

Introduction

In order to facilitate the use of this compilation some short remarks on the selection of the data and their presentation should be made in advance.

The phase equilibria are summarized in diagrams in which the temperature T of a phase transformation is plotted against the concentration of the alloy in atomic percent (at%). At the upper rim of the phase diagrams, for reasons of greater usefulness, a concentration scale in weight percent (wt%) is added. The conversion from at% into wt% or, vice versa, from wt% into at%, can be performed by using the following relationships:

$$(\text{wt}\% \text{ A}) = \frac{100(\text{at}\% \text{ A})a}{(\text{at}\% \text{ A})a + (100 - (\text{at}\% \text{ A}))b}$$

$$(\text{at}\% \text{ A}) = \frac{100(\text{wt}\% \text{ A})}{(\text{wt}\% \text{ A}) + \frac{a}{b}(100 - (\text{wt}\% \text{ A}))}$$

a = atomic weight of the component A, b = atomic weight of the component B.

All temperatures are given in Kelvin (K).

For the element 41, the name of niobium (Nb) is used.

Just as in many hitherto existing compilatory works it has been avoided to present single measured points. On the contrary, phase equilibria are represented by the construction of continuous lines. Phase equilibria not experimentally ascertained are indicated by dashed lines or dashed-dotted lines.

It has been attempted to characterize intermetallic phases by their stoichiometry. Only in cases where this seems to make no sense, e.g. due to the existence of extended ranges of homogeneity, Greek letters are used. Solid solutions are indicated by parentheses, i.e., solid solutions of the components by (A) or (B), or of intermediate phases by, for instance, (A_2B_3) . In order to explain the phase equilibria, the singular phases which are taking part in an equilibrium are given; if necessary, also two-phase regions are designated accordingly. In any case, the designation has been done in such a manner as it is necessary for the understanding of the phase equilibria.

Different modifications of a component or an intermediate phase are marked by Greek letters in such a way that the modification existing at a lower temperature is designated by α (e.g. α -U) and the following modifications at increasing temperatures are designated by β , γ , etc. (e.g. β -U, γ -U). If, however, in particular cases in the literature, the differentiation between a low temperature and a high temperature modification is familiar under the designation l (low temperature), or, respectively, h (high temperature; in the case of more than one high-temperature modification: h_1 , h_2 , ..., in rising order with increasing temperature, as is the case, e.g. for $\text{Pb}_3\text{Pd}_5(\text{l})$, $\text{Pb}_3\text{Pd}_5(h_1)$, $\text{Pb}_3\text{Pd}_5(h_2)$), this manner of differentiation is maintained.

For the presentation of phase equilibria at high pressures, the temperatures of the phase transformations are plotted versus the pressure in pascal (Pa) at constant alloy concentrations.

There is:

$$\begin{aligned} 1 \text{ physical atmosphere} &= 1 \text{ atm} = 769 \text{ Torr} = 101.325 \text{ kPa} \\ 1 \text{ technical atmosphere} &= 1 \text{ at} = 1 \text{ kp cm}^{-2} = 98.0665 \text{ kPa} \end{aligned}$$

For some systems the phase equilibria have not been investigated as yet due to too high a necessary experimental expenditure.

From experimental thermodynamic data, or, in part, on the basis of estimated or interpolated values, calculated or qualitative phase equilibria have been postulated in some cases. Also hypothetical phase diagrams have been taken into account as far as experimental data are missing.

As to the atomic structure of alloys, as a rule, the crystal structure, the respective structural type as well as the lattice constants (in nm), are reported for intermetallic phases. Data given in the

literature in kX-units have been converted into nm, by multiplication with the factor 0.100202. If, for solid solution regions (at the boundaries of the systems or, also, for intermetallic phases) the lattice constants are present in the literature as functions of either temperature or concentration, they are also depicted in respective diagrams in order to permit a quick orientation for the reader.

Metastable phases have been taken into account in the compilation of the structural data as well as in the presentation of the phase equilibria. In doing so, indications of the existence of noncrystalline, amorphous (glassy) solid phases are given. Furthermore, as far as present, short-range ordering phenomena in alloy melts are hinted at.

On compiling the thermodynamic properties of binary alloys, such data have been taken into account on the base of which it is easily possible to determine all the other important state functions. These are the integral enthalpy of formation, the integral entropy of formation (or the excess entropy) and the thermodynamic activities of the components; all these quantities are given for the solid and the liquid states, respectively, as far as they are accessible. In some cases in the literature other analogous thermodynamic data are presented, which only have been included in this compilation if the previously named ones are not immediately accessible.

The thermodynamic functions of state are related, in original works, either to 1 g-atom (N_A atoms; $N_A = \text{Avogadro's number} = 6.022 \cdot 10^{23}$) or to 1 mol (N_A molecules of an intermetallic phase, e.g. A_2B_3). In some cases, "per mol" is written, whilst "per g-atom" is meant. In cases where it is clearly understood what really is meant, the data (if necessary, after conversion) as related to g-atom are preferred. For liquid alloys as well as in solid solution regions, this is, of course, the only reasonable unit. In all of the other cases the data have been taken directly from the original work.

In general, the experimental method used for the determination of the data in consideration is reported. Furthermore, the possibly different reliability of the results stemming from different sources is mentioned.

Thermodynamic functions and notation used

The integral molar Gibbs free energy, enthalpy and entropy of mixing for liquid binary alloys or of formation for solid binary alloys A–B are related by the Helmholtz-Gibbs-equation:

$$\Delta G = \Delta H - T\Delta S$$

For an ideal solution there is $\Delta H^{\text{ideal}} = 0$ and the entropy of mixing (formation) is given, due to the random distribution of the species, by:

$$\Delta S^{\text{ideal}} = -R(x_A \ln x_A + x_B \ln x_B)$$

and thus

$$\Delta G^{\text{ideal}} = RT(x_A \ln x_A + x_B \ln x_B)$$

Often instead of the real thermodynamic functions (ΔG , ΔS) the difference between the real and the ideal function is expressed. These excess functions are:

$$\Delta G^{\text{ex}} = \Delta G - RT(x_A \ln x_A + x_B \ln x_B)$$

$$\Delta S^{\text{ex}} = \Delta S + R(x_A \ln x_A + x_B \ln x_B)$$

Obviously $\Delta H^{\text{ex}} \equiv \Delta H$.

x_A and x_B are the atomic fractions (sometimes also called mole fractions) of the components:

$$x_A + x_B = 1$$

for binary alloys.

The partial molar functions of the components are related to the integral ones:

$$\Delta G = x_A \overline{\Delta G}_A + x_B \overline{\Delta G}_B$$

$$\Delta S = x_A \overline{\Delta S}_A + x_B \overline{\Delta S}_B$$

$$\Delta H = x_A \overline{\Delta H}_A + x_B \overline{\Delta H}_B$$

The same is valid for the excess functions:

$$\Delta G^{\text{ex}} = x_A \overline{\Delta G}_A^{\text{ex}} + x_B \overline{\Delta G}_B^{\text{ex}}$$

$$\Delta S^{\text{ex}} = x_A \overline{\Delta S}_A^{\text{ex}} + x_B \overline{\Delta S}_B^{\text{ex}}$$

$$\Delta H^{\text{ex}} = \Delta H = x_A \overline{\Delta H}_A + x_B \overline{\Delta H}_B$$

The thermodynamic activities of the components are related to the partial Gibbs free energies by:

$$\overline{\Delta G}_A = RT \ln a_A$$

$$\overline{\Delta G}_B = RT \ln a_B$$

For an ideal solution there is

$$a_A = x_A; \quad a_B = x_B \quad (\text{Raoult's law}).$$

The partial enthalpy of mixing (formation), e.g. for the component A, is correlated with the activity:

$$\overline{\Delta H}_A = R \frac{\delta \ln a_A}{\delta(1/T)}$$

The activity coefficient is given by:

$$\gamma_A = \frac{a_A}{x_A}$$

The activities of both components are related to each other by the Duhem-Margules equation:

$$\ln \gamma_A = - \int_{\ln y_B(x_B=0)}^{\ln y_B(x_B)} \frac{x_B}{x_A} d \ln \gamma_B$$

Superscripts L or S have been used in this compilation to indicate whether the thermodynamic functions under consideration refer to the liquid or solid state of the alloy, respectively.

Some physical properties of the elements

Atomic weights are from the compilation published in the "Bulletin of Alloy Phase Diagrams" (1989)¹⁾. The atomic weight is taken as atomic mass unit relative to $^{12}\text{C} = 12$. The values are depending on the origin of the element; natural and artificial differences in isotopic composition (due to separation of isotopes) are possible in available material.

Density values are taken from the "Periodic Table of the Elements" published by Sargent-Welch Scientific Company (1979)²⁾.

Melting points of elements (identical with freezing points) have been compiled in the "Bulletin of Alloy Phase Diagrams" (1981)³⁾. From there the values were taken. They are valid for a pressure of 1 atm = 101.3250 kPa. See in some cases: (t.p.) = triple point; (s.p.) = sublimation point at a pressure of 1 atm.

Boiling points were taken from the "JANAF Thermochemical Tables" (1986)⁴⁾ or from the "Periodic Table of the Elements"²⁾.

Symbol	Element	Atomic number	Atomic weight	Density at 300 K [g cm ⁻³]	Melting point [K]	Boiling point [K]
Ac	Actinium	89	227.0278	10.07	1324(50)	3473
Ag	Silver	47	107.8682	10.50	1235.08	2436
Al	Aluminum	13	26.981539	2.70	933.602	2790
Am	Americium	95	243.0614	13.60	1449	2880
Ar	Argon	18	39.948		83.798 (t.p.)	87.30
As	Arsenic	33	74.92159	5.72	1081 at 28 atm	876 (s.p.)
At	Astatine	85	209.9871		575 estimated	
Au	Gold	79	196.96654	19.30	1337.58	3130
B	Boron	5	10.810	2.46	2365	4138
				(α -B)		
Ba	Barium	56	137.327	3.50	1002(2)	2118
Be	Beryllium	4	9.012182	1.85	1562(5)	2741
Bi	Bismuth	83	208.98037	9.80	544.592	1837
Bk	Berkelium	97	247.0703		1256	
Br	Bromine	35	79.904		265.90 (t.p.)	332.3
C	Carbon (graphite)	6	12.011	2.62		4100 (s.p.)
Ca	Calcium	20	40.078	1.55	1113(2)	1773
Cd	Cadmium	48	112.411	8.65	594.258	1040
Ce	Cerium	58	140.115	6.78	1071(3)	3699
Cf	Californium	98	251.0796		1213	
Cl	Chlorine	17	35.4527		172.18 (t.p.)	239.1
Cm	Curium	96	247.0703		1613	
Co	Cobalt	27	58.93320	8.90	1768	3184
Cr	Chromium	24	51.9961	7.19	2133(20)	2952
Cs	Cesium	55	132.90543	1.87	301.54(5)	947

¹⁾ King, H.W.: Bull. Alloy Phase Diagrams **10** (1989) 108

²⁾ "Periodic Table of the Elements", Skokie, Illinois: Sargent-Welch Scientific Company 1979

³⁾ King, H.W.: Bull. Alloy Phase Diagrams **2** (1981) 146

⁴⁾ Chase jr., M.W., Davies, C.A., Downey jr., J.R., Frurip, D.J., McDonald, R.A., Syverud, A.N.: "JANAF Thermochemical Tables", Third Edition, Am. Chem. Soc., Am. Inst. Phys., Natl. Bur. Stand. 1986

Symbol	Element	Atomic number	Atomic weight	Density at 300 K [g cm ⁻³]	Melting point [K]	Boiling point [K]
Cu	Copper	29	63.546	8.96	1358.02(4)	2843
Dy	Dysprosium	66	162.50	8.54	1685	2835
Er	Erbium	68	167.26	9.05	1802	3136
Es	Einsteinium	99	252.083		1093	
Eu	Europium	63	151.965	5.26	1095	1870
F	Fluorine	9	18.9984032		53.48 (t.p.)	84.95
Fe	Iron	26	55.847	7.86	1808	3139
Fm	Fermium	100	257.0951		1800 estimated	
Fr	Francium	87	223.0197		300 estimated	950
Ga	Gallium	31	69.723	5.91	302.9241(10) (t.p.)	2478
Gd	Gadolinium	64	157.25	7.89	1586	3569
Ge	Germanium	32	72.61	5.32	1211.5	3107
H	Hydrogen	1	1.00794		13.81 (t.p.)	20.30
He	Helium	2	4.002602		0.95	4.215
Hf	Hafnium	72	178.49	13.10	2504(20)	4963
Hg	Mercury	80	200.59	13.53	234.314	629
Ho	Holmium	67	164.93032	8.80	1747	2968
I	Iodine	53	126.90447	4.92	386.7 (t.p.)	458.4
In	Indium	49	114.82	7.31	429.784	2346
Ir	Iridium	77	192.22	22.50	2720	4701
K	Potassium	19	39.0983	0.86	336.34(50)	1040
Kr	Krypton	36	83.80		115.765(1)	119.80
La	Lanthanum	57	138.9055	6.70	1191	3730
Li	Lithium	3	6.941	0.53	453.7(5)	1620
Lr	Lawrencium	103	260.105		1900 estimated	
Lu	Lutetium	71	174.967	9.84	1936	3668
Md	Mendelevium	101	258.10		1100 estimated	
Mg	Magnesium	12	24.3050	1.74	922.0(5)	1366
Mn	Manganese	25	54.93805	7.43	1519(5)	2335
Mo	Molybdenum	42	95.94	10.20	2896	4952
N	Nitrogen	7	14.00674		63.1458(2) (t.p.)	77.35
Na	Sodium	11	22.989768	0.97	371.0(1)	1171
Nb	Niobium	41	92.90638	8.35	2742	5017
Nd	Neodymium	60	144.24	7.00	1294	3341
Ne	Neon	10	20.1797		24.563(2) (t.p.)	27.10
Ni	Nickel	28	58.69	8.90	1728	3157
No	Nobelium	102	259.1009		1100 estimated	
Np	Neptunium	93	237.0482	20.40	910(2)	
O	Oxygen	8	15.9994		54.361 (t.p.)	90.18
Os	Osmium	76	190.2	22.4	3306(20)	5285
P	Phosphorus (white, α -P) (red)	15	30.973762	1.82	317.29(10) 862.8 (t.p.)	550
Pa	Protactinium	91	231.03588	15.40	1848	
Pb	Lead	82	207.2	11.4	600.652	2019

Symbol	Element	Atomic number	Atomic weight	Density at 300 K [g cm ⁻³]	Melting point [K]	Boiling point [K]
Pd	Palladium	46	106.42	12.00	1828.0(4)	3237
Pm	Prometium	61	144.9127	6.48	1315	3785
Po	Polonium	84	208.9824	9.40	527	1335
Pr	Praseodymium	59	140.90765	6.77	1204	3785
Pt	Platinum	78	195.08	21.40	2042.1	4100
Pu	Plutonium	94	244.0642	19.80	913(1)	3503
Ra	Radium	88	226.0254		973	
Rb	Rubidium	37	85.4678	1.53	312.63(50)	970
Re	Rhenium	75	186.207	21.00	3459(20)	5869
Rh	Rhodium	45	102.90550	12.40	2236	3970
Rn	Radon	86	222.0716		202	211
Ru	Ruthenium	44	101.07	12.20	2607(10)	4423
S	Sulfur	16	32.066	2.07	388.37	882
Sb	Antimony	51	121.75	6.68	903.905	1860
Sc	Scandium	21	44.955910	3.00	1814	3104
Se	Selenium	34	78.96	4.80	494	958
Si	Silicon	14	28.0855	2.33	1687(2)	3505
Sm	Samarium	62	150.36	7.54	1347	2064
Sn	Tin	50	118.710	7.30	505.1181	2876
Sr	Strontium	38	87.62	2.60	1042	1685
Ta	Tantalum	73	180.9479	16.60	3293	5778
Tb	Terbium	65	158.92534	8.27	1629	3496
Tc	Technetium	43	97.9072	11.50	2477(50)	4538
Te	Tellurium	52	127.60	6.24	722.72(30)	1261
Th	Thorium	90	232.0381	11.70	2031(10)	5061
Ti	Titanium	22	47.88	4.50	1943(6)	3631
Tl	Thallium	81	204.3833	11.85	577(2)	1746
Tm	Thulium	69	168.93421	9.33	1818	2220
U	Uranium	92	238.0289	18.90	1407	4407
V	Vanadium	23	50.9415	5.80	2202(6)	3690
W	Tungsten	74	183.85	19.30	3695	5828
Xe	Xenon	54	131.29		161.3918(2) (t.p.)	165.03
Y	Yttrium	39	88.90585	4.50	1795	3611
Yb	Ytterbium	70	173.04	6.98	1092	1467
Zn	Zinc	30	65.39	7.14	692.73	1180
Zr	Zirconium	40	91.224	6.49	2128(5)	4203

Crystal structures of the elements

Structure and lattice parameters were taken from the compilation published by King¹⁾. The values are valid for 298 K, if not otherwise mentioned. For elements which can occur in different allotropic modifications at room temperature, the data for the most commonly observed modification was taken.

Element	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Remarks
Ac	cub	Cu	0.5311			
Ag	cub	Cu	0.40861			
Al	cub	Cu	0.40496			
α-Am	hex	La	0.3468		1.1241	
Ar	cub	Cu	0.5312			at 4.2 K
α-As	rhomb	As	0.41320 $\alpha = 54.12^\circ$			
Au	cub	Cu	0.40784			
γ-B	tetr		0.8756		0.5078	
Ba	cub	W	0.5023			
α-Be	hex	Mg	0.22857		0.35839	
α-Bi	rhomb	As	0.47460 $\alpha = 57.23^\circ$			
α-Bk	hex	La	0.3416		1.1069	
Br	orth		0.668	0.449	0.874	at 123 K
C (graphite)	hex		0.24612		0.67090	
α-Ca	cub	Cu	0.55884			
Cd	hex	Mg	0.29788		0.56167	
α-Ce	cub	Cu	0.51610			
Cl	orth		0.624	0.448	0.826	at 113 K
α-Cm	hex	La	0.3496		1.1331	
α-Co	hex	Mg	0.25071		0.40694	
Cr	cub	W	0.28847			
Cs	cub	W	0.6141			
Cu	cub	Cu	0.36149			
α-Dy	hex	Mg	0.35915		0.56501	
α-Er	hex	Mg	0.35592		0.55850	
Eu	cub	W	0.45827			
α-F	mon		0.550	0.328 $\beta = 102.17^\circ$	0.728	
α-Fe	cub	W	0.28665			
α-Ga	orth	Ga	0.45192	0.76586	0.45258	
α-Gd	hex	Mg	0.36336		0.57810	
α-Ge	cub	diamond	0.56574			
α-H	hex	Mg	0.3771		0.6156	at 4.2 K

¹⁾ King, H.W.: Bull. Alloy Phase Diagrams **2** (1981) 402

Element	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Remarks
α -He	hex	Mg	0.3577		0.5842	at 1.5 K
α -Hf	hex	Mg	0.31946		0.50511	
α -Hg	rhomb	Hg	0.3005 $\alpha = 70.53^\circ$			at 225 K
α -Ho	hex	Mg	0.35778		0.56178	
I	orth	Ga	0.7268	0.4797	0.9797	
In	tetr	In	0.45990		0.49470	
Ir	cub	Cu	0.38391			
K	cub	W	0.5321			
Kr	cub	Cu	0.56459			at 4.2 K
α -La	hex	La	0.37740		1.2171	
β -Li	cub	W	0.35093			
α -Lu	hex	Mg	0.35052		0.55494	
Mg	hex	Mg	0.32093		0.52107	
α -Mn	cub	α -Mn	0.89219			
Mo	cub	W	0.31470			
α -N	cub		0.5659			at 20 K
β -Na	cub	W	0.42096			
Nb	cub	W	0.33007			
α -Nd	hex	La	0.36582		1.17966	
Ne	cub	Cu	0.44622			at 4.2 K
Ni	cub	Cu	0.35241			
α -Np	orth		0.6663	0.4723	0.4887	
α -O	mon		0.5403	0.3429 $\beta = 132.53^\circ$	0.5086	at 23 K
Os	hex	Mg	0.27348		0.43913	
P (black)	orth		0.33136	1.0478	0.43763	
α -Pa	tetr	In	0.3945		0.3242	
Pb	cub	Cu	0.49502			
Pd	cub	Cu	0.38901			
Pm	hex		0.365		1.165	
α -Po	cub		0.3366			
α -Pr	hex	La	0.36721		1.18326	
Pt	cub	Cu	0.29233			
α -Pu	mon		0.6183	0.4822 $\beta = 101.78^\circ$	1.0968	
Ra	cub	W	0.5148			
Rb	cub	W	0.5703			
Re	hex	Mg	0.27608		0.44580	
Rh	cub	Cu	0.28032			
Ru	hex	Mg	0.27053		0.42814	
α -S	orth		1.0464	1.28660	2.44860	
α -Sb	rhomb	As	0.45065 $\alpha = 57.11^\circ$			
α -Sc	hex	Mg	0.33088		0.52680	
γ -Se	hex	Se	0.43655		0.49576	
Si	cub	diamond	0.54306			

Element	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Remarks
α -Sm	hex	Se	0.36290		2.6207	
β -Sn	tetr	Sn	0.58316		0.31815	
α -Sr	cub	Cu	0.6084			
Ta	cub	W	0.33031			
α -Tb	hex	Mg	0.36055		0.56966	
Tc	hex	Mg	0.2738		0.4394	
α -Te	hex	Se	0.44561		0.59271	
α -Th	cub	Cu	0.50851			
α -Ti	hex	Mg	0.29503		0.46836	
α -Tl	hex	Mg	0.34563		0.55263	
α -Tm	hex	Mg	0.35375		0.55540	
α -U	orth	U	0.28538	0.58680	0.49557	
V	cub	W	0.30238			
W	cub	W	0.31651			
Xe	cub	Cu	0.6132			at 4.2 K
α -Y	hex	Mg	0.36482		0.57318	
α -Yb	cub	Cu	0.54848			
Zn	hex	Mg	0.26644		0.49494	
α -Zr	hex	Mg	0.32317		0.51476	

Allotropic modifications of elements at normal pressure

The crystal structure, lattice parameters and the range of stability of the modifications in question were taken from the compilation published by King ¹⁾. Lattice constants at "room temperature" (RT) were given for 25°C = 298 K. Data for lower and higher temperatures are referred to the temperatures mentioned.

Modification	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Range of stability
α -Am	hex	La	0.3468		1.1241	RT
β -Am	fcc	Cu	0.4894			> 878 K
α -Ar	fcc	Cu	0.5312			< 83.8 K
β -Ar	hcp	Mg	0.3760		0.6141	> 83.8 K
α -As	rhomb	As	0.41320 $\alpha = 54.12^\circ$			RT
ϵ -As	orth	Ga	0.362	1.085	0.448	> 721 K
α -Be	hcp	Mg	0.22857		0.35839	RT
β -Be	bcc	W	0.25515			> 1523 K

¹⁾ King, H.W.: Bull. Alloy Phase Diagrams **3** (1982) 276

Modification	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Range of stability
α -Bk	hex	La	0.3416		1.1069	RT
β -Bk	fcc	Cu	0.4997			\approx RT
α -Ca	fcc	Cu	0.55884			RT
γ -Ca	bcc	W	0.4480			> 1010 K
α -Ce	fcc	Cu	0.51610			RT
β -Ce	hex	La	0.3673		1.1802	< 263 K
γ -Ce	fcc	Cu				< 95 K
α -Cm	hex	L	0.3496		1.1331	RT
β -Cm	fcc	Cu	0.4381			\approx RT
α -Co	hcp	Mg	0.25071		0.40694	RT
β -Co	fcc	Cu	0.35445			> 661 K
α -Dy	hcp	Mg	0.35915		0.56601	RT
β -Dy	bcc	W				> 1243 K
γ -Dy	orth		0.3595	0.6184	0.5678	< 86 K
α -Er	hcp	Mg	0.35592		0.55850	RT
β -Er	bcc	W				high temperature
α -F	mon		0.550	0.338 $\beta = 102.17^\circ$	0.728	4.2 K
β -F	cub		0.667			> 45.6 K
α -Fe	bcc	W	0.28665			RT
γ -Fe	fcc	Cu	0.36467			> 1183 K
δ -Fe	bcc	W	0.29135			> 1663 K
α -Gd	hcp	Mg	0.36336		0.57810	RT
β -Gd	bcc	W	0.406			> 1535 K
α -H	hcp	Mg	0.3771		0.6152	4.2 K
β -H	fcc	Cu	0.5334			< 1.3 K
α -Hf	hcp	Mg	0.31946		0.50511	RT
β -Hf	bcc	W	0.3610			> 2268 K
α -Ho	hcp	Mg	0.35778		0.56178	RT
β -Ho	bcc	W				high temperature
α -La	hex	La	0.37740		1.2171	RT
β -La	fcc	Cu	0.53045			> 613 K
γ -La	bcc	W	0.4265			> 1141 K
α -Li	hcp	Mg	0.3111		0.5093	< 72 K
β -Li	bcc	W	0.35093			RT
α -Lu	hcp	Mg	0.35052		0.55494	RT
β -Lu	bcc	W				high temperature
α -Mn	cub	α Mn	0.89219			RT
β -Mn	cub	β -Mn	0.63152			> 1000 K
γ -Mn	fcc	Cu	0.38624			> 1368 K
δ -Mn	bcc	W	0.30806			> 1408 K
α -N	cub		0.5659			4.2 K

Modification	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Range of stability
β-N	hex	La	0.4046		0.6629	> 35.6 K
α-Na	hcp	Mg	0.3767		0.6154	< 36 K
β-Na	bcc	W	0.42096			RT
α-Nd	hex	La	0.36582		1.17966	RT
β-Nd	bcc	W	0.413			> 1135 K
α-Np	orth		0.6683	0.4723	0.4887	RT
β-Np	tetr		0.4896		0.3387	> 533 K
γ-Np	bcc	W	0.352			> 850 K
α-O	mon		0.5403	0.3429 <i>β</i> = 132.53°	0.5086	4.2 K
β-O	rhomb	As	0.4210 <i>α</i> = 46.27°			> 239 K
γ-O	cub		0.683			> 436 K
α-Pa	tetr		0.3945		0.3242	RT
β-Pa	bcc	W	0.381			> 1443 K
α-Po	cub		0.3366			RT
β-Po	rhomb	Hg	0.3373 <i>α</i> = 98.98°			> 327 K
α-Pr	hex	La	0.36721		1.18326	RT
β-Pr	bcc	W	0.413			> 1094 K
α-Pu	mon		0.6183 <i>α</i> = 101.78°	0.4822	1.0968	RT
β-Pu	mon		0.9284	1.0463	0.7859	> 395 K
γ-Pu	orth		0.31587	0.57682	1.0162	> 508 K
δ-Pu	fcc	Cu	0.46371			> 592 K
δ'-Pu	tetr	In	0.33261		0.44630	> 723 K
ε-Pu	bcc	W	0.5703			> 744 K
α-Sc	hcp	Mg	0.33088		0.52680	RT
β-Sc	bcc	W				> 1607 K
α-Se	mon		0.9054	0.9083 <i>β</i> = 90.82°	0.2336	≈ RT
β-Se	mon		1.5018	1.4713 <i>β</i> = 93.6°	0.8879	≈ RT
γ-Se	hex	Se	0.43655		0.49576	RT
α-Sm	hex	Se	0.36290		2.6207	RT
β-Sm	bcc	W				> 1190 K
α-Sn	cub	diamond	0.64892			< 291 K
β-Sn	tetr	Sn	0.58316		0.31815	RT
α-Sr	fcc	Cu	0.6084			RT
β-Sr	hcp	Mg	0.428		0.705	> 486 K
γ-Sr	bcc	W	0.487			> 878 K
α-Tb	hcp	Mg	0.36055		0.56966	RT
β-Tb	bcc	W				> 1589 K
α-Th	fcc	Cu	0.50851			RT
β-Th	bcc	W	0.411			> 1673 K

Modification	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Range of stability
α -Ti	hcp	Mg	0.29503		0.46836	RT
β -Ti	bcc	W	0.33065			> 1173 K
α -Tl	hcp	Mg	0.34563		0.55263	RT
β -Tl	bcc	W	0.3879			> 503 K
α -Tm	hcp	Mg	0.3575		0.55540	RT
β -Tm	bcc	W				high temperature
α -U	orth	α -U	0.28538	0.58680	0.49557	RT
β -U	tetr		1.0759		0.5654	> 935 K
γ -U	bcc	W	0.3524			> 1045 K
α -Yb	fcc	Cu	0.54848			RT
β -Yb	bcc	W	0.444			> 1005 K
γ -Yb	hcp	Mg	0.38799		0.63859	< 270 K
α -Zr	bcc	W	0.3609		0.51476	RT
β -Zr	bcc	W	0.3609			> 1138 K

High-pressure modifications of elements

Crystallographic data for high-pressure modifications of elements were taken from the compilation published by King ¹⁾. Structure and lattice parameters at room temperature and at normal pressure were given for 25° C = 298 K and 1 atm (abbreviated: RTP). Values for high-pressure modifications are referred to the pressure mentioned (accurate to ± 0.1 GPa).

Modification	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Range of stability
Al-I	fcc	Cu	0.40496			RTP
Al-II	hcp	Mg	0.2693		0.4398	> 20.5 GPa
α -Am	hex	La	0.3468		1.1241	RTP
γ -Am	orth	α -U	0.3063	0.5968	0.5169	> 15.0 GPa
α -Ba	bcc	W	0.5023			RTP
β -Ba	hcp	Mg	0.3901		0.6154	> 5.3 GPa
γ -Ba	?					> 23.0 GPa
α -Bi	rhomb	As	0.4760 $\alpha = 57.23^\circ$			RTP
β -Bi	?					> 0.28 GPa
γ -Bi	mon		0.605	0.420	0.465	> 3.0 GPa
δ -Bi	?					> 4.3 GPa
ϵ -Bi	?					> 6.5 GPa

¹⁾ King, H.W.: Bull. Alloy Phase Diagrams **4** (1983) 450

Modification	Crystal structure	Structure type	<i>a</i> [nm]	<i>b</i> [nm]	<i>c</i> [nm]	Range of stability
ζ-Bi	bcc	W	3.800			> 9.0 GPa
C (graphite)	hex	La	0.24612		0.67090	RTP
C (diamond)	cub	diamond	0.35669			60.0 GPa
α-Ce	fcc	Cu	0.51610			RTP
α'-Ce	fcc	Cu	0.482			> 1.5 GPa
Ce-III	mon		0.4762	0.3170 $\beta = 91.7^\circ$	0.3169	5.1 GPa
α-Cr	bcc	W	0.28847			RTP
α'-Cr	bcc	W	0.2882			high pressure
Cs-I	bcc	W	0.6141			RTP
Cs-II	fcc	Cu	0.5984			> 2.37 GPa
Cs-III	fcc	Cu	0.5800			> 4.22 GPa
α-Dy	hcp	Mg	0.35915		0.56501	RTP
γ-Dy	hex	Se	0.3436		2.4830	> 7.5 GPa
α-Fe	bcc	W	0.28665			RTP
ε-Fe	hcp	Mg	0.2485		0.3990	> 13.0 GPa
α-Ga	orth	Ga	0.45192	0.76586	0.45258	RTP
β-Ga	tetr	In	0.2808		0.4458	> 1.2 GPa
γ-Ga	orth		1.0593	1.3523	0.5203	> 3.0 GPa; 220 K
α-Gd	hcp	Mg	0.36336		0.57810	RTP
γ-Gd	hex	Se	0.361		2.603	> 3.0 GPa
α-Ge	cub	diamond	0.56574			RTP
β-Ge	tetr	β-Sn	0.4884		0.2692	> 12.0 GPa
γ-Ge	tetr		0.593		0.698	decompressed β-Ge
δ-Ge	cub		0.692			> 12.0 GPa
α-Hf	hcp	Mg	0.3577		0.5842	42 K
β-He	fcc	Cu	4.240			0.125 GPa; 1.6 K
γ-He	bcc	W	1.110			0.03 GPa; 1.73 K
α-Hg	rhomb	Hg	0.3005 $\alpha = 70.53^\circ$			237 K
β-Hg	tetr	In	0.3995		0.2825	high pressure; 77 K
α-Ho	hcp	Mg	0.35778		0.56178	RTP
γ-Ho	hex		0.334		2.45	> 4.0 GPa
K-I	bcc	W	0.5321			RTP
K-II	?					28.0 GPa; 77 K
K-III	?					36.0 GPa; 77 K
α-La	hex	La	0.37740		1.2171	RTP
β'-La	fcc	Cu	0.517			> 2.0 GPa
α-N	cub		0.5659			4.2 K

Modification	Crystal structure	Structure type	a [nm]	b [nm]	c [nm]	Range of stability
N-II	tetr		0.3957		0.5101	> 3.3 GPa; 20 K
α -Nd	hex	La	0.36582		1.17966	RTP
γ -Nd	fcc	Cu	0.480			> 5.0 GPa
Pb-I	fcc	Cu	0.49502			RTP
Pb-II	hcp	Mg	0.3265		0.5387	> 10.3 GPa
α -Pr	hex	La	0.36721		1.18326	RTP
γ -Pr	fcc	Cu	0.488			> 4.0 GPa
α -Rb	bcc	W	0.5703			RTP
β -Rb	?					> 1.08 GPa
γ -Rb	?					> 2.05 GPa
Sb-I	rhomb	As	0.45065 $\alpha = 57.11^\circ$			RTP
Sb-II	cub		0.2992			> 5.0 GPa
Sb-III	hex	Mg	0.3376		0.5341	> 7.5 GPa
Sb-IV	mon		0.556	0.404 $\beta = 86.0^\circ$	0.422	14.0 GPa
α -Si	cub	diamond	0.54306			RTP
β -Si	tetr	Sn	0.4686		0.2585	> 9.5 GPa
γ -Si	cub		0.636			> 16.0 GPa
δ -Si	hex	La	0.380		0.628	decompressed β -Si
α -Sm	hex		0.36290		2.607	RTP
γ -Sm	hex	La	0.3618		1.166	> 4.0 GPa
β -Sn	tetr	Sn	0.58316		0.31815	RTP
γ -Sn	tetr	In	0.370		0.337	> 9.0 GPa
α -Sr	fcc	Cu	0.6084			RTP
Sr-II	bcc	W	0.4437			> 3.5 GPa
α -Tb	hex	Mg	0.36055		0.56966	RTP
Tb-II	hex		0.341		2.45	> 6.0 GPa
α -Te	hex	Se	0.44561		0.59271	RTP
β -Te	rhomb	As	0.469 $\alpha = 53.30^\circ$			> 3.0 GPa
γ -Te	rhomb	Hg	0.3002 $\alpha = 103.3^\circ$			> 7.0 GPa
α -Tl	hcp	Mg	0.34563		0.55540	RTP
γ -Tl	fcc	Cu				high pressure

Some thermodynamic properties of the elements

Enthalpies of fusion for the elements, ΔH^F , were selected from the "JANAF Thermochemical Tables" ²⁾, from the compilations by Hultgren et al.³⁾ and Chase ⁴⁾. The given ΔH^F values are valid for the melting point. In parentheses: estimated values.

Enthalpy of sublimation, ΔH_{subl}^0 (for 0 K), entropy S^0 and heat capacity C_p^0 (for 298 K) are taken from the compilation given in the "Bulletin of Alloy Phase Diagrams" ¹⁾.

Sublimation enthalpy at 0 K is given, even in those cases where the substance is not solid at 298 K (marked by an asterisk *). In parentheses: estimated values.

ΔH_{subl}^0 -values marked by the superscript ^a are related to 1 g-atom concerning the reaction $0.5 \text{ X}_2(\text{c}) \rightarrow 0.5 \text{ X}_2(\text{g})$ where X = element, (c) = crystalline, and (g) = gaseous.

Element	ΔH^F [kJ g-atom ⁻¹]	ΔH_{subl}^0 (0 K) [kJ g-atom ⁻¹]	S^0 (298 K) [J g-atom ⁻¹ K ⁻¹]	C_p^0 (298 K) [J g-atom ⁻¹ K ⁻¹]
Ac			54.48	27.2
Ag	11.30	284.4	42.55	25.36
Al	10.70	327.3	28.35	24.392
Am	14.40 (L→γ-Am)	284.0	54.48	25.9
Ar (g)	1.19	7.732*	154.73	20.87
α-As		300.7	35.69	24.65
Au	13.00	365.9	47.40	25.42
B(c)	50.20 (L→β-B)	556.0	5.900	11.20
Ba	7.12	182.7	62.42	28.09
Be	(12.60) (L→β-Be)	319.8	9.500	16.44
Bi	11.30	209.8	56.74	25.52
Bk			(76.15)	
Br ₂ (c)	5.286	22.850 ^a	76.105	37.84
C (graphite)		711.19	5.74	8.519
C (diamond)		708.77	2.38	6.11
Ca	8.54 (L→β-Ca)	177.30	41.60	25.940
Cd	6.20	112.05	51.76	25.98
Ce	5.46 (L→δ-Ce)	423.4	71.96	26.94
Cl ₂ (g)	3.203	15.096 ^a	111.487	16.974
Cm	14.65 (L→β-Cm)	92.6	(71.96)	(27.70)
α-Co	16.20 (L→β-Co)	423.1	30.041	24.811
Cr	(20.50)	395.4	23.62	23.44
Cs	2.09	77.580	85.228	32.18
Cu	13.05	336.4	33.150	24.443
Dy	11.06 (L→β-Dy)	293.047	74.77	28.16
Er	19.90	318.3	73.18	28.12
Eu	9.21	176.7	77.78	27.66
F ₂ (g)	0.255 (L→β-F)	4.217 ^a	101.332	15.66
α-Fe (bcc)	13.80 (L→δ-Fe)	413.0	27.32	25.10
Fr			95.40	

¹⁾ Bull. Alloy Phase Diagrams **2** (1981) 262

²⁾ Chase jr., M.W., Davies, C.A., Downey jr., J.R., Frurip, D.J., McDonald, R.A., Syverud, A.N.: "JANAF Thermochemical Tables", Third Edition, Am. Chem. Soc., Am. Inst. Phys., National Bureau of Standards 1986

³⁾ Hultgren, R., Desai, P.D., Hawkins, D.T., Gleiser, M., Kelley, K.K., Wagman, D.D.: "Selected Values of the Thermodynamic Properties of the Elements", Metals Park, Ohio: Am. Soc. Met. 1973

⁴⁾ Chase, M.W.: Bull. Alloy Phase Diagrams **4** (1983) 124

Element	ΔH^F [kJ g-atom ⁻¹]	ΔH_{subl}^0 (0 K) [kJ g-atom ⁻¹]	S^0 (298 K) [J g-atom ⁻¹ K ⁻¹]	C_p^0 (298 K) [J g-atom ⁻¹ K ⁻¹]
Ga (c)	5.565	270.10	40.83	26.15
Gd	10.05 (L→β-Gd)	399.0	68.07	37.02
Ge	37.03	371.7	31.09	33.347
H ₂ (g)	0.05868	0.376 ^{*a}	65.287	14.418
He (g)		0.060 [*]	126.039	20.786
α-Hf (hex)	(29.30)	618.90	43.55	25.73
Hg (c)	2.295	64.525 [*]	75.90	27.983
Ho	(16.90) (L→β-Ho)	302.629	75.3	27.15
I ₂ (c)	7.82	32.750 ^a	58.070	27.21
In	3.28	243.1	57.82	26.732
Ir	(26.14)	668.5	35.50	24.98
K	2.32	90.14	64.18	29.58
Kr (g)	1.638	11.075 [*]	163.975	20.786
La	6.20 (L→γ-La)	431.3	56.9	27.11
Li	3.00 (L→β-Li)	157.80	29.12	24.77
Lu	(18.65)	427.8	50.96	26.86
Mg	8.477	145.90	32.68	24.895
α-Mn	(12.45) (L→δ-Mn)	282.1	32.008	26.28
Mo	35.98	657.3	28.602	23.932
N ₂ (g)	0.3604 (L→β-N)	3.475 ^{*a}	95.751	14.560
Na	2.60 (L→β-Na)	107.57	51.212	28.24
Nb	(26.90)	730.0	36.48	24.69
Nd	7.14 (L→β-Nd)	328.7	71.6	27.45
Ne (g)	0.3317	1.870 [*]	146.22	20.786
Ni	17.47	428.0	29.87	26.07
Np	5.19 (L→γ-Np)	465.2	50.5	29.62
O ₂ (g)	0.223 (L→γ-O)	4.383 ^{*a}	102.516	14.690
Os	(31.80)	188.4	(32.6)	24.7
P (white)	0.629	315.7	41.09	23.824
P (red tricl)		329.6	22.80	21.21
Pa	12.34 (L→β-Pa)	606.76	(51.9)	(27.61)
Pb	4.80	195.9	64.80	26.51
Pd	(17.56)	377.4	37.57	25.98
Pr	6.89	356.7	73.2	27.20
Pt	(19.65)	564.4	21.63	25.85
α-Pu (mon)	2.825 (L→ε-Pu)	34.61	56.15	32.84
Ra		38.0	71.1	
Rb	2.19	82.17	76.78	31.062
Re	(33.23)	773.0	36.53	25.31
Rh	(21.49)	551.8	32.0	24.98
Rn (g)	(2.89)	20.899 [*]	176.105	20.786
Ru	(24.28)	649.8	28.54	24.06
α-S (orth)		274.74	32.054	22.70
β-S (mon)	17.18 (L→β-S)	274.47	33.024	23.21
Sb	19.90	264.2	45.52	25.23
Sc	14.10 (L→β-Sc)	376.0	34.64	25.52
γ-Se (hex)	6.70	212.6	41.97	25.04
Si	50.21	455.7	18.81	20.00
Sm	86.20 (L→β-Sm)	206.1	69.58	29.54
β-Sn (white)	7.195 (L→β-Sn)	301.3	51.18	27.17
α-Sn (gray)		303.5	44.12	25.77
Sr	7.431 (L→γ-Sr)	164.4	52.3	26.4
Ta	36.57	781.6	41.46	25.30
Tb	10.80 (L→β-Tb)	390.6	73.28	28.91
Tc			(33.5)	
Te	17.49	197.0	49.70	25.73
Th	13.81 (L→β-Th)	598.6	53.39	27.32

Element	ΔH^F [kJ g-atom ⁻¹]		ΔH_{subl}^0 (0 K) [kJ g-atom ⁻¹]	S^0 (298 K) [J g-atom ⁻¹ K ⁻¹]	C_p^0 (298 K) [J g-atom ⁻¹ K ⁻¹]
α -Ti (hex)	14.15	(L→ β -Ti)	467.1	32.63	25.02
Tl	4.20	(L→ β -Tl)	181.6	64.18	26.32
Tm	16.84		233.4	74.01	27.03
U	9.14	(L→ γ -U)	535.4	50.21	27.66
V	22.85		470.3	28.95	24.90
W	46.00		848.1	32.63	24.27
Xe (g)	2.30		15.891*	169.531	20.744
Y	11.40	(L→ β -Y)	420.4	44.43	26.53
Yb	7.66	(L→ β -Yb)	152.6	59.87	26.74
Zn	7.32		129.88	41.63	25.44
α -Zr (hex)	20.92	(L→ β -Zr)	607.5	38.99	25.36

Enthalpies of transition of elements in the solid state

Transformation enthalpies, ΔH^T , at the transformation point were taken from the compilation published by Chase ¹⁾. Estimated values are in parentheses.

Phase transition	Transition temperature [K]	ΔH^T [kJ g-atom ⁻¹]	Phase transition	Transition temperature [K]	ΔH^T [kJ g-atom ⁻¹]
α -Am – β -Am	923	0.775	β -Np – γ -Np	849	5.270
β -Am – γ -Am	1350	5.860	α -O – β -O	23.867	0.0484
α -Be – β -Be	1550	(2.10)	β -O – γ -O	43.801	0.3713
α -Ca – β -Ca	716	0.842	α -Pa – β -Pa	1443	6.640
α -Ce – β -Ce		1.95	α -Pr – β -Pr	1068	3.170
β -Ce – γ -Ce		0.19	α -Pu – β -Pu	395	3.375
γ -Ce – δ -Ce	998	2.99	β -Pu – γ -Pu	480	0.565
β -Cm – γ -Cm	1550	3.245	γ -Pu – δ -Pu	588	0.585
α -Co – β -Co	700	0.450	δ -Pu – δ' -Pu	730	0.080
α -Dy – β -Dy	1658	4.160	δ' -Pu – ϵ -Pu	752	1.840
α -F – β -F	45.55	0.364	α -S – β -S	368	0.402
α -Fe – γ -Fe	1184	0.900	α -Sc – β -Sc	1608	4.010
γ -Fe – δ -Fe	1665	0.840	α -Sm – β -Sm	1190	3.110
α -Gd – β -Gd	1533	3.910	α -Sr – γ -Sr	820	0.837
α -Hf – β -Hf	2054	(5.910)	α -Tb – β -Tb	1558	5.020
α -La – β -La	548	0.360	α -Th – β -Th	1633	3.599
β -La – γ -La	1133	3.120	α -Ti – β -Ti	1166	4.170
α -Mn – β -Mn	973	2.230	α -Tl – β -Tl	507	0.360
β -Mn – γ -Mn	1358	2.120	α -U – β -U	942	2.791
γ -Mn – δ -Mn	1408	1.880	β -U – γ -U	1049	4.757
α -N – β -N	35.61	0.116	α -Y – β -Y	1753	4.990
α -Nd – β -Nd	1128	3.030	α -Yb – β -Yb	1033	1.750
α -Np – β -Np	553	5.605	α -Zr – β -Zr	1135	4.015

¹⁾ Chase, M.W.: Bull. Alloy Phase Diagrams **4** (1983)124

List of symbols

Symbol	Unit	Quantity
A_s	K	martensitic transformation starting temperature on heating
a_A^L		thermodynamic activity of the component A in a liquid alloy
a_A^S		thermodynamic activity of the component A in a solid alloy
a, b		atomic weights of the components A and B of an alloy, respectively
a, b, c	nm	lattice parameters
C_p	J mol ⁻¹ K ⁻¹	heat capacity at constant pressure
ΔG^0	J g-atom ⁻¹ , J mol ⁻¹	standard Gibbs free energy of formation
ΔG^L	J g-atom ⁻¹	integral Gibbs free energy of mixing of a liquid alloy
$\overline{\Delta G_A^L}$	J g-atom ⁻¹	partial Gibbs free energy of mixing for the component A of a liquid alloy
$\Delta G^{L,ex}$	J g-atom ⁻¹	integral excess Gibbs free energy of mixing of a liquid alloy
$\overline{\Delta G_A^{L,ex}}$	J g-atom ⁻¹	partial excess Gibbs free energy of mixing for the component A of a liquid alloy
ΔG^S	J g-atom ⁻¹ , J mol ⁻¹	integral Gibbs free energy of formation of a solid alloy
$\overline{\Delta G_A^S}$	J g-atom ⁻¹ , J mol ⁻¹	partial Gibbs free energy of formation for the component A of a solid alloy
$\Delta G^{S,ex}$	J g-atom ⁻¹ , J mol ⁻¹	integral excess Gibbs free energy of formation of a solid alloy
$\overline{\Delta G_A^{S,ex}}$	J g-atom ⁻¹ , J mol ⁻¹	partial excess Gibbs free energy of formation for the component A of a solid alloy
ΔH_{1000}^0	J g-atom ⁻¹ , J mol ⁻¹	standard enthalpy of formation (dissociation) at 1000 K
ΔH^C	J g-atom ⁻¹ , J mol ⁻¹	enthalpy of crystallization
ΔH^F	J g-atom ⁻¹ , J mol ⁻¹	enthalpy of fusion
ΔH^L	J g-atom ⁻¹	integral enthalpy of mixing of a liquid alloy
$\overline{\Delta H_A^L}$	J g-atom ⁻¹	partial enthalpy of mixing for the component A of a liquid alloy
ΔH^R	J g-atom ⁻¹ , J mol ⁻¹	enthalpy of reaction
ΔH^S	J g-atom ⁻¹ , J mol ⁻¹	integral enthalpy of formation of a solid alloy
$\overline{\Delta H_A^S}$	J g-atom ⁻¹ , J mol ⁻¹	partial enthalpy of formation for the component A of a solid alloy
ΔH^T	J g-atom ⁻¹ , J mol ⁻¹	enthalpy of transformation
M_s	K	martensitic transformation starting temperature on cooling
N_A	mol ⁻¹	Avogadro constant, 6.022·10 ²³ mol ⁻¹
p	Pa	pressure
R	J mol ⁻¹ K ⁻¹	gas constant, 8.3145 J mol ⁻¹ K ⁻¹
ΔS_{1000}^0	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	standard entropy of formation (dissociation) at 1000 K

Symbol	Unit	Quantity
ΔS^F	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	entropy of fusion
ΔS^L	J g-atom ⁻¹ K ⁻¹	integral entropy of mixing of a liquid alloy
$\overline{\Delta S_A^L}$	J g-atom ⁻¹ K ⁻¹	partial entropy of mixing for the component A of a liquid alloy
$\Delta S^{L,ex}$	J g-atom ⁻¹ K ⁻¹	integral excess entropy of mixing of a liquid alloy
$\overline{\Delta S_A^{L,ex}}$	J g-atom ⁻¹ K ⁻¹	partial excess entropy of mixing for the component A of a liquid alloy
ΔS^S	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	integral entropy of formation of a solid alloy
$\overline{\Delta S_A^S}$	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	partial entropy of formation for the component A of a solid alloy
$\Delta S^{S,ex}$	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	integral excess entropy of formation of a solid alloy
$\overline{\Delta S_A^{S,ex}}$	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	partial excess entropy of formation for the component A of a solid alloy
ΔS^T	J g-atom ⁻¹ K ⁻¹ , J mol ⁻¹ K ⁻¹	entropy of transformation
T	K	temperature
T_C	K	Curie temperature
T_N	K	Néel temperature
V	nm ³	unit-cell volume
x_A, x_B		atomic fractions of the components A and B of an alloy, respectively
α, β, γ	deg	angles (lattice parameters)
γ_A		thermodynamic activity coefficient of the component A of an alloy
Σ	cm ³ g ⁻¹	solubility of a gas in a solid or liquid

List of abbreviations

at%	atomic percent	mon	monoclinic
bcc	body-centered cubic	m.p.	melting point
b.c.orth	body-centered orthorhombic	orth	orthorhombic
bct	body-centered tetragonal	P	paramagnetic
b.p.	boiling point	ppm	parts per million
C	crystal	RT	room temperature
c	crystalline		
cph	close packed hexagonal	rhomb	rhombohedral
cub	cubic	S, s	solid
DTA	differential thermal analysis	s.p.	sublimation point
EMF	electromotive force	subl	sublimation
ex	excess	subl. p.	sublimation point
F	fusion; ferromagnetic	T	transformation
fcc	face-centered cubic	TEM	transmission electron microscopy
G	gas		
GP	Guinier-Preston	tetr	tetragonal
g	gaseous	t.p.	triple point
h	high-temperature (phase)	transform.	transformation
hcp	hexagonal close packed	tricl	triclinic
hex	hexagonal	trig	trigonal
L	liquid	triple p.	triple point
l	low-temperature (phase)	VEC	valence electron concentration
magnet.	magnetic	wt%	weight percent
max	maximum		