The Cu-Sm (Copper-Samarium) System

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Equilibrium Diagram

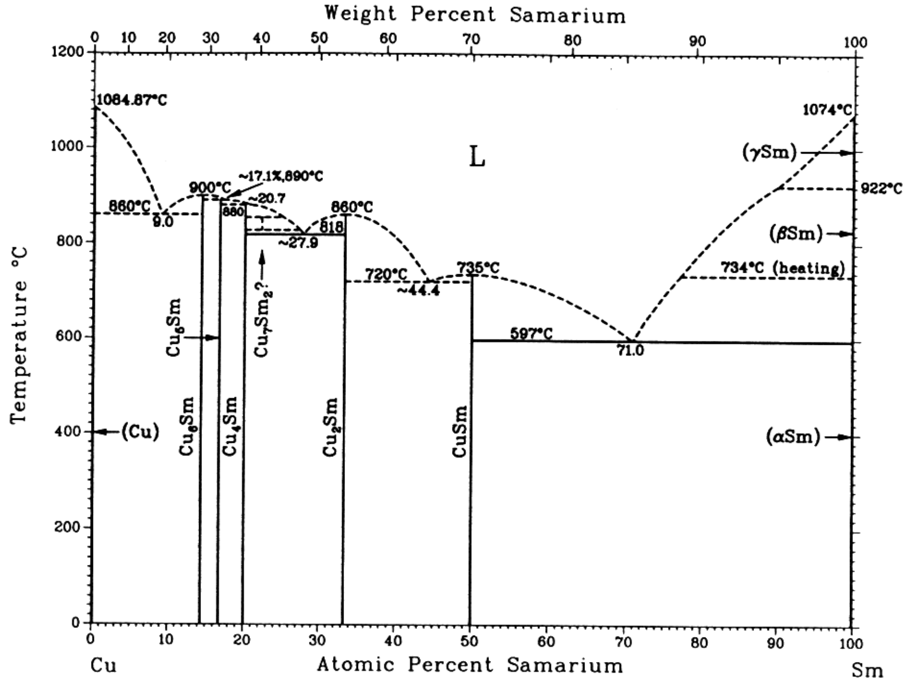
The equilibrium phases of the Cu-Sm system are: (1) the liquid, L, without any miscibility gaps; (2) the fcc terminal solid solution, (Cu), with negligible solid solubility of Sm in (Cu); (3) the Sm-rich bcc terminal solid solution, (γSm), based on the equilibrium phase of pure Sm between 922 and 1074 °C (the solid solution of Cu in (γSm) is negligible); (4) the Sm-rich cph terminal solid solution, (βSm), stable between 734 and 922 °C, with negligible solid solubility of Cu in (βSm); (5) the Sm-rich rhombohedral terminal solid solution, (αSm), stable below 734 °C (the solid solubility of Cu in (αSm) is less than 0.5 at.%); (6) the orthorhombic intermediate phase, Cu_6Sm, stable up to the congruent melting temperature of 900 °C; (7) the hexagonal phase, Cu_5Sm, stable up to the peritectic temperature of 890 °C; (8) the orthorhombic phase, Cu_4Sm, stable up to the peritectic temperature of 880 °C; (9) Cu_7Sm_2, with unknown crystal structure, occurring as a high-temperature phase between ~825 and 850 °C; (10) the orthorhombic phase, Cu_2Sm, stable up to the congruent melting temperature of 860 °C; and (11) the most Sm-rich intermediate phase, CuSm, stable up to the congruent melting temperature of 735 °C.

The Cu-Sm equilibrium diagram has been determined by several investigators [64Cop, 73Tor, 75Kuh, 77Gol]. The investigation of [64Cop] was partial and restricted to the region between 50 and 100 at.% Sm. The other investigations are in agreement with regard to the existence of Cu_6Sm, Cu_2Sm, and CuSm. However, [73Tor] reported a phase diagram without the existence of Cu_4Sm, whereas the diagram of [77Gol] does not show the existence of Cu_5Sm. [74Rus] have given the crystal structures and melting temperatures for the above mentioned five intermediate phases without including any phase diagram. Also, [74Rus] reported the existence of an additional phase, Cu_3Sm.

The phase diagram of [75Kuh], essentially complete with regard to the existence of the various intermediate phases, was determined by differential thermal analysis (DTA), metallography, and electron-microprobe analysis. The Sm used in their alloys was cited as being 99.9% pure (relative to other rare earth materials) and contained oxygen, primarily as Sm_2O_3. Their thermal studies were conducted during both heating and cooling at 2.2 °C/min, a rate sufficiently low to facilitate equilibrium.

Because there is a considerable degree of conflict in the reported phase relationships and melting temperatures, the accepted data are those that agree with the systematics of the Cu-lanthanide systems (see "The Copper-Rare Earth Systems," in this issue). These are discussed in some detail in subsequent sections. The assessed Cu-Sm phase diagram in Fig. 1 has been derived from thermodynamic modeling based on these revised data.

Fig. 1 Assessed Cu-Sm Phase Diagram



P.R. Subramanian and D.E. Laughlin, 1988.

Terminal Solid Solubility

There is no evidence of any terminal solid solubility of Sm in Cu. The terminal solid solubility of Cu in (αSm) is estimated to be less than 0.5 at.%.

Liquidus and Solidus

The melting points of (Cu) and (αSm) are accepted as 1084.87 °C [Melt] and 1074 °C [78Bea, 86Gsc], respectively. Sm exists in three allotropic forms-αSm, βSm, and γSm. The low-temperature αSm form transforms to βSm at 734 °C upon heating, whereas the reverse transformation occurs at 727 °C on cooling [78Bea, 86Gsc]. The βSm → γSm transformation temperature is accepted from [78Bea] and [86Gsc] as 922 °C. There is no evidence of the effect of Cu on the transformations at the Sm-rich end. However, in view of the conclusions presented in our earlier evaluations (see Cu-Ce, Cu-Pr, and Cu-Nd, in this issue), the transformation from (βSm) to (γSm) is proposed to take place through a catatectic reaction at the Sm-rich end, with the temperature of reaction being very close to that for elemental Sm.

Experimental data for the Cu-Sm liquidus boundaries, listed in Table 1, are compared with the assessed phase diagram in Fig. 2. There is a large degree of scatter in the experimental data, as seen in Fig. 2. The assessed phase diagram is comparable to that of [75Kuh]; however, some changes have been incorporated, as noted below. The melting points of Cu_6Sm and Cu_5Sm and the Cu-Cu_6Sm eutectic temperature have been lowered in accordance with the systematics of Cu-lanthanide systems. As such, the assessed liquidus has also been shifted toward lower temperatures, especially in the vicinity of 10 to 25 at.% Sm. Additionally, the assessed liquidus shows the existence of the Cu_2Sm-CuSm eutectic at 720 °C, along with the congruent melting of CuSm. The existence of this eutectic was proposed by [73Tor]. Although this has not been corroborated by other researchers, the DTA data of [75Kuh] show the presence of thermal arrests at 724 °C, which is in close accord with the eutectic temperature of [75Tor]. Similar Cu_2RE-CuRE eutectics have been observed for the heavy lanthanides Gd, Dy, and Er. Furthermore, the Cu-Nd system also shows a tendency for this behavior, because the difference between the CuNd and liquidus compositions at the peritectic melting temperature of CuNd is only ~2 at.%.

The various invariant reactions reported for the Cu-Sm system are summarized in Table 2. The accepted eutectics are : (1) L ↔ (Cu) + Cu_6Sm at 9.0 at.% Sm, 860 °C; (2) L ↔ Cu_4Sm + Cu_2Sm at 27.9 at.% Sm, 818 °C; (3) L ↔ Cu_2Sm + CuSm at 44.4 at.% Sm, 720 °C, and (4) L ↔ CuSm + (αSm) at 71.0 at.% Sm, 597 °C. The accepted eutectic temperatures are in agreement with the the values obtained by interpolation of the corresponding temperatures for the other Cu-lanthanide systems. The eutectic compositions are based

Table 1 Cu-Sm Experimental Liquidus Data

Reference	Composition, at.% Sm	Temperature, °C
[64Cop](a)	46.4	950
	55.6	850
	63.1	750
	69.9	650
	73.9	590
	76.0	650
	80.0	750
	84.5	850
	90.0	950
[73Tor]	4.0	1017
	13.4	965
	15.0	860
	21.2	887
	25.4	839
	32.8	810
	37.8	757
	60.8	691
	77.9	709
[75Kuh](b)	4.0	1022 (1028)
	6.6	964
	9.0	878 (884)
	11.0	900
	12.2	920
	14.3	(946)
	15.0	(942)
	16.7	(938)
[75Kuh](b)(continued)	19.2	927
	20.0	(917)
	22.0	906
	24.0	888
	26.0	868
	28.0	818
	30.0	842
	32.0	854
	33.3	860
	40.0	830 (836)
	45.0	788 (810)
	52.0	764 (772)
	55.0	754
	60.0	716 (724)
	65.0	684
	70.0	611
	80.0	768
	90.0	912
[77Gol]	10.5	931
	14.3	970
	17.5	959
	20.0	939
	25.0	884
	33.3	860
	45.0	760
	50.0	747
	75.0	609

Note: Compositions and temperatures were taken from phase diagrams in the original papers.
(a) Partial phase diagram. **(b)** Data in parentheses refer to temperatures determined from heating curves; the rest of the data refer to temperatures from cooling curves.

on the data of [75Kuh], with the exception of the Cu_2Sm-CuSm eutectic, which is from thermodynamic modeling.

Intermediate Phases

Of the five intermediate phases, Cu_6Sm, Cu_2Sm, and CuSm melt congruently, and the others melt peritectically.

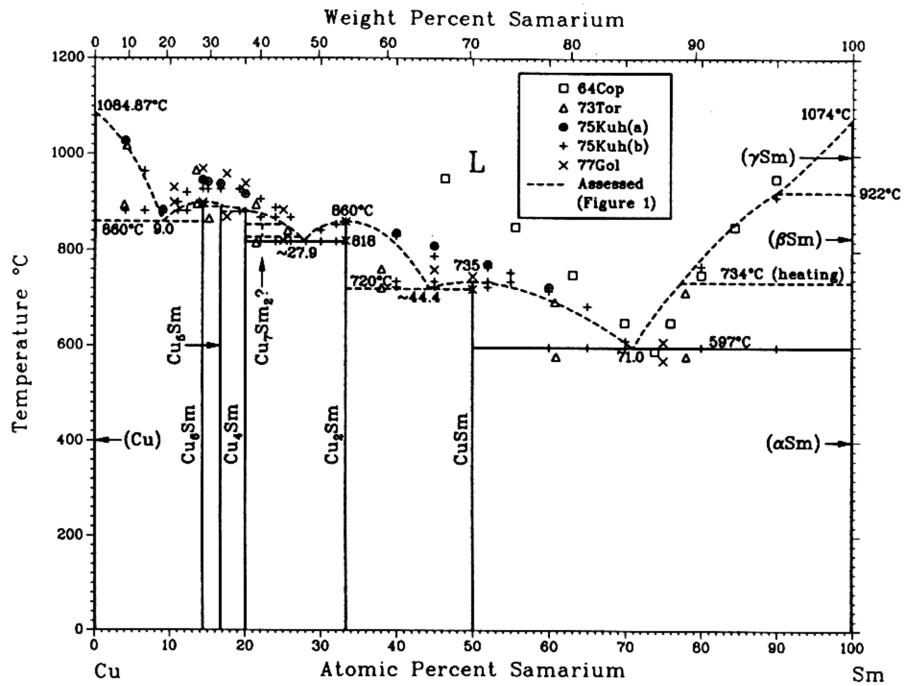
The various melting temperatures reported for the congruently forming phase, Cu_6Sm, are listed in Table 2. The accepted melting temperature of 900 °C is from the systematics of melting behavior for the other lanthanide 6-to-1 phases and is 44 °C lower than that reported by [75Kuh]. Although the melting temperatures reported by [73Tor], [74Rus], and [77Gol] are close to one another, their values are substantially higher than the accepted melting point for Cu_6Sm.

Cu_5Sm forms from the liquid and Cu_6Sm through a peritectic reaction. The accepted melting temperature of 890 °C represents an average of the data of [73Tor] and [75Kuh] and agrees well with the systematics of melting temperatures of the 5-to-1 lanthanide phases. The report of [74Rus] indicating the congruent melting of Cu_5Sm at 875 °C is contradictory to the observed melting behavior of other Cu_5RE phases. On the other hand, [77Gol] do not accept the equilibrium existence of Cu_5Sm. According to these authors, alloys with compositions corresponding to the stoichiometry of Cu_5Sm contained a two-phase mixture of Cu_6Sm and Cu_4Sm in the as-cast state, as well as after annealing at various temperatures.

The peritectic formation of Cu_4Sm has been established by [74Rus], [75Kuh], and [77Gol], although there is minor variation in the reported peritectic temperatures. The accepted melting point is from [75Kuh], primarily because it is derived from heating and cooling data obtained from at least four alloy compositions. [73Tor] do not report the formation of Cu_4Sm.

[74Rus] reported the congruent formation of a cubic phase with the stoichiometry Cu_3Sm at a temperature of 890 °C. Phases with this stoichiometry have not been observed in any of the Cu-lanthanide systems, although it is possible that it is equivalent to the Cu_7RE_2 phase that was reported for RE = Nd, Gd, and Dy (see "The Copper-Rare Earth Systems," in this issue). [77Gol] indicated that alloys corresponding to the stoichiometry of Cu_3Sm contained a mixture of Cu_4Sm, as well as the eutectic Cu_4Sm-Cu_2Sm, thus

Fig. 2 Assessed vs Calculated Cu-Sm Phase Diagram



(**a**) From heating cycle. (**b**) From cooling cycle; in the instances for which the temperatures from the heating and cooling cycles do not differ by more than 10 °C, the average values are indicated. P.R. Subramanian and D.E. Laughlin, 1988.

ruling out the presence of Cu_3Sm at temperatures below the Cu_4Sm-Cu_2Sm eutectic. In the present evaluation, Cu_7Sm_2 is tentatively accepted as a peritectically melting phase with a limited temperature range of stability, in keeping with the systematics of the other Cu_7RE_2 phases.

The congruent formation of Cu_2Sm has been uniformly accepted by the various researchers and the accepted melting temperature of 860 °C is in excellent agreement with the data of [73Tor], [75Kuh], and [77Gol], but not with that of [74Rus].

The equiatomic phase CuSm was reported by [75Kuh] to decompose peritectically at 735 °C. In addition, the thermal analysis data of [75Kuh] indicated the presence of a thermal arrest at 724 °C in all alloys containing CuSm. Electron-microprobe analysis ruled out the existence of any additional peritectic reactions, and therefore, [75Kuh] concluded that CuSm undergoes an allotropic change at 724 °C. On the other hand, [73Tor] proposed the congruent formation of CuSm at 790 °C. The congruent melting of the equiatomic CuRE phases have been observed for the heavy lanthanides Gd, Dy, and Er. In the present evaluation, CuSm is shown as congruently melting at 735 °C.

Crystal Structures and Lattice Parameters

Table 3 gives the experimental values for the lattice parameters of the five Cu-Sm intermediate phases. The accepted lattice parameter data, crystal structures, and related parameters for the various phases are summarized in Tables 4 and 5.

From X-ray diffraction data, [70Bus] confirmed that Cu_6Sm crystallizes with the orthorhombic $CeCu_6$ structure. Lattice parameters reported for this phase by [70Bus], [73Tor], [74Rus], and [80Iva] are in disagreement. The data of [70Bus] and [80Iva] are preferred because of the use of higher purity starting materials and also because the volume/formula unit of Cu_6Sm derived from their data is closest to the value obtained by interpolation of data for the other Cu-lanthanide 6-to-1 phases.

There is universal agreement with regard to the formation of the Cu_5Sm phase with the hexagonal $CaCu_5$ structure, and lattice parameters reported by the various authors are given in Table 3. The accepted lattice parameters in Table 5 represent an average of the data of [60Has], [71Bus], [80Iva], and [81Rus].

[74Rus] reported the formation of Cu_4Sm with a hexagonal structure, whereas [81Rus] (not the same authors) have established from X-ray studies that Cu_4Sm is isostructural with $CeCu_4$ and crystallizes with an orthorhombic structure. The lattice parameters reported for Cu_4Sm by [74Rus] are fairly close to those reported for Cu_5Sm, and it is therefore possible that the crystal structure and lattice parameters reported for Cu_4Sm by [74Rus] might indeed refer to Cu_5Sm. Moreover, the existence of a Cu_4RE phase

Table 2 Special Points of the Assessed Cu-Sm Phase Diagram

Reaction	Compositions of the respective phases, at.% Sm			Temperature, °C	Reaction type	Reference
(Cu) ↔ L		0.0		1084.87	Melting point	[Melt]
L ↔ (Cu) + Cu_6Sm	~10	~0	14.3	890	Eutectic	[73Tor]
	9	~0	14.3	882		[75Kuh]
	~8	~0	14.3	900		[77Gol]
	9	**~0**	**14.3**	**860**		(a)
L ↔ Cu_6Sm		14.3		975	Congruent	[73Tor]
		14.3		980		[74Rus]
		14.3		944		[75Kuh]
		14.3		970		[77Gol]
		14.3		**900**		(a)
L + Cu_6Sm ↔ Cu_5Sm	~25.0	14.3	16.7	860	Peritectic	[73Tor]
	19.2	14.3	16.7	927		[75Kuh]
	17.1	**14.3**	**16.7**	**890**		(a)
L + Cu_5Sm ↔ Cu_4Sm	?	16.7	20	860	Peritectic	[74Rus](b)
	25.4	16.7	20	880		[75Kuh]
	26.5	...	20	870		[77Gol]
	20.7	**16.7**	**20**	**880**		(a)
L ↔ Cu_4Sm + Cu_2Sm	28.0	20	33.3	818	Eutectic	[75Kuh]
	29.0	20	33.3	820		[77Gol]
	27.9	**20**	**33.3**	**818**		(a)
L ↔ Cu_2Sm		33.3		865	Congruent	[73Tor]
		33.3		950		[74Rus]
		33.3		**860**		[75Kuh]
		33.3		860		[77Gol]
L ↔ Cu_2Sm + CuSm	38.8	33.3	50	720	Eutectic	[73Tor]
	44.4	**33.3**	**50**	**720**		(a)
L ↔ CuSm		50		790	Congruent	[73Tor]
		50		**735**		(a)
L + Cu_2Sm ↔ CuSm	~63.1	33.3	50	750	Peritectic	[64Cop]
	?	33.3	50	830		[74Rus](b)
	58.0	33.3	50	735		[75Kuh]
	53.3	33.3	50	720		[77Gol]
L ↔ CuSm + (αSm)	~73.9	50	~98.9	590	Eutectic	[64Cop]
	~70	50	~100	575		[73Tor]
	72	50	~100	570		[77Gol]
(αSm) ↔ (βSm)		100		734(c)	Allotropic	[78Bea, 86Gsc]
(γSm) ↔ L + (βSm)	~100	<89.8	~100	<922	Catatectic	(a)
L ↔ (γSm)		100		1074	Melting point	[78Bea, 86Gsc]

Note: Selected values for the assessed phase diagram are shown in boldface type.
(a) From the assessed phase diagram. **(b)** The report of [74Rus] does not contain an equilibrium diagram, so liquidus compositions are not known. **(c)** The allotropic transformation occurs at 724 °C on cooling.

with the $CeCu_4$ orthorhombic structure has been confirmed for RE = Pr and Nd, and as such, the accepted lattice parameters and crystal structure data for Cu_4Sm are from [81Rus].

From powder X-ray diffraction, [63Sto] have shown that Cu_2Sm is orthorhombic and isostructural with $CeCu_2$. In contrast, [74Rus] indicated that Cu_2Sm is hexagonal with the space group *P6/mmm*. However, the results of [63Sto] are accepted because Cu_2RE phases with the $CeCu_2$ structure have been confirmed to exist for almost all of the lanthanides, with the exception of La.

The equiatomic phase CuSm is the most Sm-rich phase in the Cu-Sm system, and there is some conflict in the literature with regard to the crystal structure of this phase. For CuSm, [64Cha] reported that the cubic CsCl structure can be obtained only after rapid cooling from the melt. [65Wal] indicated that CuSm has an orthorhombic FeB structure. In contrast, [65Dwi] proposed the stable existence of CuSm with the cubic CsCl structure. Also, [65Dwi] concluded that CuSm lies intermediate between the group of CuRE lanthanide equiatomic phases with the orthorhombic FeB structure and that with the cubic CsCl structure, and that CuSm might crystallize in either form, depending

Table 3 Cu-Sm Experimental Lattice Parameters

Phase	Crystal structure	Lattice parameters, nm a	b	c	Reference
Cu_6Sm	Orthorhombic	0.8060	0.5034	1.0049	[70Bus](a)
		0.8080	0.5092	1.0210	[73Tor]
		0.8120	0.5100	1.0130	[74Rus]
		0.8057	0.5036	1.0094	[80Iva](b)
Cu_5Sm	Hexagonal	0.5074 ± 0.0005	...	0.4099 ± 0.0005	[60Has]
		0.507	...	0.410	[71Bus](a)
		0.5071	...	0.4151	[73Tor]
		0.507	...	0.412	[74Rus]
		0.5077	...	0.4102	[80Iva](b)
		0.5074	...	0.4098	[81Rus]
Cu_4Sm	Hexagonal	0.519	...	0.415	[74Rus]
	Orthorhombic	0.442	0.801	0.901	[81Rus]
Cu_2Sm	Orthorhombic	0.4360 ± 0.0005	0.6925 ± 0.0005	0.7375 ± 0.0005	[63Sto](c)
	Hexagonal	0.438	...	0.382	[74Rus]
CuSm	Cubic	0.3528 ± 0.0002	...	...	[64Cha](d)
		0.3535	...	...	[65Dwi]
		0.354	...	...	[74Rus]
	Orthorhombic	0.724	0.431	0.617	[65Wal]

(a) Alloys prepared from 99.99% pure Cu and 99.9% pure Sm. (b) From an as-cast specimen; alloys made from 99.99% pure Cu and 99.8% pure Sm. (c) Alloys prepared from 99.999% pure Cu and 99% pure Sm. (d) According to [64Cha], this phase is found only after rapid cooling from the melt.

Table 4 Cu-Sm Crystal Structure Data

Phase	Composition, at.% Sm	Pearson symbol	Space group	Strukturbericht designation	Prototype
(Cu)	0	*cF*4	$Fm\bar{3}m$	*A*1	Cu
Cu_6Sm	~14.29	*oP*28	*Pnma*	...	$CeCu_6$
Cu_5Sm	~16.67	*hP*6	*P*6/*mmm*	$D2_d$	$CaCu_5$
Cu_4Sm	~20.0	*oP*20	*Pnnm*	...	$CeCu_4$
Cu_2Sm	~33.3	*oI*12	*Imma*	...	$CeCu_2$
CuSm	~50	*cP*2	$Pm\bar{3}m$	*B*2	CsCl
(γSm)	100	*cI*2	$Im\bar{3}m$	*A*2	W
(βSm)	100	*hP*2	$P6_3/mmc$	*A*3	Mg
(αSm)	100	*hR*3	$R\bar{3}m$	...	(αSm)

on heat treatment or impurity content. [74Rus] also confirmed the existence of CuSm with a cubic CsCl structure. Lattice parameters reported for CuSm by [64Cha], [65Dwi] and [74Rus] are in close accord. Also, the formula unit volume of the Cu-lanthanide equiatomic phases decreases linearly with decreasing trivalent ionic radii of the lanthanide element, and in this instance, the data for the CsCl structure shows the best fit with this linear trend.

Thermodynamic Modeling

No experimental thermodynamic data are available for the Cu-Sm system. In the present modeling, therefore, the revised Cu-Sm invariant and melting data were utilized to derive analytical expressions for the Gibbs energy function of the liquid, as well as the Gibbs energies of formation of the various Cu-Sm intermediate phases. The basic assumptions behind the modeling are discussed in earlier evaluations (see Cu-Ce and Cu-Pr, in this issue). However, it should be pointed out that the lattice stability parameters for the (αSm) phase are not known, and therefore, the effect of the (αSm) ↔ (βSm) transformation is not taken into consideration in deriving the thermodynamic parameters of the liquid.

In the present evaluation, data for the two eutectic points at 9 at.% Sm, 860 °C and 71 at.% Sm, 597 °C were utilized for deriving the integral molar excess Gibbs energy of the liquid. The resultant expression for the integral Gibbs energy of the liquid is given in Table 6. The integral molar Gibbs energies of the intermediate phases were derived by solving for equilibrium between the liquid and the respective intermediate phases at various invariant temperatures. The invariant temperatures were selected as follows.

Table 5 Cu-Sm Lattice Parameter Data

Phase	Composition range, at.% Sm	a	Lattice parameters, nm b	c	Comment	Reference
(Cu)	0	0.36146	...	...	At 25 °C	[Massalski]
Cu_6Sm	~14.29	0.8059	0.5035	1.0072	...	[70Bus, 80Iva]
Cu_5Sm	~16.67	0.5073	...	0.4099	...	(c)
Cu_4Sm	~20.0	0.442	0.801	0.901	...	[81Rus]
Cu_2Sm	~33.3	0.4360	0.6925	0.7375	...	[63Sto]
CuSm	~50	0.3534	...	...	...	(d)
(γSm)	100	...	...	...	>922 °C	[78Bea, 86Gsc]
(βSm)	100	0.36630	...	0.58448	At 450 °C(a)	[78Bea, 86Gsc]
(αSm)	100	0.36290	...	2.6207	At 24 °C(b)	[78Bea, 86Gsc]

(**a**) The (βSm) phase is stabilized by impurities, and the temperature of measurement is below the transition temperature listed in Table 2. (**b**) The primitive cell is rhombohedral. Lattice parameters given are for the non-primitive hexagonal cell. (**c**) [60Has, 71Bus, 80Iva, 81Rus]. (**d**) [64Cha, 65Dwi, 74Rus].

Table 6 Cu-Sm Thermodynamic Properties

Lattice stability parameters for Cu(a)

$G^0(\mathrm{Cu, L}) = 0$

$G^0(\mathrm{Cu, fcc}) = -13\,054 + 9.613\,T$

Lattice stability parameters for Sm(b)

$G^0(\mathrm{Sm, L}) = 0$

$G^0(\mathrm{Sm, bcc}) = -8620 + 6.399\,T$

$G^0(\mathrm{Sm, cph}) = -11\,730 + 9.001\,T$

Integral molar Gibbs energies(c)

$G(\mathrm{L}) = X(1-X)(-105\,784 + 62\,604\,X) + RT[X\ln X + (1-X)\ln(1-X)]$

$\Delta_f G(\mathrm{Cu_6Sm}) = -28\,063 + 10.41\,T$

$\Delta_f G(\mathrm{Cu_5Sm}) = -43\,175 + 21.99\,T$

$\Delta_f G(\mathrm{Cu_4Sm}) = -31\,472 + 10.19\,T$

$\Delta_f G(\mathrm{Cu_2Sm}) = -29\,651 + 4.22\,T$

$\Delta_f G(\mathrm{CuSm}) = -39\,273 + 14.72\,T$

Note: Standard states: pure liquid Cu and pure liquid Sm. Gibbs energies are expressed in J/mol, and temperatures are in K. X is the atomic fraction of Sm. Mol refers to the atom as the elementary entity.
(**a**) From [Hultgren,E]. (**b**) From [83Cha]; melting and transformation temperatures are from [78Bea] and [86Gsc]. (**c**) From the phase diagram [this work].

The melting temperatures of Cu_6Sm and Cu_5Sm and the (Cu)-Cu_6Sm and Cu_2Sm-CuSm eutectic temperatures are from systematics. The melting temperatures of Cu_4Sm, Cu_2Sm, and CuSm, as well as the Cu_4Sm-Cu_2Sm and CuSm-(Sm) eutectic temperatures, are from [75Kuh]. The Gibbs energies of the phases at various temperatures were then fitted by least-squares analysis to give the analytic expressions that are listed in Table 6. The assessed liquidus boundaries in Fig. 1 were generated from these Gibbs energy functions.

The enthalpy data from the present modeling are compared in Table 7 with the enthalpies of formation derived with the semi-empirical model of Miedema [80Mie, 83Nie]. The two results are closely comparable for Cu_6Sm, Cu_4Sm, and CuSm; the agreement is not so good for Cu_5Sm and Cu_2Sm.

Table 7 Calculated Enthalpies of Formation of Cu-Sm Intermediate Phases vs Theoretical Estimates Based on Miedema's Model

Phase	Enthalpy of formation, kJ/mol: Present modeling	Miedema model
Cu_6Sm	−28.1	−29.1
Cu_5Sm	−43.2	−31.7
Cu_4Sm	−31.5	−35.1
Cu_2Sm	−29.7	−44.6
CuSm	−39.3	−44.2

Note: Standard states are liquid Cu and liquid Sm.

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*Indicates key paper.
#Indicates presence of a phase diagram.

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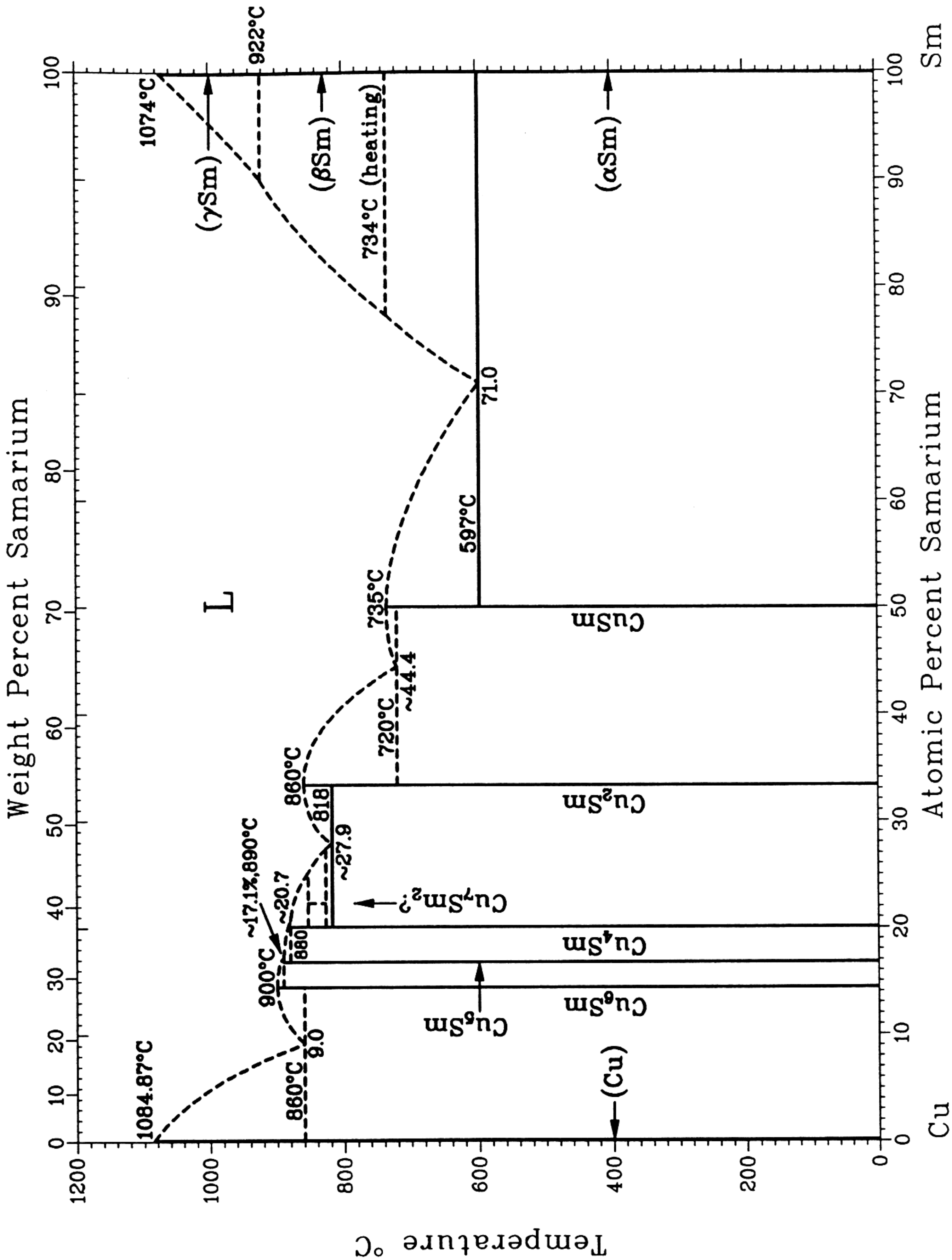
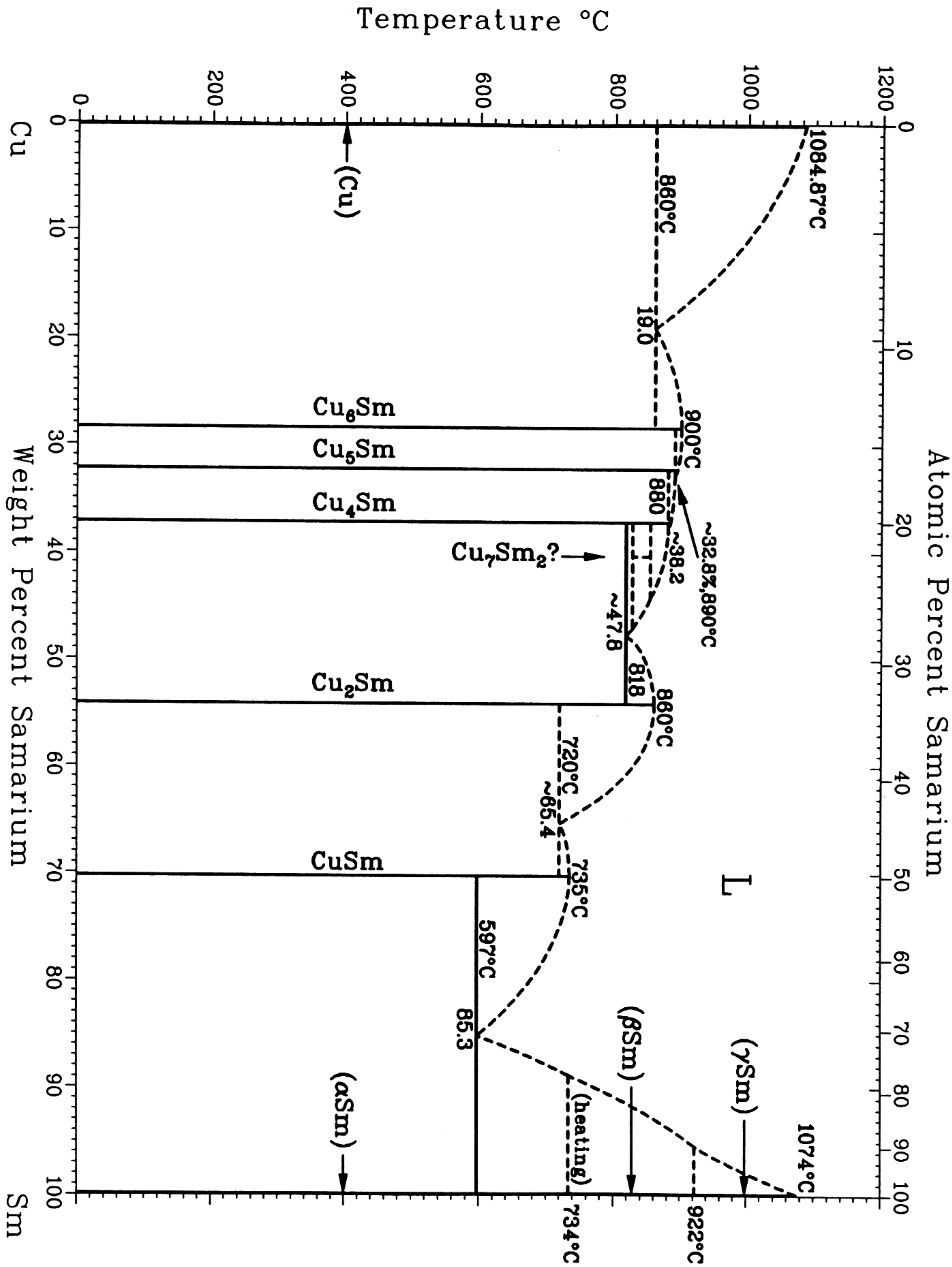


P.R. Subramanian and D.E. Laughlin



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