Heats of Transition of the Elements

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The transition properties listed below and on the reverse of this tear-out page were selected from several critical evaluations of data. All values, given in J mol $^{-1}$, are for one gram-atom of substance at the standard state pressure of 1 atmosphere (1.01325 bar). ΔH represents the heat absorbed when transforming from the lower temperature phase to the higher temperature phase, or the heat evolved when transforming from the higher to the lower temperature phase. Values that appear in parentheses are estimates or extrapolations. The significant figures shown are a guide to relative accuracy.

Footnotes to Table

(a) Triple point values, which are defined fixed points of IPTS-68. (b) Melting points or freezing points, which are defined fixed points of IPTS-68. (c) Triple point values, which are secondary reference points of IPTS-68 (d) Melting points or freezing points, which are secondary reference points of IPTS-68

References

[1] Private communication from K. A. Gschneidner, Jr (1983), Ce($\beta \rightleftarrows \gamma$) [2] Gschneidner, K A., Jr., and Beaudry, B.J., *Metals Handbook*, 9th ed , Vol 2, ASM, Metals Park, OH, p 738 (Ho data) and p 788 (Pm data) (1979) [3] Oetting, F. L., Rand, M. H., and Ackermann, R.J , *The Chemical Thermodynamics of Actinide Elements and Compounds*, Part 1, *The Actinide Elements*, International Atomic Energy Agency, Vienna (1976), Th, Pa, U, Np, Pu, Am, and Cm data. [4] Hultgren, R , *et al* , *Selected Values of the Thermodynamic Properties of the Elements*, ASM, Metals Park, OH (1973). [5a] Stull, D. R. and Prophet, H., *The JANAF Thermochemical Tables*, 2nd ed., NSRDS-NBS 37, U.S GPO, Washington, DC (1971); [5b] Chase, M. W., *et al* , "1974 Supplement", *J Phys Chem Ref. Data, 3*, p 311-480 (1974); [5c] "1975 Supplement", *J. Phys. Chem. Ref. Data, 4*, p 1-175 (1975); [5d] "1978 Supplement", *J Phys Chem Ref Data, 7*, p 793-940 (1978); [5e] "1981 Supplement"; [5f] Third Edition, to be published. [6] Glushko, V. P , *et al* , *Termicheskii Konstanty Veshchestv*, Viniti, Moscow, Vol. 1 (1965) to Vol. 10 (1982). [7] Glushko, V P , *et al* , *Termodinamecheskie Svoistva Individual'nykh Veshchestv*, Viniti, Moscow, Vol 1 (1978) to Vol. 4 (1982)

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Element	Atomic number	Transformation	Enthalpy (ΔH), J/mol	Temperature, °C
Ag	47	L ⇄ S	11 300	961.93(b)
Al	13	L ⇄ S	10 700	660.457(d)
Am	95	L ⇄ γ	14 395	1176
		γ ⇄ β	5 860	1077
		β ⇄ α	775	650
Ar	18	L ⇄ S	1 190	83.798 K(a)
Au	79	L ⇄ S	13 000	1064.43(b)
B	5	L ⇄ β	50 200	2077
Ba	56	L ⇄ S	7 120	727
Be	4	L ⇄ β	(12 600)	1287
		β ⇄ α	(2 100)	1277
Bi	83	L ⇄ S	11 300	271.442(c)
Br	35	L ⇄ S	5 286	265.9 K
Ca	20	L ⇄ β	8 540	842
		β ⇄ α	842	443
Cd	48	L ⇄ S	6 200	321.108(d)
Ce	58	L ⇄ δ	5 460	800
		δ ⇄ γ	2 990	725
		γ ⇄ β	190	-
		β ⇄ α	1 950	-
Cl	17	L ⇄ S	3 203	172.16 K
Cm	96	L ⇄ β	14 645	1345
		β ⇄ γ	3 245	1277
Co	27	L ⇄ β	16 200	1495(d)
		β ⇄ α	450	427
Cr	24	L ⇄ S	(20 500)	1857
Cs	55	L ⇄ S	2 090	28.44
Cu	29	L ⇄ S	13 050	1084.88(d)
Dy	66	L ⇄ β	11 060	1409
		β ⇄ α	4 160	1385
Er	68	L ⇄ S	19 900	1522
Eu	63	L ⇄ S	9 210	817
F	9	L ⇄ β	255	53.48 K
		β ⇄ α	364	45.55 K
Fe	26	L ⇄ δ	13 800	1535(d)
		δ ⇄ γ	840	1392
		γ ⇄ α	900	911
Ga	31	L ⇄ S	5 565	29.771(d)
Gd	64	L ⇄ β	10 050	1312
		β ⇄ α	3 910	1260
Ge	32	L ⇄ S	37 030	937
H	1	L ⇄ S	58.68	13.81 K(a)
Hf	72	L ⇄ S	(29 300)	2227
		β ⇄ α	(5 910)	1781
Hg	80	L ⇄ α	2 295	−38.836(d)
Ho	67	L ⇄ β	(16 900)	1470
I	53	L ⇄ S	7 820	113.5
In	49	L ⇄ S	3 280	156.634(d)
Ir	77	L ⇄ S	(26 140)	2447(d)
K	19	L ⇄ S	2 320	63.71
Kr	36	L ⇄ S	1 638	115.770 K(c)
La	57	L ⇄ γ	6 200	920
		γ ⇄ β	3 120	860
		β ⇄ α	360	275
Li	3	L ⇄ β	3 000	180.54
Lu	71	L ⇄ S	(18 650)	1663
Mg	12	L ⇄ S	8 477	650
Mn	25	L ⇄ δ	(12 060)	1245
		δ ⇄ γ	1 880	1135
		γ ⇄ β	2 120	1085
		β ⇄ α	2 230	700
Mo	42	L ⇄ S	35 980	2623(d)
N	7	L ⇄ β	360.4	63.146 K(c)
		β ⇄ α	116	35.61 K
Na	11	L ⇄ β	2 600	97.86
Nb	41	L ⇄ S	(26 900)	2473(d)
Nd	60	L ⇄ β	7 140	1015

Element	Atomic number	Transformation	Enthalpy (ΔH), J/mol	Temperature, °C
Nd	60	β ⇄ α	3030	855
Ne	10	L ⇄ S	331.7	24.561 K(c)
Ni	28	L ⇄ S	17 470	1455(d)
Np	93	L ⇄ γ	5 190	639
		γ ⇄ β	5 270	576
		β ⇄ α	5 605	280
O	8	L ⇄ γ	223	54.361 K(a)
		γ ⇄ β	371.3	43.801 K
		β ⇄ α	48.4	23.867 K
Os	76	L ⇄ S	(31 800)	3025
P(white or)	15	L ⇄ α	629	44
Pa	91	L ⇄ β	12 340	1572
		β ⇄ α	6 640	1170
Pb	82	L ⇄ S	4 800	327.502(d)
Pd	46	L ⇄ S	(17 560)	1554(d)
Pm	61	L ⇄ S	(7 550)	...
		β ⇄ α	(2 900)	...
Pr	59	L ⇄ β	6 890	930
		β ⇄ α	3 170	795
Pt	78	L ⇄ S	(19 650)	1769(d)
Pu	94	L ⇄ ε	2 825	640
		ε ⇄ δ'	1 840	479
		δ' ⇄ δ	80	457
		δ ⇄ γ	585	315
		γ ⇄ β	565	207
		β ⇄ α	3 375	122
Rb	37	L ⇄ S	2 190	39.32
Re	75	L ⇄ S	(33 230)	3180
Rh	45	L ⇄ S	(21 490)	1963(d)
Rn	86	L ⇄ S	(2 890)	−71
Ru	44	L ⇄ S	(24 280)	2250
S	16	L ⇄ β	1 718	115
		β ⇄ α	402	95
Sb	51	L ⇄ S	19 900	630.775(d)
Sc	21	L ⇄ β	14 100	1539
		β ⇄ α	4 010	1335
Se	34	L ⇄ S	6 700	220
Si	14	L ⇄ S	50 210	1417
Sm	62	L ⇄ β	8 620	1072
		β ⇄ α	3 110	917
Sn	50	L ⇄ β	7 195	231.9681(b)
Sr	38	L ⇄ γ	7 431	777
		γ ⇄ α	837	547
Ta	73	L ⇄ S	36 570	2985
Tb	65	L ⇄ β	10 800	1355
		β ⇄ α	5 020	1285
Te	52	L ⇄ S	17 490	449.5
Th	90	L ⇄ β	13 807	1750
		β ⇄ α	3 599	1360
Ti	22	L ⇄ β	14 150	1663
		β ⇄ α	4 170	893
Tl	81	L ⇄ β	4 200	303
		β ⇄ α	360	234
Tm	69	L ⇄ S	16 840	1545
U	92	L ⇄ γ	9 142	1135
		β → γ	4 757	776
		α → β	2 791	669
V	23	L ⇄ S	22 845	1917
W	74	L ⇄ S	46 000	3422(d)
Xe	54	L ⇄ S	2 300	161.388 K(c)
Y	39	L ⇄ β	11 400	1525
		β ⇄ α	4 990	1480
Yb	70	L ⇄ β	7 660	824
		β ⇄ α	1 750	760
Zn	30	L ⇄ S	7 320	419.58(b)
Zr	40	L ⇄ β	20 920	1855(d)
		β ⇄ α	4 015	862

Heats of Transition of the Elements

See reverse for explanation and for transition temperatures of the phases

Key

Chemical symbol → Fe 26 ← Atomic number
13807 ← Enthalpy (ΔH), L ⇄ S, J/mol of atoms
837
900 ← Enthalpy (ΔH), S ⇄ S, J mol of atoms

	I A	II A											III B	IV B	Pnictide Elements V B	Chalcogens VI B	Halogens VII B	Inert Gases
1	H 1 58.68																	He 2
2	Li 3 3000	Be 4 (12600) (2100)											B 5 50200	C 6	N 7 360.4 116	O 8 223 371 3 48.4	F 9 255 364	Ne 10 331.7
3	Na 11 2600	Mg 12 8477											Al 13 10700	Si 14 50210	P 15 629 (white α)	S 16 1718 402	Cl 17 3203	Ar 18 1190
			Transition Metals															
			III A	IV A	V A	VI A	VII A	VIII A	IX A	X A	I B	II B						
4	K 19 2320	Ca 20 8540 842	Sc 21 14100 4010	Ti 22 14150 4170	V 23 22845	Cr 24 (20500)	Mn 25 (12060) 1880 2120 2230	Fe 26 13800 840 900	Co 27 16200 450	Ni 28 17470	Cu 29 13050	Zn 30 7320	Ga 31 5565	Ge 32 37030	As 33	Se 34 6700	Br 35 5286	Kr 36 1638
5	Rb 37 2190	Sr 38	Y 39 11400 4990	Zr 40 20920 4015	Nb 41 26900	Mo 42 35980	Tc 43	Ru 44 (24280)	Rh 45 (21490)	Pd 46 (17560)	Ag 47 11300	Cd 48 6200	In 49 3280	Sn 50 7195	Sb 51 19900	Te 52 17490	I 53 7820	Xe 54 2300
6	Cs 55 2095	Ba 56 7120	La-Lu	Hf 72 (29300) 5910	Ta 73 36570	W 74 46000	Re 75 (33230)	Os 76 (31800)	Ir 77 (26140)	Pt 78 (19650)	Au 79 13000	Hg 80 2295	Tl 81 4200 360	Pb 82 4800	Bi 83 11300	Po 84	At 85	Rn 86 (2890)
7	Fr 87	Ra 88	Ac-Lr															

Lanthanide Metals

La 57	Ce 58	Pr 59	Nd 60	Pm 61	Sm 62	Eu 63	Gd 64	Tb 65	Dy 66	Ho 67	Er 68	Tm 69	Yb 70	Lu 71
6200	5460	6890	7140	(7550)	8620	9210	10050	10800	11060	(16900)	19900	16840	7660	(18650)
3120 360	2990 190 1950	3170	3030	(2900)	3110		3910	5020	4160				1750	

Actinide Metals

Ac 89	Th 90	Pa 91	U 92	Np 93	Pu 94	Am 95	Cm 96	Bk 97	Cf 98	Es 99	Fm 100	Md 101	No 102	Lr 103
	13807	12340	9142	5190	2825	14395	14645							
	3599	6640	4757 2791	5270 5605	1840 80 585 565 3375	5860 775	3245							

Alkali Metals — Alkaline Earth Metals