The Co-Y (Cobalt-Yttrium) System

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Equilibrium Diagram

The assessed Y-Co phase diagram is presented in Fig. 1. The Co-rich portion (>55 at.% Co) is drawn mainly from data reported by [65Str] and includes some features from [71Bus1] and [74Kha]. The region 25 to 50 at.% Co is based on the results of [82Gro]. In addition, the melting points of Co and Y and the $\alpha \leftrightarrow \beta$ transformation temperature of Y were adjusted to bring them into agreement with the accepted values [83Nis] and [86Gsc], respectively. Invariant temperatures and compositions are listed in Table 1.

The Y-Co system has been studied by several research groups, with some inconsistency in their reported results. [65Pel] investigated the Y-Co system with thermal analysis, metallography, and X-ray methods. Their alloys were prepared from 99.9 wt.% pure Co and Y. Samples were arc melted under an inert gas atmosphere. [65Pel] reported nine intermetallic compounds—Y_3Co (peritectic at 885 ± 3 °C), Y_3Co_2 (peritectic at 735 ± 6 °C), YCo (peritectic at 803 ± 5 °C), Y_2Co_3 (peritectic at 855 ± 7 °C), YCo_2 (peritectic at 1155 ± 4 °C), YCo_3 (peritectic at 1325 ± 6 °C), "YCo_4" (congruently melting at 1500 ± 5 °C), YCo_5 (peritectic at 1420 ± 5 °C), and Y_2Co_{17} (peritectic at 1365 ± 7 °C). In addition, they observed two eutectic reactions in this system—Y_3Co-Y_3Co_2 at 725 ± 2 °C and 37.5 at.% Co and (αCo)-Y_2Co_{17} at 1340 ± 5 °C and 93.0 at.% Co. They found that the solid solubility of Y in (Co) does not exceed 0.14 at.% Y at room temperature.

[65Str] also investigated the Y-Co system by thermal analysis, X-ray diffraction (XRD), and metallography. Their Co was of 99.5 wt.% or 99.99 wt.% purity, and their Y was of 99.9 wt.% purity. The metallographic and X-ray samples were prepared by co-melting the two metals and casting them in a levitation furnace in argon atmosphere, with subsequent vacuum annealing when appropriate. The thermal analysis was performed immediately after sample preparation by melting together the component metals directly in the recrystallized alumina crucible.

The phase diagram proposed by [65Str] differs rather significantly from that of [65Pel] between 50 and 90 at.% Co. [65Str] did not observe the peritectic phase YCo and the congruently melting phase "YCo_4," but rather the peritectic phase Y_2Co_7. They also found that the phase Y_2Co_{17} was congruently melting rather than peritectic. They positively identified seven intermediate phases in this system—Y_3Co (peritectic at 880 °C), Y_2Co_3 (peritectic at 790 °C), YCo_2 (peritectic at 1150 °C), YCo_3 (peritectic at 1315 °C), Y_2Co_7 (peritectic at 1325 °C), YCo_5 (peritectic at 1352 °C), and Y_2Co_{17} (congruently melting at 1362 °C)—and reported the possible existence of another phase, Y_3Co_2 (peritectic at 730 °C) near 40 at.% Co. In addition, [65Str] observed two eutectic reactions in this system, in substantial agreement with those reported by [65Pel].

[65Str] reported that in the as-cast condition an alloy of 88.6 at.% Co is single phase, whereas an alloy of stoichiometric composition Y_2Co_{17} (89.5 at.% Co) has an appreciable amount of eutectic between primary Y_2Co_{17} grains and an 88.0 at.% Co alloy shows Y_2Co_{17} surrounded by dark-etching YCo_5. This indicates that Y_2Co_{17} melts congruently at the approximate composition 88.6 at.% Co. [65Str] outlined a finite homogeneity range for Y_2Co_{17} at 1200 °C with limiting compositions of 88.0 and 89.5 at.% Co.

However, of the same alloys annealed at 800 °C, only the 88.0 at.% Co sample was single phase. In addition, they found that the alloys of 84.4 and 85.2 at.% Co are very nearly single-phase YCo_5 in the as-cast condition. This seems to indicate that the YCo_5 may be single phase between the above two concentrations in the as-cast condition and probably is a congruently melting phase.

Table 1 Special Points of the Assessed Y-Co Phase Diagram

Reaction	Composition of the respective phases, at.% Co			Temperature, °C	Reaction type	Reference
$L \leftrightarrow \beta Y$		0		1522	Melting	[86Gsc]
$\beta Y \leftrightarrow \alpha Y$		0		1478	Allotropic	[86Gsc]
$L + (\alpha Y) \leftrightarrow Y_3Co$	~28.7	~0	25.0	880	Peritectic	[65Str,71Bus1]
$L \leftrightarrow Y_3Co + Y_8Co_5$	37.0	25.0	38.46	735 ± 2	Eutectic	[82Gro]
$L + YCo \leftrightarrow Y_8Co_5$	~37.7	50.0	38.46	740 ± 2	Peritectic	[82Gro]
$YCo + Y_8Co_5 \leftrightarrow Y_9Co_7$	50.0	38.46	43.75	725 ± 5	Peritectoid	[82Gro]
$L + Y_2Co_3 \leftrightarrow YCo$	~43.0	60.0	50.0	802 ± 2	Peritectic	[65Pel,82Gro]
$L + YCo_2 \leftrightarrow Y_2Co_3$	~45.5	66.7	60.0	855 ± 7	Peritectic	[65Pel]
$L + YCo_3 \leftrightarrow YCo_2$	~59.0	75.0	66.7	1150	Peritectic	[65Str,71Bus1]
$L + Y_2Co_7 \leftrightarrow YCo_3$	~72.0	77.8	75.0	1315	Peritectic	[65Str]
$L + YCo_5 \leftrightarrow Y_2Co_7$	~73.0	83.3	77.8	1325	Peritectic	[65Str]
$L \leftrightarrow YCo_5$		~85.0		~1350	Congruent	[74Kha]
$L \leftrightarrow Y_2Co_{17} + YCo_5$	~87.0	~88.5	~85.5	~1330	Eutectic	[74Kha]
$L \leftrightarrow Y_2Co_{17}$		88.6		1362	Congruent	[65Str]
$L \leftrightarrow (\alpha Co) + Y_2Co_{17}$	93.0	~100	89.5	1340 ± 5	Eutectic	[65Pel]
$L \leftrightarrow \alpha Co$		100		1495	Melting	[83Nis]

The phase diagram of this system was reinvestigated by [71Bus1] with metallography, thermal analysis, and XRD techniques. The Co and Y used in preparing his samples were of 99.9 wt.% and 99.99 wt.% purity, and samples were prepared by arc melting. [71Bus1] observed seven intermetallic compounds in this system—Y_3Co (peritectic at 880 °C), "Y_4Co_3" (peritectic at 725 °C), YCo_2 (peritectic at 1150 °C), YCo_3 (peritectic at 1330 °C), Y_2Co_7 (peritectic at 1340 °C), YCo_5 (peritectic at 1350 °C), and Y_2Co_{17} (congruently melting at 1370 °C). His results are in fair agreement with those reported by [65Str], except for some minor differences in the melting temperatures in the Co-rich region.

[71Bus1] observed by metallography that in addition to that of Y_2Co_{17}, a homogeneity region also exists for YCo_5 at high

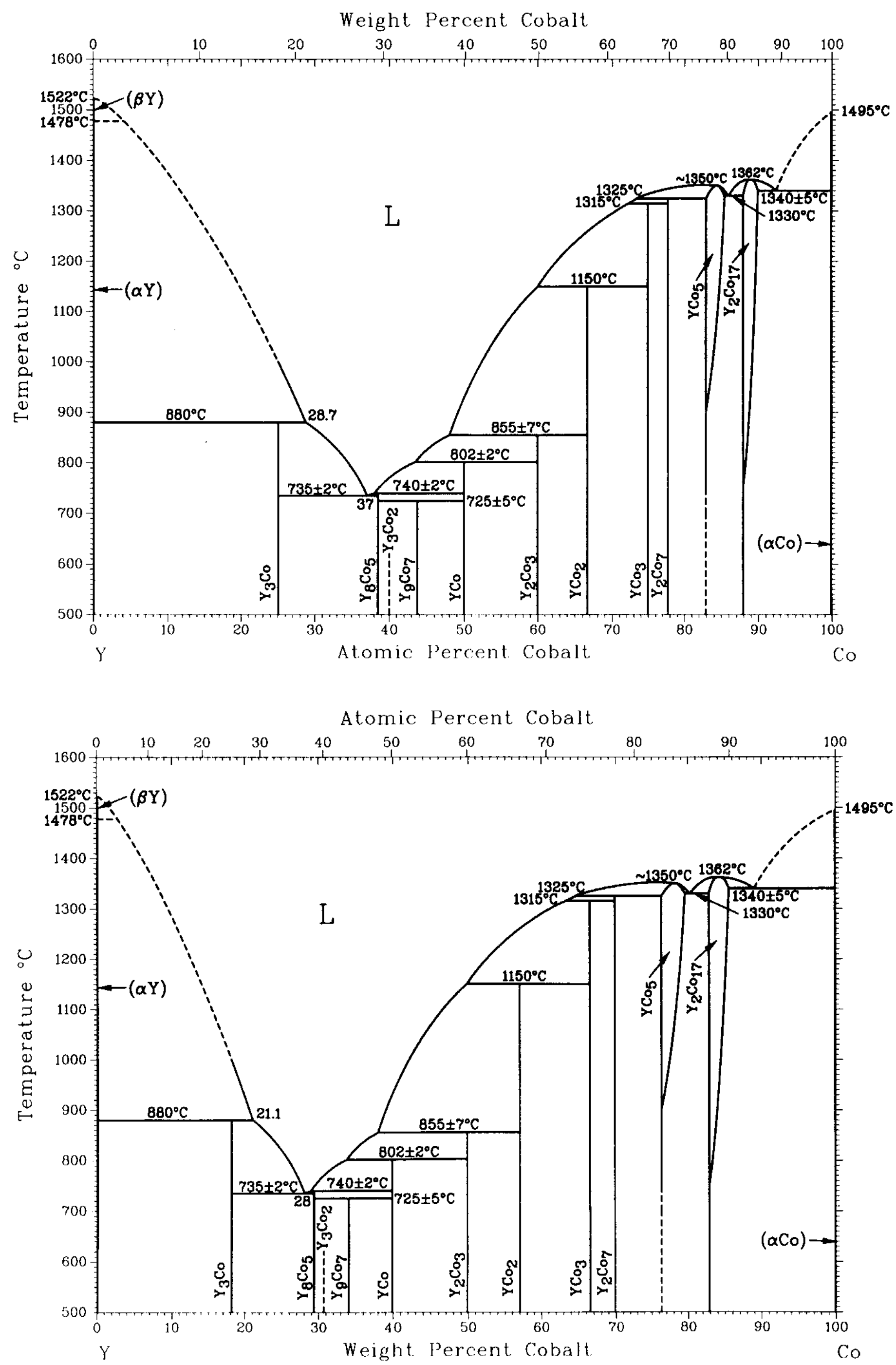

Fig. 1 Assessed Y-Co phase diagram.

Table 2 Y-Co Crystal Structure Data

Phase	Composition, at.% Co	Pearson symbol	Space group	Strukturbericht designation	Prototype
(αY)(a)	~0	*hP*2	*P*6$_3$/*mmc*	*A*3	Mg
(βY)(b)	~0	*cI*2	*Im*$\bar{3}$*m*	*A*2	W
Y_3Co	25.0	*oP*16	*Pnma*	*D*0$_{20}$	Al_3Ni
Y_8Co_5	38.46	*mP*52	*P*2$_1$/*c*	...	...
Y_9Co_7	43.75	(c)	...	...	...,
YCo	50.0	...	...	...	...
Y_2Co_3	60.0	...	...	...	Gd_2Co_3
YCo_2	66.7	*cF*24	*Fd*$\bar{3}$*m*	*C*15	Cu_2Mg
YCo_3	75.0	*hR*12	*R*$\bar{3}$*m*	...	Be_3Nb
		*hP*24	*P*6$_3$/*mmc*	...	$CeNi_3$
Y_2Co_7	77.8	*hR*18	*R*$\bar{3}$*m*	...	Gd_2Co_7
YCo_5	83.3	*hP*6	*P*6/*mmm*	*D*2$_d$	$CaCu_5$
Y_2Co_{17}	89.3	*hP*38	*P*6$_3$/*mmc*	...	Th_2Ni_{17}
		*hR*19	*R*$\bar{3}$*m*	...	Th_2Zn_{17}
(αCo)(d)	~100	*cF*4	*Fm*$\bar{3}$*m*	*A*1	Cu
Metastable phase					
Y_3Co_2	40.0	*oP*20	*Pnnm*	...	...

(a) Below 1478 °C. (b) From 1478 to 1522 °C. (c) Hexagonal. (d) From 422 to 1495 °C at 100 at.% Co.

temperatures, with limiting compositions of 83.05 and 85.71 at.% Co; however in a sample of 82.6 at.% Co, an appreciable amount of Y_2Co_7 was present after quenching from 1200 and 1300 °C. [69Sch] also reported a small homogeneity range for YCo_5, with limiting compositions of 82.6 and 85.71 at.% Co. [73Bus] showed that YCo_5 is unstable below about 725 °C. [71Bus1] asserted that there are two phases—not identified—with compositions close to the "Y_4Co_3" phase. One of these was identified later by [76Mor] as a monoclinic compound, Y_8Co_5, and the other was identified by [75Mor] as orthorhombic Y_3Co_2 and was assumed to be a low-temperature phase. However, [82Gro] showed that Y_3Co_2 is a metastable phase in as-cast alloy.

[74Kha] prepared Y-Co alloys from Co and Y metal of 99.9 wt.% purity. The alloys were melted in a medium-frequency oven under purified argon atmosphere and cast in copper mold. He reported a Co-rich (≥60 at.% Co) region that differed significantly from those proposed by [65Str] and [71Bus1]. [74Kha] observed the peritectic phase "Y_5Co_{19}" (1300 °C), which decomposed eutectoidally to Y_2Co_7 and YCo_5 at elevated temperature (~1200 °C). YCo_5 was reported as a congruently melting rather than as peritectically melting. It decomposed eutectoidally to Y_2Co_{17} and Y_2Co_7 phases at about 975 °C. [74Kha] also reported that YCo_5 and Y_2Co_{17} possess finite homogeneity ranges at high temperatures, but did not report the congruent temperatures and compositions for YCo_5 and the Y_2Co_{17}. However, by scaling of his phase diagram, these are about 1350 °C at 85 at.% Co and 1360 °C at 89.3 at.% Co, respectively.

[74Kha] observed two eutectic reactions in the Co-rich portion of the Co-Y system, but did not propose values for the eutectic temperatures and eutectic compositions. Scaling of his phase diagram indicates the values for eutectic temperatures and compositions of YCo_5-Y_2Co_{17} and Y_2Co_{17}-(αCo) to be about 1330 °C at 87.5 at.% Co and 1335 °C at 92.5 at.% Co, respectively. The values for the eutectic temperature and composition of the Y_2Co_{17}-(αCo) reaction are in reasonable agreement with the values reported by [65Str] (1320 °C at ~92 at.% Co) and [65Pel] (1340 °C at 93 at.% Co).

[85Sub] determined the thermodynamic functions of formation for Y-Co alloys by emf measurements, and the "Y_5Co_{19}" phase was not observed.

The Y-Co phase diagram in the region 25 to 50 at.% Co was restudied carefully by [82Gro]. They showed clearly that the stable phase diagram in this range includes four phases—Y_3Co (25 at.% Co, peritectic at 885 °C), Y_8Co_5 (38.46 at.% Co, peritectic at 740 ± 2 °C), Y_9Co_7 (43.75 at.% Co, peritectoid at 725 ± 5 °C), and YCo (50 at.% Co, peritectic at 802 ± 2 °C). Y_9Co_7, which forms by a peritectoid reaction at 725 °C, formerly was thought to be "Y_4Co_3". Y_3Co_2 is a metastable phase that was found only in as-cast alloys. However, [83Yvo] studied a minute single crystal of irregular shape isolated from an arc-melted and annealed sample of nominal composition Y_9Co_7 by X-ray diffraction analysis. They proposed that the sample is Y_4Co_3 rather than Y_9Co_7. [85Sub] reported that YCo was not observed from their emf measurements. They believed that Y-Co alloys with minor differences in impurity content might differ with respect to the presence or absence of one or another phase.

Metastable Phases

[82Gro] reported the metastable phase Y_3Co_2 as occurring only in as-cast alloys. [75Mor] presented data for the crystal structure of Y_3Co_2 and concluded that it is a low-temperature phase. These conflicting reports have not been resolved.

Table 3 Y-Co Lattice Parameter Data

Phase	Composition, at.% Co	Lattice parameters, nm a	b	c	Comment	Reference
αY	0	0.36482	...	0.57318	At 25 °C	[86Gsc]
βY	0	0.407	...	...	...	[86Gsc]
Y_3Co	25.0	0.7026	0.9454	0.629	...	[71Bus1]
Y_8Co_5	38.46	0.7058	0.7286	2.4227	β = 102.11°(a)	[76Mor]
Y_4Co_3	42.90	1.1521	...	0.4042	(b)	[83Yvo]
Y_9Co_7	43.75	1.1529	...	1.2123	...	[82Gro]
Y_2Co_3	60.0	0.7996	...	...	Cubic(c)	[65Pel]
YCo_2	66.7	0.7217	...	...	(d)	[61Dwi,65Pel]
		0.7215	...	...	(e)	[72Bur]
		0.7216	...	...	(f)	[60Bea,60Wer,65Str]
YCo_3	75.0	0.5020	...	2.440	As cast	[65Smi]
		0.51033	...	2.4371	(g)	[66Vuc]
		0.5005	...	2.427	...	[71Bus1]
		0.5015	...	1.628	(h)	[65Ost,65Str]
Y_2Co_7	77.8	0.5002	...	3.615	...	[71Bus1]
		0.4998	...	3.618	(j)	[67Ost]
YCo_5	83.3	0.4935	...	0.3964	...	[68Vel]
		0.4995	...	0.3994	...	[65Pel]
		0.4931	...	0.3980	(k)	[65Str]
		0.4956	...	0.3969	(m)	[61Dwi]
		0.4928	...	0.3992	...	[59Wer]
Y_2Co_{17}	89.5	0.8355	...	0.8128	As cast	[73Kha]
		0.8341	...	0.8125	At 1000 °C	[66Bus]
		0.8355	...	1.2192	Below 1100 °C	[73Kha]
		0.8344	...	1.2190	(n)	[66Bus]
		0.8331	...	1.2186	(p)	[65Ost,65Str]
αCo	100	0.35446	...	...	...	[83Nis]
Metastable phase						
Y_3Co_2	40.0	1.2248	0.9389	0.3975	...	[75Mor]

Note: Sample previously heat treated at: (a) 700 °C for 48 h. (b) 550 °C for five weeks. (c) 700 °C for 75 h. (d) 700 °C. (e) 800 °C for 24 h. (f) 690 °C. (g) 1000 °C for 48 h. (h) 960 °C for 224 h. (j) 900 °C for 400 h. (k) 960 °C. (m) 900 °C. (n) 1000 °C for 15 days. (p) 800 °C for 200 h.

Crystal Structures and Lattice Parameters

Y has two allotropic forms, and it transforms from cph to bcc at 1478 °C on heating [86Gsc]. Co also has two allotropic modifications. αCo is stable from 422 to 1495 °C (melting point) and has a fcc structure [83Nis]. Crystal structure and lattice parameter data for the stable and metastable intermediate phases in the Y-Co system are listed in Tables 2 and 3, respectively.

Thermodynamics

[85Sub] determined the Gibbs energies, enthalpies, and entropies of phase formation of nine Y-Co intermetallic compounds by emf measurements over the temperature range 850 to 1200 K. They assumed that the solid solubility of Y in (Co) in negligible and that there is no appreciable range of homogeneity in any of these intermetallic compounds at the temperature of measurement. On this basis, the pure solid phases can be chosen as standard states, with invariant activities in the alloys. Therefore, the experimentally measured emf data yield standard Gibbs energies of phase formation as follows:

$$\Delta_f G^0 (Y_2Co_{17}) = -144.39 - (4.05 \times 10^{-3})\, T \text{ kJ/mol}$$

$$\Delta_f G^0 (YCo_5) = -73.18 + (0.72 \times 10^{-3})\, T \text{ kJ/mol}$$

$$\Delta_f G^0 (Y_2Co_7) = -155.23 + (12.15 \times 10^{-3})\, T \text{ kJ/mol}$$

$$\Delta_f G^0 (YCo_3) = -77.38 + (6.27 \times 10^{-3})\, T \text{ kJ/mol}$$

Table 4 Thermodynamic Functions for the Formation of Y-Co Alloys: Gibbs Energies of Formation at 973 K and Mean Values for Enthalpies and Entropies of Formation in the Range 850 to 1200 K

Phase	$-\Delta_f G^0$ (973 K), kJ/mol of atoms	$-\Delta_f H^0$ (850 to 1200 K), kJ/mol of atoms	$-\Delta_f S^0$ (850 to 1200 K), J/K·mol of atoms
Y_2Co_{17}	7.81 ± 0.10	7.60 ± 0.80	−0.21 ± 0.73
YCo_5	12.08 ± 0.11	12.20 ± 0.87	0.15 ± 0.80
Y_2Co_7	15.93 ± 0.12	17.25 ± 0.96	1.35 ± 0.87
YCo_3	17.81 ± 0.13	19.35 ± 1.05	1.57 ± 0.94
YCo_2	20.41 ± 0.14	22.76 ± 1.33	2.38 ± 1.25
Y_2Co_3	20.72 ± 0.16	27.06 ± 1.90	6.49 ± 1.81
Y_9Co_7	19.00 ± 0.18	26.02 ± 3.07	7.16 ± 3.11
Y_8Co_5	18.63 ± 0.23	21.83 ± 4.07	3.25 ± 4.21
Y_3Co	16.51 ± 0.36	15.80 ± 4.98	−0.72 ± 5.27

From [85Sub].

Table 5 Magnetic Properties of Intermetallic Compounds of Y and Co

Phase	Composition, at.% Co	Magnetic moment, μB	Curie temperature, K, T_C	Comment	Reference
Y_3Co	25.0	~0	<2	...	[71Giv]
Y_4Co_3	42.90	0.11	13	...	[68Ber]
Y_9Co_7	43.75	0.85	...	(a)	[82Sar]
YCo_2	66.7	0.23	296	...	[64Wal]
		~0	<2	...	[66Lem]
YCo_3	75.0	1.4	301	(b)	[66Lem,69Kre]
		1.6	402	(c)	[66Lem]
		...	310	...	[71Bus2]
Y_2Co_7	77.8	7.4	639	...	[66Lem]
		...	545	...	[71Bus2]
YCo_5	83.3	7.7	975	...	[60Nas]
		6.8	977	...	[66Lem]
		7.5	...	...	[68Vel]
		7.5	977	...	[69Kre]
		...	955	...	[71Bus2]
Y_2Co_{17}	89.5	27.8	1167	...	[66Lem]
		27.37	1110	...	[66Str]

(a) Superconducting transition $T = 2.15$ K [84Ora]; superconductivity at 2.8 K [82Sar]. (b) Sample previously annealed at 1000 °C. (c) Sample previously quenched from 1000 °C.

$$\Delta_f G^0\,(YCo_2) = -68.27 + (7.17 \times 10^{-3})\,T\,\text{kJ/mol}$$

$$\Delta_f G^0\,(Y_2Co_3) = -135.28 + (32.45 \times 10^{-3})\,T\,\text{kJ/mol}$$

$$\Delta_f G^0\,(Y_9Co_7) = -416.23 + (114.58 \times 10^{-3})\,T\,\text{kJ/mol}$$

$$\Delta_f G^0\,(Y_8Co_5) = -283.72 + (42.29 \times 10^{-3})\,T\,\text{kJ/mol}$$

$$\Delta_f G^0\,(Y_3Co) = -63.20 - (2.89 \times 10^{-3})\,T\,\text{kJ/mol}$$

where mol is a mole of the formula unit, and T is in K. The reported data for the thermodynamic functions of formation for Y-Co intermediate phases are given in Table 4.

[83Nie] computed the theoretical enthalpies of Y-Co phase formation on the basis of Miedema's theory. Their calculated values for YCo_5, YCo_3, YCo_2, YCo, and Y_3Co are −18.0, −26.0, −31.0, −31.0, and −16.0 kJ/mol of atoms, respectively. The Miedema predictions and the experimental enthalpies of formation for some Y-Co phases (Table 4) are in fair agreement. [89Sid] determined and computed the enthalpy of formation for YCo_3 by calorimetry and based on Miedema's theory, respectively. Their experimental and theoretical enthalpies of formation for YCo_3 are 20 ± 3 and 18 kJ/mol of atoms, respectively.

Magnetism

The data of magnetic properties such as saturation moment (at 0 K or 4.2 K), expressed in Bohr magnetron/formula unit and Curie temperature, T_C, given in K for intermetallic compounds of Y with Co, are listed in Table 5.

Cited References

59Wer: J.H. Wernick and S. Geller, "Transition Element-Rare Earth Compounds with the $CaCu_5$ Structure," *Acta Crystallogr., 12,* 662-665 (1959). (Crys Structure; Experimental)

60Bea: B.J. Beaudry, J.F. Haefling, and A.H. Daane, "Some Laves Phases of Yttrium with Transition Elements," *Acta Crystallogr., 13,* 743-744 (1960). (Crys Structure; Experimental)

60Nas: K. Nassau, L.V. Cherry, and W.E. Wallace, "Intermetallic Compounds Between Lanthanons and Transition Metals of the First Long Period, II-Ferrimagnetism of AB_5 Cobalt Compounds," *J. Phys. Chem. Solids, 16,* 131-137 (1960). (Magnetism; Experimental)

60Wer: J.H. Wernick and S. Geller, "Rare-Earth Compounds with the $MgCu_2$ Structure," *Trans. Metall. Soc. AIME, 218,* 866-868 (1960). (Crys Structure; Experimental)

61Dwi: A.E. Dwight, "Factors Controlling the Occurrence of Laves Phases and AB_5 Compounds Among Transition Elements," *Trans. ASM, 53,* 479-500 (1961). (Crys Structure; Experimental)

64Wal: W.E. Wallace and E.A. Skrabek, "Magnetic Moments and Iron Nuclear Hyperfine Field in Laves Phase Containing Lanthanides Combined with Iron and Cobalt," *Rare Earth Research,* Vol. 2, K.S. Vorres, Ed., Gordon and Breach, New York, 431-441 (1964). (Magnetism; Experimental)

65Ost: W. Ostertag, "Crystallographic Data for YCo_3 and Y_2Co_{17}," *Acta Crystallogr., 19,* 150-151 (1965). (Crys Structure; Experimental)

65Pel: J. Pelleg and O.N. Carlson, "The Yttrium-Cobalt System," *J. Less-Common Met., 9,* 281-288 (1965). (Equi Diagram, Crys Structure; Experimental)

65Smi: J.F. Smith and D.A. Hansen, "The Structures of YNi_3, YCo_3, $ThFe_3$ and $GdFe_3$," *Acta Crystallogr., 19,* 1019-1024 (1965). (Crys Structure; Experimental)

65Str: K.J. Strnat, W. Ostertag, N.J. Adams, and J.C. Olson, "The Yttrium-Cobalt Alloy System," Proc. 5th Rare Earth Res. Conf., Ames, Iowa, Vol. 5, 67-76 (1965). (Equi Diagram, Crys Structure; Experimental)

66Bus: K.H.J. Buschow, "The Crystal Structures of the Rare Earth Compounds of the Form R_2Ni_{17}, R_2Co_{17} and R_2Fe_{17}," *J. Less-Common Met., 11,* 204-208 (1966). (Crys Structure; Experimental)

66Lem: R. Lemaire, "Magnetic Properties of the Intermetallic Compounds of Cobalt with the Rare Earth Metals and Yttrium," *Cobalt, 32,* 132-140 (1966), and *33,* 201-211 (1966). (Magnetism; Experimental)

66Str: K. Strnat, G. Hoffer, W. Ostertag, and J.C. Olson, "Ferrimagnetism of the Rare-Earth-Cobalt Intermetallic Compounds R_2Co_{17}," *J. Appl. Phys., 37,* 1252-1253 (1966). (Magnetism; Experimental)

66Vuc: J.H.N. van Vucht, "Note on the Structures of $GdFe_3$, $GdNi_3$, $GdCo_3$ and the Corresponding Yttrium Compounds," *J. Less-Common Met., 10,* 146-147 (1966). (Crys Structure; Experimental)

67Ost: W. Ostertag, "The Crystal Structure of Er_2Co_7 and Other Rare Earth-Cobalt Compounds R_2Co_7 (R = Gd, Tb, Dy, Ho, Tm, Lu, Y)," *J. Less-Common Met., 13,* 385-390 (1967). (Crys Structure; Experimental)

68Ber: C. Berthet-Colominas, J. Laforest, R. Lemaire, R. Pauthenet, and J. Schweizer, "Magnetic Properties of R_4Co_3-Type Intermetallic Compounds of Cobalt with Rare-Earth Metals and Yttrium," *Cobalt, 39,* 97-101 (1968). (Magnetism; Experimental)

68Vel: W.A.J.J. Velge and K.H.J. Buschow, "Magnetic and Crystallographic Properties of Some Rare Earth Cobalt Compounds with $CaZn_5$ Structure," *J. Appl. Phys., 39,* 1717-1720 (1968). (Crys Structure, Magnetism; Experimental)

69Kre: E. Kren, J. Schweizer, and F. Tasset, "Polarized-Neutron-Diffraction Study of Magnetic Moments in Yttrium-Cobalt Alloys," *Phys. Rev., 186,* 479-483 (1969). (Magnetism; Experimental)

69Sch: J. Schweizer and F. Tasset, "A Study of the Variation of Stoichiometry in the Intermetallic Compound YCo_5 and the Preparation of a Single Crystal," *Mater. Res. Bull., 4,* 369-375 (1969). (Equi Diagram; Experimental)

71Bus1: K.H.J. Buschow, "Rare Earth-Cobalt Intermetallic Compounds," *Philips Res. Rep., 26,* 49-64 (1971). (Equi Diagram, Crys Structure; Experimental)

71Bus2: K.H.J. Buschow, "Structural and Magnetic Characteristics of Th-Co and Th-Fe Compounds," *J. Appl. Phys., 42,* 3433-3437 (1971). (Magnetism; Experimental)

71Giv: F. Givord and R. Lemaire, "Crystallographic and Magnetic Properties of the Composition Between Cobalt and Lutetium," *Solid State Commun., 9,* 341-346 (1971). (Magnetism; Review)

72Bur: E. Burzo, "Crystallographic, Magnetic and E.P.R. Studies of Rare-Earth and Yttrium-Cobalt Laves Phase," *Int. J. Magn., 3,* 161-170 (1972). (Crys Structure; Experimental)

73Bus: K.H.J. Buschow, "Composition and Stability of $CaCu_5$-Type Compound of Yttrium with Iron and Cobalt," *J. Less-Common Met., 31,* 359-364 (1973). (Equi Diagram; Experimental)

73Kha: Y. Khan, "The Crystal Structures of R_2Co_{17} Intermetallic Compounds," *Acta Crystallogr. B, 29,* 2502-2507 (1973). (Crys Structure; Experimental)

74Kha: Y. Khan, "On the Constitution of the *R-T* Systems (*R* = Rare Earths and Yttrium, *T* = Iron, Cobalt and Nickel," *Z. Metallkd., 65,* 489-495 (1974). (Equi Diagram; Experimental)

75Mor: J.M. Moreau, E. Parthé, and D. Paccard, "The Orthorhombic Structure of Y_3Co_2, a Shift Structure Variation of the Monoclinic Dy_3Ni_2 Type," *Acta Crystallogr. B, 31,* 747-749 (1975). (Equi Diagram, Meta Phases, Crys Structure; Experimental)

76Fig: H. Figiel, A. Oppelt, E. Dormann, and K.H.J. Buschow, "Transferred Hyperfine Fields at the Y Sites in Y-Co Compounds," *Phys. Status Solidi (a), 36,* 275-283 (1976). (Magnetism; Experimental)

76Mor: J.M. Moreau, D. Paccard, and E. Parthé, "Y_8Co_5, a New Monoclinic Phase with Co-Centered Trigonal Prisms," *Acta Crystallogr. B, 32,* 496-500 (1976). (Equi Diagram, Crys Structure; Experimental)

82Gro: A.K. Grover, B.R. Coles, B.V.B. Sarkissian, and H.E.N. Stone, "The Y-Co System: A Partial Phase Diagram Study," *J. Less-Common Met., 86,* 29-36 (1982). (Equi Diagram, Meta Phases, Crys Structure; Experimental)

82Sar: B.V.B. Sarkissian, A.K. Grover, and B.R. Coles, "Magnetic and Superconducting Behavior of $Y_{36}Co_{28}$ ("Y_4Co_3"), *Physica, 109-110B,* 2041-2044, (1982). (Magnetism; Experimental)

83Nie: A.K. Niessen, F.R. de Boer, R. Boom, P.F. de Châtel, W.C.M. Mattens, and A.R. Miedema, "Model Predictions for the Enthalpy of Formation of Transition Metal Alloys II," *Calphad, 7,* 51-70 (1983). (Thermo; Theory)

83Nis: T. Nishizawa and K. Ishida, "The Co (Cobalt) System," *Bull. Alloy Phase Diagrams, 4,* 387-390 (1983). (Equi Diagram, Crys Structure; Compilation)

83Yvo: K. Yvon, H.F. Braun, and E. Gratz, "On the Structure of the So-called Y_4Co_3 Phase, and Its Stabilization by Silicon," *J. Phys. F, Met. Phys., 13,* L131-L135 (1983). (Crys Structure; Experimental)

84Ora: R.G. Oraltay, J.J.M. Franse, P.E. Brommer, and A. Menovsky, "Thermal Expansion, Specific Heat and Forced Magnetostriction in Y_9Co_7," *J. Phys. F, Met. Phys., 14,* 937-947 (1984). (Magnetism; Experimental)

85Sub: P.R. Subramanian and J.F. Smith, "Thermodynamics of Formation of Y-Co Alloys," *Metall. Trans. A, 16,* 1195-1201 (1985). (Equi Diagram, Thermo; Experimental)

86Gsc: K.A. Gschneidner, Jr. and F.W. Calderwood, "Intra Rare Earth Binary Alloys: Phase Relationships, Lattice Parameters and Systematics," *Handbook on the Physics and Chemistry of Rare Earths,* Vol. 8, K.A. Gschneidner, Jr. and L. Eyring, Ed., North-Holland Physics Publishing, Amsterdam, 1-161 (1986). (Equi Diagram, Crys Structure; Compilation)

89Sid: O.Yu. Sidorov, M.G. Valishev, A.F. Ermakov, Yu.O. Esin, and P.V. Gel'd, "Enthalpies of Formation for Intermetallic Compounds $Fe_{0.75}Y_{0.25}$, $Co_{0.75}Y_{0.25}$, $Ni_{0.5}Y_{0.5}$, and $Co_{0.5}Y_{0.5}$," *Zh. Fiz. Khim., 63,* 1123-1124 (1989). (Thermo; Experimental)

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