0.00134	0.00123	0.00114	0.00104	0.00096
12	0.00088	0.00081	0.00075	0.00069	0.00063	0.00058	0.00054	0.00049	0.00045	0.00042
13	0.00038	0.00035	0.00032	0.00030	0.00027	0.00025	0.00023	0.00021	0.00019	0.00018
14	0.00016	0.00015	0.00014	0.00013	0.00012	0.00011	0.00010	0.00009	0.00008	0.00008

Ohio State University, under contract between the Office of Naval Research and the Ohio State University Research Foundation, 1949.

Debye assumed that the oscillators occupying the lattice points in a crystalline solid vibrated with a continuous spectrum of frequencies from zero to a maximum value ν_m. Defining the "Debye temperature" Θ_D and y by the equations

$$\Theta_D = \frac{h\nu_m}{k} \qquad y = \frac{\Theta_D}{T}$$

TABLE 4e-6. $\frac{S}{3R}$ (EINSTEIN)

$\frac{\Theta_E}{T}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	∞	3.30300	2.61110	2.20772	1.92293	1.70350	1.52569	1.37684	1.24939	1.13845
1	1.04066	0.95363	0.87560	0.80521	0.74139	0.68331	0.63027	0.58171	0.53714	0.49617
2	0.45845	0.42367	0.39158	0.36194	0.33455	0.30921	0.28579	0.26410	0.24403	0.22546
3	0.20826	0.19234	0.17760	0.16396	0.15133	0.13964	0.12884	0.11883	0.10958	0.10102
4	0.09312	0.08580	0.07905	0.07281	0.06704	0.06172	0.05681	0.05228	0.04809	0.04423
5	0.04068	0.03740	0.03438	0.03159	0.02903	0.02666	0.02450	0.02249	0.02064	0.01896
6	0.01739	0.01596	0.01464	0.01343	0.01232	0.01130	0.01035	0.00949	0.00869	0.00797
7	0.00730	0.00660	0.00613	0.00562	0.00514	0.00470	0.00431	0.00394	0.00361	0.00330
8	0.00303	0.00276	0.00252	0.00231	0.00211	0.00193	0.00176	0.00162	0.00148	0.00135
9	0.00123	0.00113	0.00103	0.00094	0.00086	0.00078	0.00072	0.00065	0.00060	0.00055
10	0.00050	0.00046	0.00042	0.00038	0.00035	0.00032	0.00028	0.00026	0.00024	0.00022
11	0.00020	0.00019	0.00016	0.00015	0.00014	0.00013	0.00012	0.00011	0.00010	0.00009
12	0.00008	0.00008	0.00007	0.00006	0.00005	0.00005	0.00004	0.00004	0.00004	0.00003
13	0.00003	0.00003	0.00002	0.00002	0.00002	0.00002	0.00002	0.00002	0.00001	0.00001
14	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001	0.00001

TABLE 4e-7. $\frac{U - U_0}{3RT}$ (DEBYE)

$\frac{\Theta_D}{T}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1.000000	.963000	.926999	.891995	.857985	.824963	.792923	.761858	.781759	.702615
1	.674416	.647148	.620798	.595351	.570793	.547107	.524275	.502280	.481103	.460726
2	.441128	.422291	.404194	.386816	.370137	.354136	.338793	.324086	.309995	.296500
3	.283580	.271215	.259385	.248070	.237252	.226911	.217029	.207589	.198571	.189959
4	.181737	.173888	.166396	.159246	.152424	.145914	.139704	.133780	.128129	.122739
5	.117597	.112694	.108016	.103555	.099300	.095241	.091369	.087675	.084152	.080789
6	.077581	.074520	.071598	.068809	.066146	.063604	.061177	.058858	.056644	.054528
7	.052506	.050573	.048726	.046960	.045271	.043655	.042109	.040630	.039214	.037858
8	.036560	.035317	.034126	.032984	.031890	.030840	.029834	.028869	.027942	.027053
9	.026200	.025380	.024593	.023837	.023110	.022411	.021739	.021092	.020470	.019872
10	.019296	.018741	.018207	.017692	.017196	.016718	.016257	.015812	.015384	.014970
11	.014570	.014185	.013813	.013453	.013106	.012770	.012445	.012131	.011828	.011534
12	.011250	.010975	.010709	.010452	.010202	.009960	.009726	.009499	.009279	.009066
13	.008859	.008658	.008463	.008275	.008091	.007913	.007740	.007572	.007409	.007251
14	.007097	.006947	.006801	.006660	.006522	.006388	.006258	.006132	.006008	.005888

$\frac{\Theta_D}{T}$	0	1	2	3	4	5	6	7	8	9
10	.019296	.014570	.011250	.008859	.007097	.005771	.004756	.003965	.003340	.002840
20	.002435	.002104	.001830	.001601	.001409	.001247	.001108	.000990	.000887	.000799
30	.000722	.000654	.000595	000542	000496	.000454	.000418	.000385	.000355	.000328
40	.000304	.000283	.000263	.000245	.000229	.000214	.000200	.000188	.000176	.000166

TABLE 4e-8. $\frac{C_V}{3R}$ (DEBYE)

$\frac{\Theta_D}{T}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1.000000	.999500	.998003	.915514	.992046	.987611	.982229	.975922	.968717	.960643
1	.951732	.942020	.931545	.920346	.908467	.895950	.882842	.869186	.855031	.840422
2	.825408	.810034	.794347	.778392	.762213	.745853	.729355	.712759	.696103	.679424
3	.662758	.646137	.629593	.613154	.596848	.580700	.564732	.548966	.533421	.518113
4	.503059	.488272	.473763	.459543	.445620	.432002	.418693	.405700	.393024	.380669
5	.368635	.356922	.345529	.334456	.323698	.313255	.303121	.293293	.283767	.274536
6	.265597	.256943	.248568	.240466	.232631	.225056	.217735	.210662	.203828	.197229
7	.190856	.184704	.178766	.173035	.167505	.162169	.157021	.152055	.147264	.142644
8	.138187	.133889	.129744	.125746	.121890	.118172	.114585	.111126	.107790	.104572
9	.101467	.098472	.095583	.092795	.090105	.087509	.085004	082585	.080251	.077997
10	.075821	.073719	.071690	.069729	.067835	.066005	.064236	.062526	.060874	.059276
11	.057731	.056237	.054791	.053393	.052039	.050730	.049462	.048235	.047046	.045895
12	.044780	.043700	.042653	.041639	.040655	.039702	.038777	.037880	.037010	.036166
13	.035347	.034552	.033781	.033031	.032304	.031597	.030910	.030243	.029595	.028964
14	.028352	.027756	.027177	.026613	.026065	.025532	.025013	.024508	.024016	.023537

$\frac{\Theta_D}{T}$	0	1	2	3	4	5	6	7	8	9
10	.075821	.057731	.044780	.035347	.028352	.023071	.019018	.015859	.013361	.011361
20	.009741	.008414	.007318	.006405	.005637	.004987	.004434	.003959	.003550	.003195
30	.002886	.002616	.002378	.002168	.001983	.001818	.001670	.001538	.001420	.001314
40	.001218	.001131	.001052	.000980	.000915	.000855	.000801	.000751	.000705	.000662

the values of molar energy, molar heat capacity at constant volume and molar entropy were found to be

$$(\text{Debye})\ \frac{U - U_0}{3RT} = D(y) = \frac{3}{y^3}\int_0^y \frac{z^3\,dz}{e^z - 1} \tag{4e-4}$$

$$(\text{Debye})\ \frac{C_V}{3R} = 4D(y) - \frac{3y}{e^y - 1} \tag{4e-5}$$

$$(\text{Debye})\ \frac{S}{3R} = \frac{4}{3}D(y) - \ln(1 - e^{-y}) \tag{4e-6}$$

Values of the quantities in Eqs. (4e-4), (4e-5) and (4e-6) are given in Tables 4e-7, 4e-8 and 4e-9, prepared by John E. Kilpatrick and Robert H. Sherman, of the Los Alamos Scientific Laboratory, under contract with the U.S. Atomic Energy Commission, 1964.

To calculate $U - U_0$ in joules/mole, and C_V and S in joules/mole kelvin, take as the value of R

$$R = 8.3143 \text{ joules/mole kelvin}$$

To convert to calories, it must be kept in mind that there are three different calories:

The 15-degree calorie = 4.1858 joules
The International steam table calorie = 4.1868 joules
The thermochemical calorie = 4.1840 joules

TABLE 4e-9. $\frac{S}{3R}$ (DEBYE)

$\frac{\Theta_D}{T}$	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	∞	3.636168	2.943771	2.539553	2.253613	2.032703	1.853102	1.702152	1.572296	1.458656
1	1.357896	1.267635	1.186113	1.111987	1.044212	0.981958	0.924550	0.871435	0.822152	0.776313
2	0.733585	0.693684	0.656362	0.621403	0.588616	0.557832	0.528900	0.501685	0.476064	0.451928
3	0.429176	0.407715	0.387463	0.368341	0.350279	0.333211	0.317077	0.301819	0.287386	0.273728
4	0.260801	0.248562	0.236970	0.225990	0.215585	0.205724	0.196375	0.187510	0.179103	0.171126
5	0.163557	0.156373	0.149554	0.143077	0.136926	0.131083	0.125530	0.120252	0.115234	0.110462
6	0.105924	0.101605	0.097495	0.093583	0.089858	0.086310	0.082930	0.079709	0.076639	0.073712
7	0.070920	0.068257	0.065715	0.063289	0.060972	0.058760	0.056646	0.054626	0.052695	0.050849
8	0.049083	0.047393	0.045775	0.044227	0.042744	0.041324	0.039963	0.038658	0.037407	0.036208
9	0.035057	0.033952	0.032892	0.031873	0.030895	0.029956	0.029053	0.028184	0.027349	0.026546
10	0.025773	0.025029	0.024313	0.023623	0.022959	0.022318	0.021701	0.021106	0.020532	0.019978
11	0.019444	0.018928	0.018431	0.017950	0.017485	0.017037	0.016603	0.016184	0.015778	0.015386
12	0.015007	0.014639	0.014284	0.013940	0.013607	0.013284	0.012972	0.012669	0.012375	0.012090
13	0.011814	0.011546	0.011286	0.011034	0.010790	0.010552	0.010321	0.010097	0.009880	0.009669
14	0.009463	0.009263	0.009069	0.008881	0.008697	0.008519	0.008345	0.008176	0.008011	0.007851

$\frac{\Theta_D}{T}$	0	1	2	3	4	5	6	7	8	9
10	0.025773	0.019444	0.015007	0.011814	0.009463	0.007695	0.006341	0.005287	0.004454	0.003787
20	0.003247	0.002805	0.002439	0.002135	0.001879	0.001662	0.001478	0.001320	0.001183	0.001065
30	0.000962	0.000872	0.000793	0.000723	0.000661	0.000606	0.000557	0.000513	0.000473	0.000438
40	0.000406	0.000377	0.000351	0.000327	0.000305	0.000285	0.000267	0.000250	0.000235	0.000221

At values of the temperature less than $\Theta_D/100$, the Debye theory can be relied upon to give correctly the contribution to the heat capacity attributable to lattice vibrations. In some cases it holds well at temperatures up to $\Theta_D/50$. At these low temperatures the Debye expression for C_V reduces to

$$C_V = \frac{12\pi^4 R}{5\Theta_D{}^3} \cdot T^3 \tag{4e-7}$$

or

$$C_V = 124.8 \frac{\text{mJ}}{\text{mole} \cdot \text{K}} \left(\frac{T}{\Theta_D}\right)^3 \tag{4e-8}$$

For metals there is a contribution to the heat capacity due to the free electrons equal to γT, where γ is known as the electronic constant. The total heat capacity of a metal is therefore

$$C_V = \frac{12\pi^4 R}{5\Theta_D{}^3} \cdot T^3 + \gamma T \tag{4e-9}$$

The most reliable values of Θ_D and γ are obtained from heat-capacity measurements in the liquid helium region. It is customary in such work to plot C_V/T against T^2. On such a plot a nonmetal gives a straight line through the origin, whereas a metal gives a straight line with a positive intercept.

Values of Θ_D and γ are given in Table 4e-10. They were obtained in almost all cases by calorimetric measurements in the liquid helium range or lower. Values of Θ_D are given in kelvins, and those of γ in millijoules per mole kelvin squared.

TABLE 4e-10. VALUES OF Θ_D AND γ, IN THE HEAT-CAPACITY EQUATION (4e-9).

Substance	Symbol	Θ_D, K	γ, $\frac{\text{mJ}}{\text{mole} \cdot \text{K}^2}$	Refs.
Aluminum	Al	428	1.35	1, 2, 89
Antimony	Sb	211	0.112	3
Argon	A	93		
Arsenic	As	282	0.19	3, 4
Barium	Ba	110	2.7	5
Beryllium	Be	1440	0.17	6, 7
Bismuth	Bi	119	0.021	8, 9
Bismuth telluride	Bi_2Te_3	155	.....	31
Cadmium	Cd	209	0.69	10
Calcium	Ca	230	2.9	11, 5
Calcium fluoride	CaF_2	510	.....	32
Carbon (graphite)	C	420	.....	12
Carbon (diamond)	C	2230	.....	13, 14, 90
Cesium	Cs	38	3.2	15
Chlorine	Cl	115		
Chromium	Cr	630	1.40	16
Cobalt	Co	445	4.7	17, 18, 19
Copper	Cu	343	0.688	20, 21, 22, 54
Dysprosium	Dy	210	.....	23
Gadolinium	Gd	195	.....	93
Gallium	Ga	320	0.60	10, 24
Germanium	Ge	370	.....	25, 26
Germanium telluride	GeTe	166	1.32	85
Gold	Au	165	0.69	20, 27, 91
Hafnium	Hf	252	2.16	28
Helium^4 (hcp)	He^4 (hcp)	26.4	.....	84
Helium^3 (bcc)	He^3 (bcc)	16		
Hydrogen	H	105		
Hydrogen^2	H^2	97		
Ice	H_2O	192		
Indium	In	108	1.6	29, 30
Indium antimonide	InSb	200	.....	44
Iodine	I	106		
Iridium	Ir	420	3.1	59
Iron	Fe	467	5.0	60, 61, 92
Iron oxide	Fe_2O_3	660	.....	33
Iron selenide	$FeSe_2$	366	.....	66
Iron sulfide	FeS_2	637	.....	66
Krypton	Kr	72		
Lanthanum	La	142	10	62, 95
Lead	Pb	105	3.0	56
Lead selenide	PbSe	135–160		
Lead sulfide	PbS	194		
Lead telluride	PbTe	124–135		
Lithium	Li	344	1.63	15
Lithium chloride	LiCl	422	.....	86
Lithium fluoride	LiF	732	.....	34, 35, 36
Magnesium	Mg	400	1.3	63, 64
Magnesium cadmide	Mg_3Cd	290	0.8	37
Magnesium oxide	MgO	946	.....	38
Manganese	Mn	410	14	48, 49, 50
Mercury	Hg	71.9	1.79	65, 75
Molybdenum	Mo	450	2.0	59, 67, 68, 94
Neon	Ne	75	.....	45
Nickel	Ni	450	7.1	16, 69
Nickel selenide	$NiSe_2$	297	.....	66
Niobium	Nb	275	7.79	52, 58, 94

TABLE 4e-10. VALUES OF Θ AND γ, IN THE HEAT-CAPACITY EQUATION (4e-9) (*Continued*)

Substance	Symbol	Θ_D, K	γ, $\frac{mJ}{mole \cdot K^2}$	Refs.
Niobium-tin	Nb_3Sn	228	13.1	87
Nitrogen	N	68		
Osmium	Os	500	2.4	59
Oxygen	O	91		
Palladium	Pd	274	9.42	53
Platinum	Pt	240	6.8	27
Potassium	K	91	2.1	15
Potassium bromide	KBr	174	.....	39
Potassium chloride	KCl	235	.....	39, 40, 41
Potassium fluoride	KF	330	.....	86
Potassium iodide	KI	132	.....	39
Rhenium	Re	430	2.3	59, 70, 94
Rhodium	Rh	480	4.9	59
Rubidium	Rb	56	2.4	15
Rubidium bromide	RbBr	131	.....	86
Rubidium chloride	RbCl	165	.....	86
Rubidium iodide	RbI	103	.....	86
Ruthenium	Ru	600	3.3	59
Scandium	Sc	360	10.7	46, 96
Selenium	Se	90	.....	71
Silicon	Si	640	.....	25, 26
Silicon dioxide	SiO_2	470	.....	42
Silver	Ag	225	0.650	54
Silver bromide	AgBr	144		
Silver chloride	AgCl	183		
Sodium	Na	158	1.4	5, 72, 73
Sodium bromide	NaBr	225	.....	86
Sodium chloride	NaCl	321	.....	39
Sodium fluoride	NaF	492	.....	86
Sodium iodide	NaI	164	.....	39
Strontium	Sr	147	3.6	5
Tantalum	Ta	240	5.9	59, 68, 74, 94
Tellurium	Te	153	.....	71
Thallium	Tl	78.5	1.47	75
Thorium	Th	163	4.3	76, 97
Tin (white)	Sn	199	1.78	67, 77, 78
Tin (gray)	Sn	210	.....	41
Titanium	Ti	420	3.5	28, 79, 80
Titanium dioxide	TiO_2	760	.....	43
Tungsten	W	400	1.3	59, 68, 81
Uranium	U	207	10.0	57, 97
Uranium dioxide	UO_2	160		
Vanadium	V	380	9.8	47
Xenon	Xe	64	.....	45
Yttrium	Y	280	10.2	51, 94
Yttrium iron garnet	YIG	510		
Zinc	Zn	327	0.65	24, 82, 83
Zinc sulfide	ZnS	315	.....	35
Zirconium	Zr	291	2.80	28

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