CHAPTER 7

Tables

These tables are from

Understanding the properties of matter

by Michael de Podesta.

The data from the tables is derived primarily, but not exclusively, from the following compilations:

- G. W. C. Kaye and T. H. Laby, *Tables of Physical and Chemical Constants*: 14th, 15th and 16th Editions, published by Longman (Harlow) in the UK and Wiley (New York) in the USA. This is referred to as *Kaye & Laby* in the text.
- Weast *CRC Handbook of Chemistry and Physics:* 65th *Edition* [also known as the 'Rubber Bible'], published by Chemical Rubber Publishing Company (Chicago, Ill)
- John Emsley, *The Elements*, published by Clarendon Press / Oxford University Press (Oxford).

Table 7.1 The approximate values of the density of some solids.

Solid	**ρ(kg m^{-3})**
Metals	
Aluminium/Dural	2700–2800
Phosphor–bronze	8900
Brass	8400–8500
Gold (22 carat)	17500
Gold (9 carat)	11300
Mild steel	7900
Stainless steel	7700–7800
Wrought iron	7800
Invar	8000
Platinum/Iridium	21500
Wood	
Balsa	200
Pine	500
Oak	700
Beech	750
Teak	850
Ebony	1200
Natural materials	
Amber	1100
Beeswax	950
Granite	2700
Ice	920
Coal	1.4–1.6
Mica	2800

Table 7.2 The density of the elements (kg m^{-3}). Also shown is the atomic number Z and the atomic weight A in units of the atomic mass unit u = 1.66×10^{-27} kg. For example, the density of *magnesium*, whose atoms each contain 12 protons, is 1.738×10^3 kg m^{-3}. The mass of an atom of magnesium is $24.31 \times 1.66 \times 10^{-27}$ kg. The densities of elements that are normally gaseous at room temperature are evaluated at a temperature just below their freezing point at atmospheric pressure. For helium, which does not solidify at atmospheric pressure at any temperature, the density is evaluated at 4.2 K and 25 atmospheres (25×10^5 Pa) pressure which is sufficient to cause solidification.

Z	Element and symbol	A	Density	Z	Element and symbol	A	Density
1	Hydrogen, H	1.008	89				
2	Helium, He	4.003	120	51	Antimony, Sb	121.7	6692
3	Lithium , Li	6.941	533	52	Tellurium, Te	127.6	6247
4	Beryllium, Be	9.012	1846	53	Iodine, I	126.9	4953
5	Boron, B	10.81	2466	54	Xenon, Xe	131.3	3560
6	Carbon (graphite), C	12.01	2266	55	Caesium, Cs	132.9	1900
6	Carbon (diamond), C	12.01	3513	56	Barium, Ba	137.3	3594
7	Nitrogen, N	14.01	1035	57	Lanthanum, La	138.9	6174
8	Oxygen, O	16.00	1460	58	Cerium, Ce	140.1	6711
9	Fluorine, F	19.00	1140	59	Praseodymium, Pr	140.9	6779
10	Neon, Ne	20.18	1442	60	Neodymium, Ne	144.2	7000
11	Sodium, Na	22.99	966	61	Promethium, Pm	145.0	7220
12	Magnesium, Mg	24.31	1738	62	Samarium, Sm	150.4	7536
13	Aluminium, Al	26.98	2698	63	Europium, Eu	152.0	5248
14	Silicon, Si	28.09	2329	64	Gadolinium, Gd	157.2	7870
15	Phosphorus, P	30.97	1820	65	Terbium, Tb	158.9	8267
16	Sulphur, S	32.06	2086	66	Dysprosium, Dy	162.5	8531
17	Chlorine, Cl	35.45	2030	67	Holmium, Ho	164.9	8797
18	Argon, Ar	39.95	1656	68	Erbium, Er	167.3	9044
19	Potassium, K	39.10	862	69	Thulium, Th	168.9	9325
20	Calcium, Ca	40.08	1530	70	Ytterbium, Yb	173.0	6966
21	Scandium, Sc	44.96	2992	71	Lutetium, Lu	175.0	9842
22	Titanium, Ti	47.90	4508	72	Hafnium, Hf	178.5	13276
23	Vanadium, V	50.94	6090	73	Tantalum, Ta	180.9	16670
24	Chromium, Cr	52.00	7194	74	Tungsten, W	183.9	19254
25	Manganese, Mn	54.94	7473	75	Rhenium, Re	186.2	21023
26	Iron, Fe	55.85	7873	76	Osmium, Os	190.2	22580
27	Cobalt, Co	58.93	8800	77	Iridium, Ir	192.2	22550
28	Nickel, Ni	58.70	8907	78	Platinum, Pt	195.1	21450
29	Copper, Cu	63.55	8933	79	Gold, Au	197.0	19281
30	Zinc, Zn	65.38	7135	80	Mercury, Hg	200.6	13546
31	Gallium, Ga	69.72	5905	81	Thallium, Th	204.4	11871
32	Germanium, Ge	72.59	5323	82	Lead, Pb	207.2	11343
33	Arsenic, As	74.92	5776	83	Bismuth, Bi	209.0	9803
34	Selenium, Se	78.96	4808	84	Polonium, Po	209.0	9400
35	Bromine, Br	79.90	3120	85	Astatine, At	210.0	—
36	Krypton, Kr	83.80	3000	86	Radon, Rn	222.0	4400
37	Rubidium, Rb	85.47	1533	87	Francium, Fr	223.0	—
38	Strontium, Sr	87.62	2583	88	Radium, Ra	226.0	5000
39	Yttrium, Y	88.91	4475	89	Actinium, Ac	227.0	10060
40	Zirconium, Zr	91.22	6507	90	Thorium, Th	232.0	11725
41	Niobium, Nb	92.91	8578	91	Protractinium, Pa	231.0	15370
42	Molybdenum, Mo	95.94	10222	92	Uranium, U	238.0	19050
43	Technetium, Tc	97.00	11496	93	Neptunium, Np	237.0	20250
44	Ruthenium, Ru	101.1	12360	94	Plutonium, Pu	244.0	19840
45	Rhodium, Rh	102.9	12420	95	Americium, Am	243.0	13670
46	Palladium, Pd	106.4	11995	96	Curium, Cm	247.0	13300
47	Silver, Ag	107.9	10500	97	Berkelium, Bk	247.0	14790
48	Cadmium, Cd	112.4	8647	98	Californium, Cf	251.0	15100
49	Indium, In	114.8	7290	99	Einsteinium, Es	254.0	—
50	Tin, Sn	118.7	7285	100	Fermium, Fm	257.0	—

Table 7.3 The atomic number *Z*, atomic mass *A* and the density ρ of the lanthanide elements extracted from Table 7.2. The row marked %*A* is the % density increase (compared with La) expected if the separation between atoms is unchanged and only the atomic mass changes. The row marked %ρ is the % density increase (compared with La) actually found. It shows that the 59% density increase is much greater than can be explained by the 26% increase in atomic mass alone.

	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Z	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71
A	138.9	140.1	140.9	144.2	145	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.0	175.0
%*A*	0	0.87	1.44	3.84	4.39	8.28	9.40	13.21	14.41	16.99	18.74	20.41	21.62	24.57	25.96
ρ	6174	6711	6779	7000	7220	7536	5248	7870	8267	8531	8797	9044	9325	6966	9842
%ρ	0	8.7	9.8	13.4	16.9	22.1	-15.0	27.4	33.9	38.2	42.5	46.5	51.4	12.8	59.4

Table 7.4 The bulk modulus of the elements in their solid state. The temperature of the measurements varies considerably and there are discrepancies of the up to 50% in figures from different sources.

Z	Element	*B* (GPa)	Z	Element	*B* (GPa)	Z	Element	*B* (GPa)
1	Hydrogen	0.2	29	Copper	137.8	59	Praseodymium	30.6
2	Helium	0.1	30	Zinc	72.0	60	Neodymium	32.7
3	Lithium	11.1	31	Gallium	56.9	61	Promethium	35.0
4	Beryllium	100.3	32	Germanium	7.7	62	Samarium	39.4
5	Boron	178.0	33	Arsenic	22.0	63	Europium	14.7
6	Carbon (diamond)	542.0	34	Selenium	8.3	64	Gadolinium	38.3
6	Carbon (graphite)	33.0	35	Bromine	1.9	65	Terbium	39.9
7	Nitrogen	1.2	36	Krypton	3.5	66	Dysprosium	38.4
8	Oxygen		37	Rubidium	1.9	67	Holmium	39.7
9	Fluorine		38	Strontium	1.2	68	Erbium	41.1
10	Neon	1.1	39	Yttrium	36.6	69	Thulium	39.7
11	Sodium	6.4	40	Zirconium	83.3	70	Ytterbium	13.3
12	Magnesium	44.7	41	Niobium	170.2	71	Lutetium	41.1
13	Aluminum	75.5	42	Molybdenum	231.0	72	Hafnium	109.0
14	Silicon	98.8	43	Technetium	297.0	73	Tantalum	200.0
15	Phosphorous (Red)	10.9	44	Ruthenium	320.8	74	Tungsten	323.2
15	Phosphorous(White)	4.9	45	Rhodium	270.4	75	Rhenium	372.0
16	Sulphur	17.8	46	Palladium	182.0	76	Osmium	418.0
17	Chlorine		47	Silver	100.7	77	Iridium	355.0
18	Argon	2.7	48	Cadmium	41.6	78	Platinum	228.0
19	Potassium	3.1	49	Indium	41.1	79	Gold	217.0
20	Calcium	17.2	50	Tin	58.2	80	Mercury	25.0
21	Scandium	43.5	51	Antimony	42.0	81	Thallium	35.9
22	Titanium	105.1	52	Tellurium	23.0	82	Lead	45.8
23	Vanadium	161.9	53	Iodine	7.7	83	Bismuth	31.3
24	Chromium	160.1	54	Xenon	3.6	84	Polonium	26.0
25	Manganese	118.0	55	Caesium	1.6	29	Copper	137.8
26	Iron	169.8	56	Barium	10.3	30	Zinc	72.0
27	Cobalt	191.4	57	Lanthanum	24.3			
28	Nickel	186.0	58	Cerium	23.9			

Table 7.5 Values of the bulk modulus of the noble gas solids calculated according to Equation 7.6, compared with experimental data from Table 7.4.

	Substance			
	Ne	**Ar**	**Kr**	**Xe**
σ ($\times 10^{-10}$ m)	2.74	3.44	3.65	3.98
ε ($\times 10^{-3}$ eV)	3.1	10.3	14.0	20.0
$75.13\varepsilon/\sigma^3$($\times 10^9$ Pa)	1.81	3.18	3.46	3.81
Data	1.1	2.7	3.5	3.6
Ratio (theory/expt)	1.65	1.18	0.99	1.06

Table 7.6 Values of the bulk modulus of the alkali metals calculated according to Equation 7.11, compared with experimental data from Table 7.4.

	Substance				
	Li	**Na**	**K**	**Rb**	**Cs**
n ($\times 10^{28}$ m^{-3})	4.63	2.53	1.33	1.08	0.86
ε_F ($\times$ eV)	4.7	3.14	2.05	1.78	1.53
$2n\varepsilon_F/3$($\times 10^9$ Pa)	23.2	8.5	2.9	2.06	1.41
Data	11.1	6.4	3.1	1.9	1.6
Ratio (theory/expt)	2.10	1.33	0.94	1.08	0.88

Table 7.7 The coefficient of linear expansivity α for various solids at temperatures around room temperature. (*Kaye & Laby*). The volume expansivity of the elements is given by β = 3α as shown in Example 7.4.

Elemental metals	**α (°C^{-1})**	**Miscellaneous**	**α (°C^{-1})**	**Alloys**	**α (°C^{-1})**
Aluminium (Al)	23	Brick	3–10	Brass (68% Cu/32% Zn)	18–19
Antimony (Sb)	≈ 11	Cement and concrete	10–14	Bronze (80% Cu/20% Sn)	17–18
Bismuth (Bi)	≈ 13	Marble	3–15	Constantan (60% Cu/40% Ni)	15–17
Cadmium (Cd)	≈ 30	Lead glass (46% pbo)	≈ 8	Duralumin (95% Al/4% Cu)	23
Chromium (Cr)	≈ 7	Typical glass	≈ 8–10	Magnalium (90% Al/10% Mg)	≈ 23
Cobalt (Co)	≈ 12	Porcelain	2–6	Nickel steel(10% Ni/90%Fe)	13
Copper (Cu)	16.7	Silica	0.4	Nickel steel(36% Ni/64%Fe)	0–1.5
Gold (Au)	13	Typical wood (along grain)	3–5	Nickel steel(43% Ni/57%Fe)	7.9
Iridium (Ir)	6.5	Typical wood (across grain)	35–60	Nickel steel(58% Ni/42%Fe)	11.4
Iron (Fe)	11.7			Carbon steel	≈11
Lead (Pb)	29	**Plastics**		Stainless steel (74%Fe/18%Cr/8%Ni)	29
Magnesium (Mg)	25	Epoxy resins	45–65	Phosphor-bronze	17
Nickel (Ni)	12.8	Epoxy resins	45–65	Platinum–Iridium (90% Pt/10% Ir)	8.7
Palladium (Pd)	≈ 11	Polycarbonates	66		
Platinum (Pt)	8.9	Low-density polyethylene	40–150	**Carbon**	
Rhodium (Rh)	8.4	Medium-density polyethylene	80–220	Diamond	1.0
Silver (Ag)	19	High density polyethylene	200–360	Graphite (polycrystalline)	7.1
Tantalum (Ta)	6.5	Natural rubber	220		
Thallium (Tl)	≈ 28	Hard rubber	60		
Tin (Sn)	≈ 21	Perspex	50–90		
Titanium (Ti)	≈ 9	Nylon	80–280		
Tungsten (W)	4.5	Polystyrene	34–210		
Vanadium (V)	≈ 8	Polyvinyl chloride (pvc)	70–80		
Zinc (Zn)	≈ 30				

Table 7.8 Expected and experimentally determined values the coefficient of linear expansivity thermal expansivity α for some alloys and their component metals.

Alloy composition	Expected (see text)	Experimental α (°C^{-1})
Aluminium alloys		
Duralumin (95% Al/4% Cu)	22.5×10^{-6}	23×10^{-6}
Magnalium (90% Al/10% Mg)	23.2×10^{-6}	$\approx 23 \times 10^{-6}$
Aluminium	—	23×10^{-6}
Copper	—	16.7×10^{-6}
Magnesium	—	$\approx 25 \times 10^{-6}$
Copper alloys		
Brass (68% Cu/32% Zn)	21×10^{-6}	18-19 $\times 10^{-6}$
Bronze (80% Cu/20% Sn)	17.6×10^{-6}	17-18 $\times 10^{-6}$
Constantan (60% Cu/40% Ni)	15.1×10^{-6}	15-17 $\times 10^{-6}$
Copper	—	16.7×10^{-6}
Zinc	—	$\approx 30 \times 10^{-6}$
Tin	—	$\approx 21 \times 10^{-6}$
Ni	—	12.8×10^{-6}
Platinum alloys		
Platinum-Iridium (90% Pt/10% Ir)	8.66×10^{-6}	8.7×10^{-6}
Platinum	—	8.9×10^{-6}
Iridium	—	6.5×10^{-6}
Iron alloys		
Nickel steel (10% Ni/90%Fe)	11.8×10^{-6}	13×10^{-6}
Nickel steel(36% Ni/64%Fe)	12.1×10^{-6}	0–1.5 $\times 10^{-6}$
Nickel steel(43% Ni/57%Fe)	12.2×10^{-6}	7.9×10^{-6}
Nickel steel(58% Ni/42%Fe)	12.3×10^{-6}	11.4×10^{-6}
Stainless steel (74%Fe/18% Cr/8%Ni)	10.9×10^{-6}	29×10^{-6}
Iron	—	11.7×10^{-6}
Nickel	—	12.8×10^{-6}
Chromium	—	7×10^{-6}

Table 7.9 The speed of sound in solids at 20 °C showing c_L, the speed of longitudinal waves, and c_T, the speed of transverse (shear waves).

	Speed of sound	
Elemental metals	**c_L(ms^{-1})**	**c_T(ms^{-1})**
Aluminium, Al	6374	3111
Beryllium, Be	12890	8880
Cadmium, Cd	2780	—
Chromium, Cr	6608	4005
Copper, Cu	4759	2325
Gold, Au	3240	1200
Iron, Fe	5957	3224
Lead, Pb	2160	700
Magnesium, Mg	5823	3163
Manganese, Mn	4600	—
Molybdenum, Mo	6475	3505
Nickel, Ni	5700	3000
Niobium, Nb	5068	2092
Platinum, Pt	3260	1730
Silver, Ag	3704	1698
Tantalum, Ta	4159	2036
Tin, Sn	3380	1594
Titanium, Ti	6130	3182
Tungsten, W	5221	2887
Uranium, U	3370	1940
Vanadium, V	6023	2774
Zinc, Zn	4187	2421
Zirconium, Zr	4650	2250
Insulators	**c_L(ms^{-1})**	**c_T(ms^{-1})**
Carbon (diamond)	18350	9200
Glass (crown)	5660	3420
Glass (heavy flint)	5260	2960
Glass (pyrex)	5640	3280
Quartz crystal X-cut	5720	—
Quartz fused	5970	3765
Concrete	4250–5250	—
Ice (-20°C)	≈3840	—
Plastics	**c_L(ms^{-1})**	**c_T(ms^{-1})**
Polyethylene	2000	3111
Polystyrene	2350	1120
PVC	2300	—
Rubber	1600	4005

Table 7.10 The molar heat capacity at constant pressure C_P of the elements at room temperature 25 °C (298.15K). The shaded data are elements that are either liquids or gases at this temperature.

Z	Element	A	ρ (kg m^{-3})	C_P (J K mol^{-1})	Z	Element	A	ρ (kg m^{-3})	C_P (J K mol^{-1})
1	Hydrogen, H	1.008	89	28.824	49	Indium, In	114.8	7290	26.74
2	Helium, He	4.003	120	20.786	50	Tin, Sn	118.7	7285	26.99
3	Lithium , Li	6.941	533	24.770	51	Antimony, Sb	121.7	6692	25.23
4	Beryllium, Be	9.012	1846	16.44	52	Tellurium, Te	127.6	6247	25.73
5	Boron, B	10.81	2466	11.09	53	Iodine, I	126.9	4953	54.438
6	Carbon (graphite), C	12.01	2266	8.53	54	Xenon, Xe	131.3	3560	20.786
6	Carbon (diamond), C	12.01	3513	6.11	55	Caesium, Cs	132.9	1900	32.17
7	Nitrogen, N	14.01	1035	29.125	56	Barium, Ba	137.3	3594	28.07
8	Oxygen, O	16.00	1460	29.355	57	Lanthanum, La	138.9	6174	27.11
9	Fluorine, F	19.00	1140	31.300	58	Cerium, Ce	140.1	6711	26.94
10	Neon, Ne	20.18	1442	20.786	59	Praseodymium, Pr	140.9	6779	27.20
11	Sodium, Na	22.99	966	28.24	60	Neodymium, Ne	144.2	7000	27.45
12	Magnesium, Mg	24.31	1738	24.89	61	Promethium, Pm	145.0	7220	26.81
13	Aluminium, Al	26.98	2698	24.35	62	Samarium, Sm	150.4	7536	29.54
14	Silicon, Si	28.09	2329	20.0	63	Europium, Eu	152.0	5248	27.66
15	Phosphorus, P	30.97	1820	23.84	64	Gadolinium, Gd	157.2	7870	37.03
16	Sulphur, S	32.06	2086	22.64	65	Terbium, Tb	158.9	8267	28.91
17	Chlorine, Cl	35.45	2030	33.907	66	Dysprosium, Dy	162.5	8531	28.16
18	Argon, Ar	39.95	1656	20.786	67	Holmium, Ho	164.9	8797	27.15
19	Potassium, K	39.10	862	29.58	68	Erbium, Er	167.3	9044	28.12
20	Calcium, Ca	40.08	1530	25.31	69	Thulium, Th	168.9	9325	27.03
21	Scandium, Sc	44.96	2992	25.52	70	Ytterbium, Yb	173.0	6966	26.74
22	Titanium, Ti	47.90	4508	25.02	71	Lutetium, Lu	175.0	9842	26.86
23	Vanadium, V	50.94	6090	24.89	72	Hafnium, Hf	178.5	13276	25.73
24	Chromium, Cr	52.00	7194	23.35	73	Tantalum, Ta	180.9	16670	25.36
25	Manganese, Mn	54.94	7473	26.32	74	Tungsten, W	183.9	19254	24.27
26	Iron, Fe	55.85	7873	25.10	75	Rhenium, Re	186.2	21023	25.48
27	Cobalt, Co	58.93	8800	24.81	76	Osmium, Os	190.2	22580	24.70
28	Nickel, Ni	58.70	8907	26.07	77	Iridium, Ir	192.2	22550	25.10
29	Copper, Cu	63.55	8933	24.44	78	Platinum, Pt	195.1	21450	25.86
30	Zinc, Zn	65.38	7135	25.40	79	Gold, Au	197.0	19281	25.42
31	Gallium, Ga	69.72	5905	25.86	80	Mercury, Hg	200.6	13546	27.98
32	Germanium, Ge	72.59	5323	23.35	81	Thallium, Th	204.4	11871	26.32
33	Arsenic, As	74.92	5776	24.64	82	Lead, Pb	207.2	11343	26.44
34	Selenium, Se	78.96	4808	25.36	83	Bismuth, Bi	209.0	9803	25.52
35	Bromine, Br	79.90	3120	75.69	84	Polonium, Po	209	9400	25.75
36	Krypton, Kr	83.80	3000	20.79	85	Astatine, At	210		
37	Rubidium, Rb	85.47	1533	31.06	86	Radon, Rn	222	4400	20.786
38	Strontium, Sr	87.62	2583	26.40	87	Francium, Fr	223	2410	31.70
39	Yttrium, Y	88.91	4475	26.53	88	Radium, Ra	226	5000	25.76
40	Zirconium, Zr	91.22	6507	25.36	89	Actinium, Ac	227	10060	27.20
41	Niobium, Nb	92.91	8578	24.60	90	Thorium, Th	232	11725	27.32
42	Molybdenum, Mo	95.94	10222	24.06	91	Protractinium, Pa	231	15370	27.20
43	Technetium, Tc	97	11496	25.88	92	Uranium, U	238	19050	27.66
44	Ruthenium, Ru	101.1	12360	24.06	93	Neptunium, Np	237	20250	29.62
45	Rhodium, Rh	102.9	12420	24.98	94	Plutonium, Pu	244	19840	32.80
46	Palladium, Pd	106.4	11995	25.98	95	Americium, Am	243	13670	25.86
47	Silver, Ag	107.9	10500	25.35	96	Curium, Cm	247	1330	27.70
48	Cadmium, Cd	112.4	8647	25.98					

Table 7.11 The predicted value of the heat capacity of monatomic solids according to the Debye theory. Also tabulated is the fraction of the high temperature limiting value ($3R$) expected at the temperature indicated.

T/Θ_D	$C(T)$ J K^{-1} mol^{-1}	$C(T)/R$
0	0	0
0.01	1.944×10^{-3}	7.7927×10^{-5}
0.02	1.555×10^{-2}	6.2342×10^{-4}
0.03	5.248×10^{-2}	2.1040×10^{-3}
0.04	0.1244	4.9873×10^{-3}
0.05	0.2430	9.7408×10^{-3}
0.06	0.4198	1.6829×10^{-2}
0.07	0.6658	2.6693×10^{-2}
0.08	0.9903	3.9702×10^{-2}
0.09	1.399	5.6074×10^{-2}
0.1	1.891	7.5821×10^{-2}
0.2	9.195	0.36863
0.3	15.158	0.60770
0.4	18.604	0.74585
0.5	20.588	0.82541
0.6	21.795	0.87380
0.7	22.572	0.90495
0.8	23.098	0.92603
0.9	23.469	0.94089
1.0	23.739	0.95173
1.1	23.942	0.95987
1.2	24.098	0.96612
1.3	24.221	0.97103
1.4	24.318	0.97495
1.5	24.398	0.97813
1.6	24.463	0.98074
1.7	24.517	0.98291
1.8	24.562	0.98474
1.9	24.601	0.98629
2.0	24.634	0.98761

Table 7.12 The Debye temperatures θ_D of several elements as determined by analysis of the T^3 behaviour of their low-temperature heat capacity (Equation 7.61).

Element	Z	Θ_D (K)	Element	Z	Θ_D (K)
Beryllium	4	1440	Zirconium	40	291
C(Diamond)	6	2230	Molybdenum	42	450
Magnesium	12	400	Silver	47	225
Aluminium	13	428	Cadmium	48	209
Titanium	22	420	Tin	50	200
Vanadium	23	380	Tantalum	73	240
Chromium	24	630	Tungsten	74	400
Manganese	25	410	Platinum	78	240
Iron	26	470	Gold	79	165
Nickel	28	450	Lead	82	105
Copper	29	343	Uranium	92	207

Table 7.13 The electrical resistivity of the elements which are solid at around room temperature. Take care with the exponents of values in this table which vary from entry to entry and column to column by 46 orders of magnitude.

Z	Element	ρ(Ω m)	σ(S m^{-1})	Z	Element	ρ(Ω m)	σ(S m^{-1})
1	Hydrogen, H	—	—	49	Indium, In	8.37×10^{-8}	1.19×10^{7}
2	Helium, He	—	—	50	Tin, Sn	1.1×10^{-7}	9.1×10^{6}
3	Lithium , Li	8.55×10^{-8}	1.17×10^{7}	51	Antimony, Sb	3.9×10^{-7}	2.56×10^{6}
4	Beryllium, Be	4×10^{-8}	2.5×10^{7}	52	Tellurium, Te	0.00436	229
5	Boron, B	18000	5.56×10^{5}	53	Iodine, I	1.37×10^{-7}	7.30×10^{8}
6	Carbon (diamond), C	10^{11}	10^{-11}	54	Xenon, Xe	—	—
7	Nitrogen, N	—	—	55	Caesium, Cs	2×10^{-7}	5×10^{6}
8	Oxygen, O	—	—	56	Barium, Ba	5×10^{-7}	2×10^{6}
9	Fluorine, F	—	—	57	Lanthanum, La	5.7×10^{-7}	1.75×10^{6}
10	Neon, Ne	—	—	58	Cerium, Ce	7.3×10^{-7}	1.37×10^{6}
11	Sodium, Na	4.2×10^{-8}	2.38×10^{7}	59	Praseodymium, Pr	6.8×10^{-7}	1.47×10^{6}
12	Magnesium, Mg	4.38×10^{-8}	2.28×10^{7}	60	Neodymium, Ne	6.4×10^{-7}	1.56×10^{6}
13	Aluminium, Al	2.66×10^{-8}	3.77×10^{7}	61	Promethium, Pm	5×10^{-7}	2×10^{6}
14	Silicon, Si	0.001	1000	62	Samarium, Sm	9.4×10^{-7}	1.06×10^{6}
15	Phosphorus, P	1×10^{-9}	1×10^{9}	63	Europium, Eu	9×10^{-7}	1.11×10^{6}
16	Sulphur, S	2×10^{15}	5×10^{-16}	64	Gadolinium, Gd	1.34×10^{-6}	7.46×10^{5}
17	Chlorine, Cl	—	—	65	Terbium, Tb	1.14×10^{-6}	8.77×10^{5}
18	Argon, Ar	—	—	66	Dysprosium, Dy	5.7×10^{-7}	1.75×10^{6}
19	Potassium, K	6.15×10^{-8}	1.63×10^{7}	67	Holmium, Ho	8.7×10^{-7}	1.15×10^{6}
20	Calcium, Ca	3.43×10^{-8}	2.92×10^{7}	68	Erbium, Er	8.7×10^{-7}	1.15×10^{6}
21	Scandium, Sc	6.1×10^{-7}	1.64×10^{6}	69	Thulium, Th	7.9×10^{-7}	1.27×10^{6}
22	Titanium, Ti	4.2×10^{-7}	2.38×10^{6}	70	Ytterbium, Yb	2.9×10^{-7}	3.45×10^{6}
23	Vanadium, V	2.48×10^{-7}	4.03×10^{6}	71	Lutetium, Lu	7.9×10^{-7}	1.27×10^{6}
24	Chromium, Cr	1.27×10^{-7}	7.87×10^{6}	72	Hafnium, Hf	3.51×10^{-7}	2.85×10^{6}
25	Manganese, Mn	1.85×10^{-6}	5.41×10^{5}	73	Tantalum, Ta	1.25×10^{-7}	8.03×10^{6}
26	Iron, Fe	9.71×10^{-8}	1.03×10^{7}	74	Tungsten, W	5.65×10^{-8}	1.77×10^{7}
27	Cobalt, Co	6.24×10^{-8}	1.60×10^{7}	75	Rhenium, Re	1.93×10^{-7}	5.18×10^{6}
28	Nickel, Ni	6.84×10^{-8}	1.46×10^{7}	76	Osmium, Os	8.12×10^{-8}	1.23×10^{7}
29	Copper, Cu	1.67×10^{-8}	5.98×10^{7}	77	Iridium, Ir	5.3×10^{-8}	1.89×10^{7}
30	Zinc, Zn	5.92×10^{-8}	1.69×10^{7}	78	Platinum, Pt	1.06×10^{-7}	9.43×10^{6}
31	Gallium, Ga	2.7×10^{-7}	3.70×10^{6}	79	Gold, Au	2.35×10^{-8}	4.26×10^{7}
32	Germanium, Ge	0.46	2.1739	80	Mercury, Hg	9.41×10^{-7}	1.06×10^{6}
33	Arsenic, As	2.6×10^{-7}	3.85×10^{6}	81	Thallium, Th	1.8×10^{-7}	5.56×10^{6}
34	Selenium, Se	0.01	100	82	Lead, Pb	2.07×10^{-7}	4.84×10^{6}
35	Bromine, Br	—	—	83	Bismuth, Bi	1.068×10^{-6}	9.36×10^{5}
36	Krypton, Kr	—	—	84	Polonium, Po	1.4×10^{-6}	7.14×10^{5}
37	Rubidium, Rb	1.25×10^{-7}	8×10^{6}	85	Astatine, At	—	—
38	Strontium, Sr	2.3×10^{-7}	4.35×10^{6}	86	Radon, Rn	—	—
39	Yttrium, Y	5.7×10^{-7}	1.75×10^{6}	87	Francium, Fr	_	_
40	Zirconium, Zr	4.21×10^{-7}	2.37×10^{6}	88	Radium, Ra	1×10^{-6}	1×10^{6}
41	Niobium, Nb	1.25×10^{-7}	8×10^{6}	89	Actinium, Ac	_	_
42	Molybdenum, Mo	5.2×10^{-8}	1.92×10^{7}	90	Thorium, Th	1.3×10^{-7}	7.69×10^{6}
43	Technetium, Tc	2.26×10^{-7}	4.42×10^{6}	91	Protractinium, Pa	1.77×10^{-7}	5.65×10^{6}
44	Ruthenium, Ru	7.6×10^{-8}	1.32×10^{7}	92	Uranium, U	3.08×10^{-7}	3.25×10^{6}
45	Rhodium, Rh	4.51×10^{-8}	2.22×10^{7}	93	Neptunium, Np	1.22×10^{-6}	8.20×10^{5}
46	Palladium, Pd	1.08×10^{-7}	9.26×10^{6}	94	Plutonium, Pu	1.46×10^{-6}	6.85×10^{5}
47	Silver, Ag	1.59×10^{-8}	6.29×10^{7}	95	Americium, Am	6.8×10^{-7}	1.4706×10^{6}
48	Cadmium, Cd	6.83×10^{-8}	1.46×10^{7}				

Table 7.14 The resistivities (Ω m) of three alloys at around room temperature is shown in centre of the three tables below. On either side of the data for the alloy, are the resistivities of the component elements.

Component 1	Alloy	Component 2
Cu	**Cu(Zn)**	**Zn**
1.55×10^{-8}	6.3×10^{-8}	5.5×10^{-8}
Pt	**Pt(10% Ir)**	**Ir**
9.81×10^{-8}	24.8×10^{-8}	4.7×10^{-8}
Pt	**Pt(10% Rh)**	**Rh**
9.81×10^{-8}	18.7×10^{-8}	4.3×10^{-8}

Table 7.15 Examples of substances which display superconducting behaviour below the temperature shown.

Substance	Alloy
Low-temperature superconductors: elements	
Aluminium	1.75
Lead	7.2
Niobium	9.25
Tin	3.72
Vanadium	5.4
Low-temperature superconductors: alloys	
V_3Si	17.1
Nb_3Sn	18.3
MgB_2	39
High-temperature superconductors	
$YBa_2Cu_3O_{7-\delta}$	93
$Hg_1Ba_2Ca_2Cu_3O_{10}$	133

Table 7.16 The relative dielectric permittivity ε of various insulators (and semiconductors) The relative permittivity of vacuum is exactly 1. All measurements refer to 20°C, but are insensitive to small changes ≈ ±10°C around this temperature.

Substance		ε
Elements		
Silicon	Si	11.9
Germanium	Ge	16.0
Ceramics		
Alumina	Al_2O_3	8.5
Strontium titanate	$SrTiO_3$	200
Strontium zirconate	$SrZrO_3$	38
Glass		
Quartz	SiO_2	4.5
Borosilicate glass	SiO_2 with BO	4 – 5
Lead glass	SiO_2 with PbO	7
Plastics		
Polyethylene		2.3
Polystyrene		2.6
Polytetrafluoroethylene	PTFE	2.1
Polyamide	Nylon	3 – 4

Table 7.17 Typical orders of magnitude of the resistivity of some insulating substances at around room temperature. The data correspond to values of ρ determined one minute after the electric field is applied.

Insulator	ρ (Ω m)	Insulator	ρ (Ω m)
Alumina Al_2O_3	$10^9 – 10^{12}$	Paper	$\approx 10^{10}$
QuartzSiO_2	$\approx 10^{16}$	PTFE	$10^{15} – 10^{19}$
Diamond C	$10^{10} – 10^{11}$	Polystyrene	10^{15} - 10^{19}
Boron B	$10^{10} – 10^{11}$	Varnish	10^7
Iodine I_2	10^{13}	Soil	$10^2 – 10^4$
Glass	$10^9 – 10^{12}$	Distilled water	$10^2 – 10^5$

Table 7.18 Typical values (and ranges of values) of the dielectric strength of some insulating substances.

Insulator	Vm^{-1}
Alumina, Al_2O_3	$10 – 35 \times 10^6$
Sapphire, Al_2O_3	17×10^6
Quartz, SiO_2	$25 – 40 \times 10^6$
Beryllia	$10 – 14 \times 10^6$

Table 7.19 Thermal conductivity κ of solid elements (W K^{-1} m^{-1}) as a function of absolute temperature. The shaded entries refer to data above the melting temperature of the element. The labels M, I and SC stand for metal, insulator and semiconductor respectively. The two results for phosphorus at 173.2 K correspond to different crystal structures known as 'black' and 'yellow' phosphorus respectively.

Element and type of material		Temperature (K) 73.2 K	173.2 K	273.2 K	373.2 K	1273 K
Lithium, Li	M	94	86	82	47	59
Beryllium, Be	M	367	218	168	129	93
Boron, B	I	72	32	19	11	10
Carbon (Graphite), C	I	70–220	80–230	75–195	50–130	35–70
Carbon (Diamond), C	I	1700–4900	1000–2600	700–1700	—	—
Sodium, Na	M	141	142	88	78	60
Magnesium, Mg	M	160	157	154	150	—
Aluminium, Al	M	241	236	240	233	92
Silicon, Si	SC	330	168	108	65	32
Phosphorous, P	I	20	13/0.25	0.18	0.16	—
Sulphur, S	I	0.39	0.29	0.15	0.17	—
Potassium, K	M	105	104	53	45	32
Scandium, Sc	M	15	16			
Titanium, Ti	M	26	22	21	19	21
Vanadium, V	M	32	31	31	33	38
Chromium, Cr	M	120	96.5	92	82	66
Manganese, Mn	M	7	8	—	—	—
Iron, Fe	M	99	83.5	72	56	34
Cobalt, Co	M	130	105	89	69	53
Nickel, Ni	M	113	94	83	67	71
Copper, Cu	M	420	403	395	381	354
Zinc, Zn	M	117	117	112	104	66
Gallium, Ga	M	43	41	33	45	—
Germanium, Ge	SC	113	67	46.5	29	17.5
Selenium (*c*-axis), Se	I	6.8	4.8	4.8	—	—
Rubidium, Rb	M	59	58	32	29	22
Yttrium, Y	M	16.5	17	—	—	—
Zirconium, Zr	M	26	23	22	21	23
Niobium, Nb	M	53	53	55	58	64
Molybdenum, Mo	M	145	139	135	127	113
Technetium, Tc	M	—	51	50	50	—
Ruthenium, Ru	M	123	117	115	108	98
Rhodium, Rh	M	156	151	147	137	—
Palladium, Pd	M	72	72	73	79	93
Silver, Ag	M	432	428	422	407	377
Cadmium, Cd	M	100	97	95	89	445
Indium, In	M	92	84	76	42	—
Tin, Sn	M	76	68	63	32	40
Antimony, Sb	M	33	25.5	22	19	27
Tellurium(*c*-axis), Te	I	5.1	3.6	2.9	2.4	6.3

Table 7.20 Thermal conductivity of a variety materials ($WK^{-1}\ m^{-1}$). The tables refer to metallic alloys, refractory materials, i.e. those suitable for use in high temperatures without degradation, and a selection of everyday materials.

	173.2K	273.2K	373.2K	573.2K	873.2K	973.2K	1473.2K
Brass (Cu70%,Zn30%)	89	106	128	146	—	—	—
Bronze (Cu90%,Sn10%)	—	53	60	80	—	—	—
Carbon steel	48	50	48.5	54.5	—	30.5	—
Silicon steel	—	25	28.5	31	—	28	—
Stainless steel	—	24.5	25	25.5	—	24.8	—
Alumina (Al_2O_3)	—	40	28	—	9.2	—	5.7
Beryllia (BeO)	—	300	213	—	61	—	22
Fire brick	—	—	—	—	1.1	—	1.3
Silica (SiO_2) fused quartz	—	1.33	1.48	—	2.4	—	—
Zirconia (ZrO_2)	—	—	1.8	—	2.0	—	2.2

Substance	κ ($WK^{-1}\ m^{-1}$)	Substance	κ ($WK^{-1}\ m^{-1}$)	Substance	κ ($WK^{-1}\ m^{-1}$)
Brick wall	≈1	Porcelain	1.5	Glass wool	0.037
Plaster	≈0.13	Rubber	≈0.2	Cotton wool	0.03
Timber	≈ 0.15	Polystyrene	≈0.1	Sheep's wool	0.05
Balsa wood	≈0.06	Glass (crown)	1.1	Nylon	0.25
Paper	0.06	Glass (flint)	0.85	Epoxy resins	≈0.2
Cardboard	0.21	Glass (pyrex)	1.1	Cellular polystyrene	≈0.04

Table 7.21 Summary of our predictions for the temperature dependence of the thermal conductivity of phonon and electron gases at high and low temperatures.

	Low temperature	**High temperature**
Phonon gas	KT^3	$1/T$
Electron gas	T	constant

Table 7.22 The reflectivity of polished surfaces of several metals. The figures represent averages across the optical spectrum.

	Reflectivity (%)
Steel	58
Aluminium	92
Silver	98
Copper	67
Gold	81