Silver – Copper – Indium

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Introduction

[1951Geb] and [1952Geb] investigated phase relationships in the indium poor region of this system by thermal analysis, metallography and electrical conductivity measurements. They established six four-phase equilibrium reactions and represented their findings by constructing three isothermal sections and four isopleths. [1955Val], [1967Mcd] and [1979Dri] reviewed the work of [1951Geb] and [1952Geb]. Later work by [1988Woy] is in substantial disagreement with [1951Geb] and [1952Geb]. The γ_1 phase occurring at high temperatures in the Cu-In system, forms a solid solution series with the low-temperature γ_2 phase of the Ag-In system. [1951Geb] and [1952Geb] assumed the bcc high temperature phases of Cu-In(β_1) and Ag-In(β_2) both to be stabilized in the ternary and to decompose eutectically at 490 and 475°C, respectively. [1988Woy] found both β phases to be already decomposed at 505°C. Since [1951Geb] and [1952Geb] identified the phases by metallography only and not by X-ray diffraction, a partial explanation of the disagreement with [1988Woy] may be a misinterpretation of the γ phase as ternary solutions of the β phases. Nevertheless only part of the micrographs of annealed specimen published by [1952Geb] can be interpreted by the isothermal sections given by [1988Woy].

Binary Systems

The binary Ag-Cu system was taken from the recent, published in the MSIT Evaluation Program by [2002Rom]. Ag-In and Cu-In are accepted from [Mas2].

Solid Phases

The solid phases of Ag-In and Cu-In are listed in Table 1. No ternary phases have been reported.

Invariant Equilibria

Almost the entire reaction scheme can be derived from the liquidus surface given by [1988Woy] (Fig. 1) but without temperatures for the four-phase equilibria. This disagrees with the partial reaction scheme given by [1952Geb] in as far the two β phases react and disappear before the L + α_1 + α_2 three-phase field reacts with another three-phase field. Since temperatures of Gebhardt's [1952Geb] scheme are tentatively assigned to the invariant equilibria, which probably explain the thermal analysis effects of Gebhardt's isopleths, it is not possible to reinterpret all measured points of these isopleths to be consistent with the findings of [1988Woy]. Invariant solid-state reactions were not studied by [1988Woy]. The superstructure phases are ignored in the reaction scheme.

Liquidus Surface

In Fig. 2 the liquidus surface according to [1988Woy] is shown. In the In poor part some isotherms from [1951Geb] are inserted. For comparison the partial liquidus surface published by [1951Geb] is shown in Fig. 3.

Isothermal Sections

In Fig. 4 and Fig. 5 the 676 and 505°C isothermal sections as published by [1988Woy] are shown. Figure 5 shows the overwhelming influence of the γ phase on the ternary equilibria. The 676°C isothermal section (Fig. 4) does not correspond with the isopleths at 20 and 25 mass% In (Fig. 7 and Fig. 8). In particular [1952Geb] indicates that the liquid phase occurs at 676°C on the 20 mass% In section. [1988Woy] shows the liquidus isotherm located at higher In contents. It should be noted that the liquid apexes of the four tie triangles in Fig. 4 do not correspond with points on the monovariant curves in Fig. 2. The L + γ+ ζ field in the 505°C isotherm is changed because the original disagrees with the liquidus surface. The L + α_2 + β_2 field in Fig. 4 fits more closely Gebhardt's liquidus surface (Fig. 3) than to Fig. 2. Gebhardt's 500°C isothermal section is shown in Fig. 6 for comparison.

Temperature – Composition Sections

Figures 7 and 8 show the isopleths at 20 and 25 mass% In, respectively, according to [1952Geb].

Notes on Materials Properties and Applications

The effect of quenching on the stress-strain characteristics of Ag alloy with 2 mass% Cu and 0.5 mass% In was investigated in the temperature range from 500 to 650°C by [2004Nad].

References

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Table 1: Crystallographic Data of Solid Phases

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
α_2, (Ag) < 961.93	*cF*4 $Fm\bar{3}m$ Cu	*a* = 408.57	at 25°C [Mas2]
α_1, (Cu) < 1084.62	*cF*4 $Fm\bar{3}m$ Cu	*a* = 361.46	at 25°C [Mas2] melting point [1994Sub]

Phase/ Temperature Range [°C]	Pearson Symbol/ Space Group/ Prototype	Lattice Parameters [pm]	Comments/References
(In) < 156.634	*tI*2 *I*4/*mmm* In	*a* = 325.3 *c* = 494.7	at 25°C [Mas2]
β_2, $Ag_3In(h_2)$ 695 - 660	*cI*2 $Im\bar{3}m$ W	*a* = 336.82	[V-C2]
ζ, $Ag_3In(r)$ < 670	*hP*2 $P6_3/mmc$ Mg	*a* = 295.63 *c* = 478.57	[Mas2]
ζ', Ag_3In < 187	*cP*4 $Pm\bar{3}m$ $AuCu_3$	*a* = 414.4 ± 0.4	[Mas2]
γ, $(Cu,Ag)_9In_4$ γ_2, $Ag_9In_4(h)$ ≲ 314 γ_1, $Cu_9In_4(h)$ 684 - 614	*cP*52 $P\bar{4}3m$ Cu_9Al_4	 *a* = 992.2 *a* = 925.03	 [V-C2] [V-C2]
γ', $AgIn_2$ < 166	*tI*12 *I*4/*mcm* Al_2Cu	*a* = 688.1 *c* = 562	[V-C2]
β_1, $Cu_4In(h)$ 710 - 574	*cI*2 $Im\bar{3}m$ W	*a* = 304.6	[Mas2, V-C]
δ, $Cu_7In_3(r)$ < 631	*aP*40 $P\bar{1}$ Cu_7In_3	*a* = 1007.1 *b* = 912.6 *c* = 672.4 α = 90.22° β = 82.84° γ = 106.81°	[V-C2]
η, $Cu_2In(h_3)$ 667 - 440	*hP*6 $P6_3/mmc$ Ni_2In	*a* = 412.0 *c* = 526.3	[V-C2]
$Cu_7In_4(h_2)$ 480 - 350	*oP*55 *P**	*a* = 2137.5 *b* = 740.5 *c* = 521.8	[1972Jai] superstructure of the Ni_2In type
$Cu_7In_4(h_1)$ 450 - 298	*oP*88 *P**	*a* = 3419.4 *b* = 739.5 *c* = 526.2	[1972Jai] superstructure of the Ni_2In type
$Cu_7In_4(r)$ < 390	-	-	[1972Jai]
$Cu_{15}In_8$ < 355	-	-	[1972Jai]
φ, $Cu_{11}In_9$ < 310	*mC*20 *C*2/*m* CuAl	*a* = 1281.4 *b* = 435.43 *c* = 735.3 β = 54.49°	[V-C2]

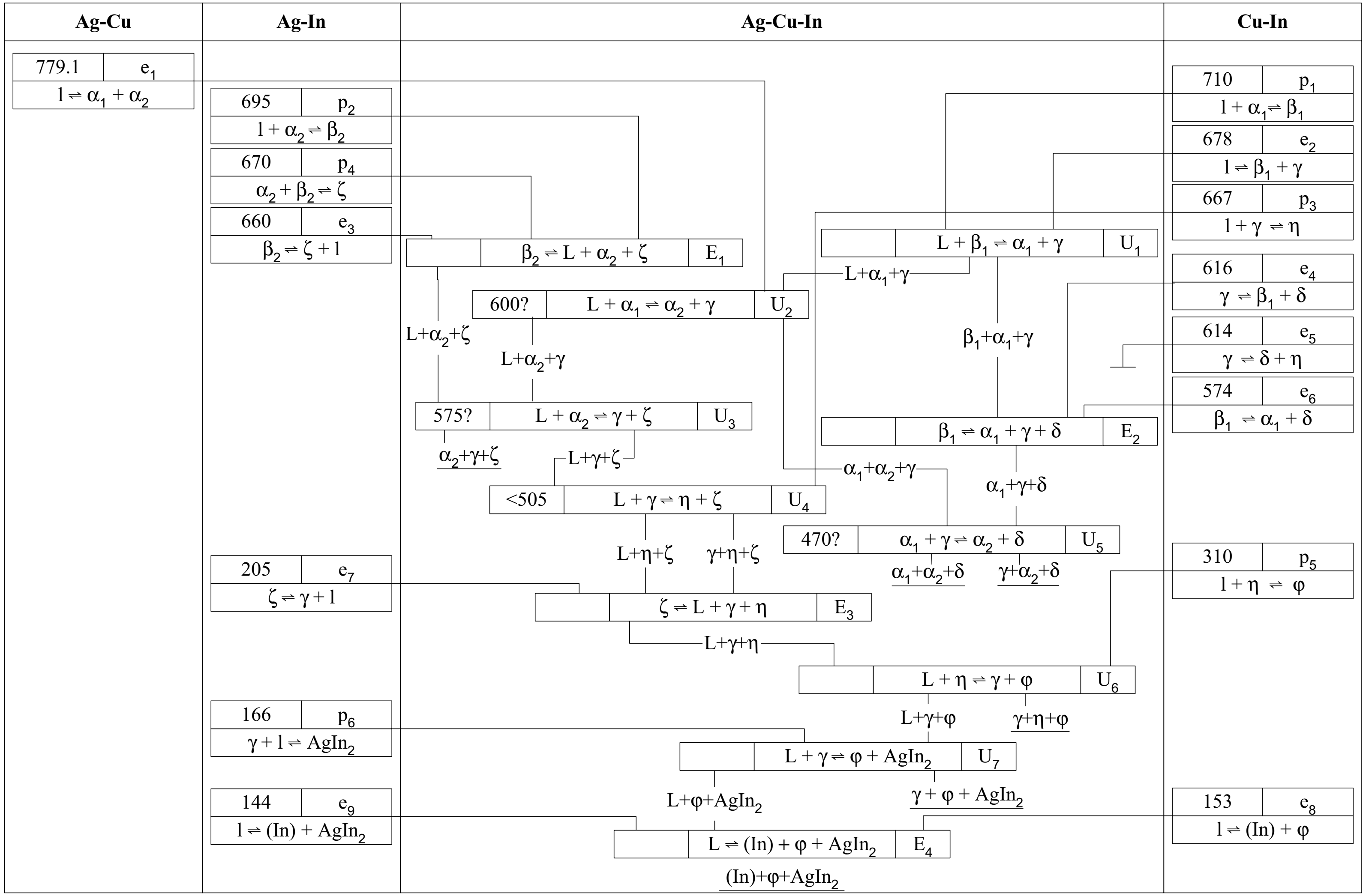


Fig. 1: Ag-Cu-In. Reaction scheme

Fig. 2: Ag-Cu-In.
Liquidus surface projection [1988Woy]

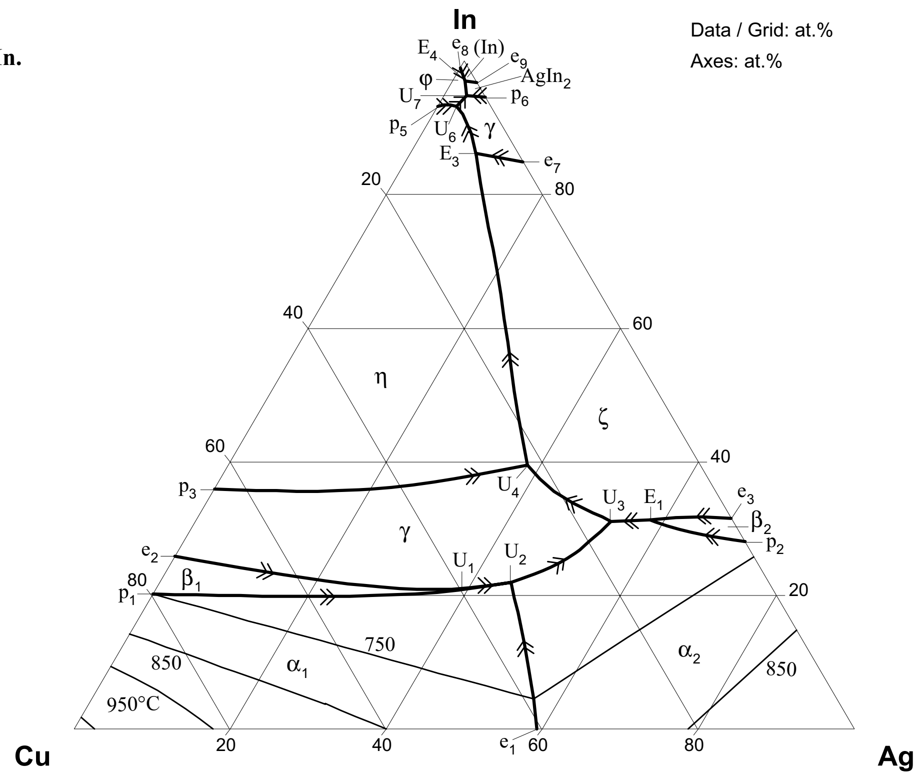


Fig. 3: Ag-Cu-In.
Indium poor liquidus surface projection [1951Geb]

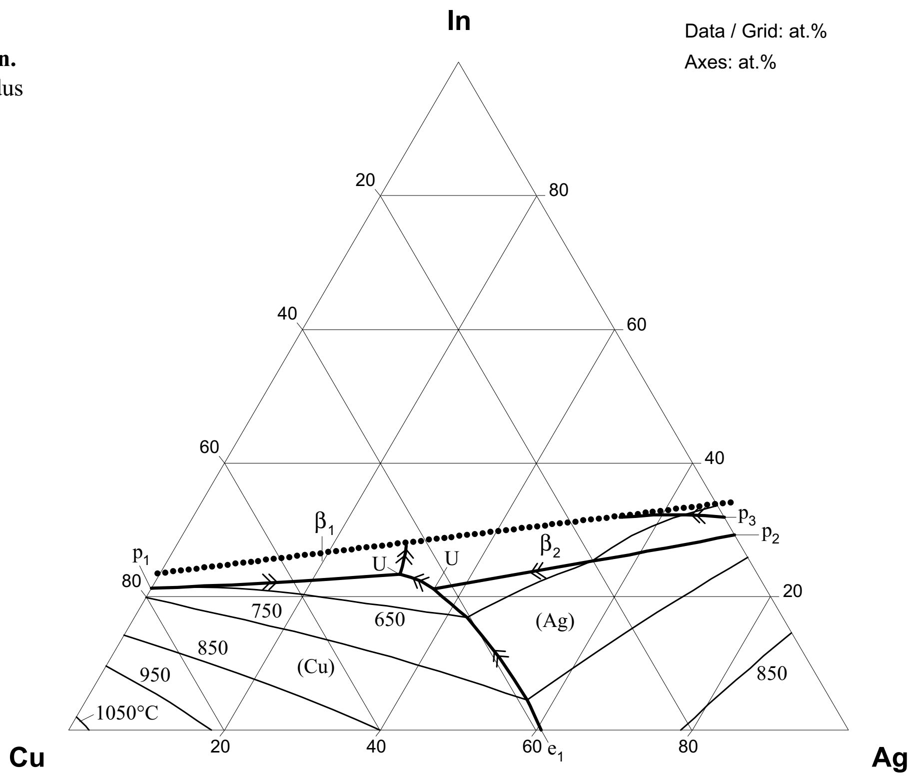


Fig. 4: Ag-Cu-In.
Isothermal section at 676°C

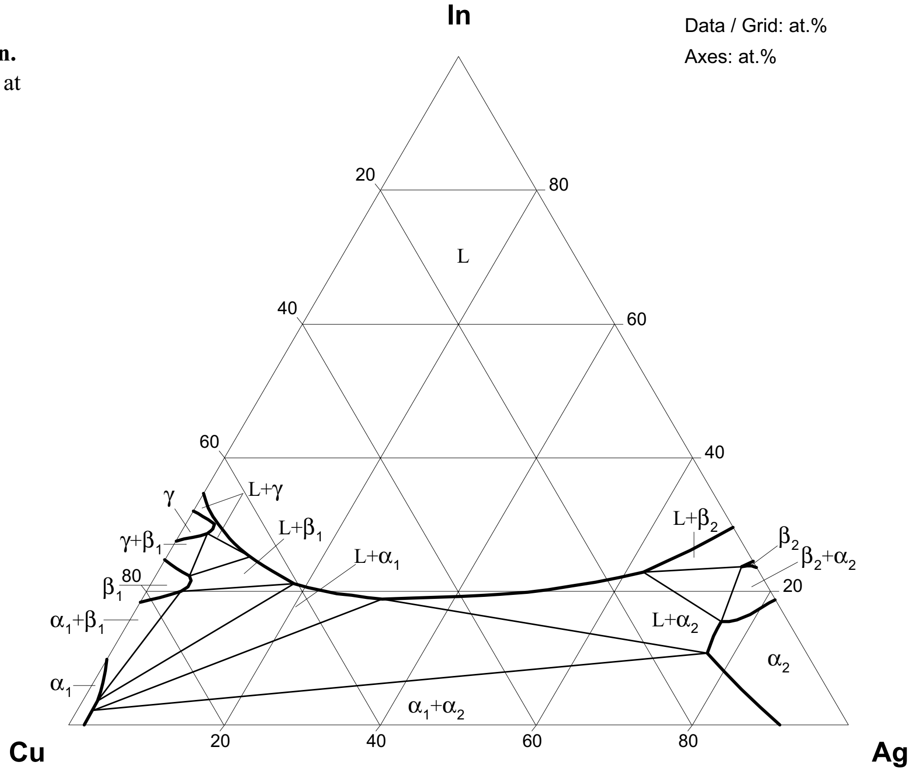


Fig. 5: Ag-Cu-In.
Isothermal section at 505°C

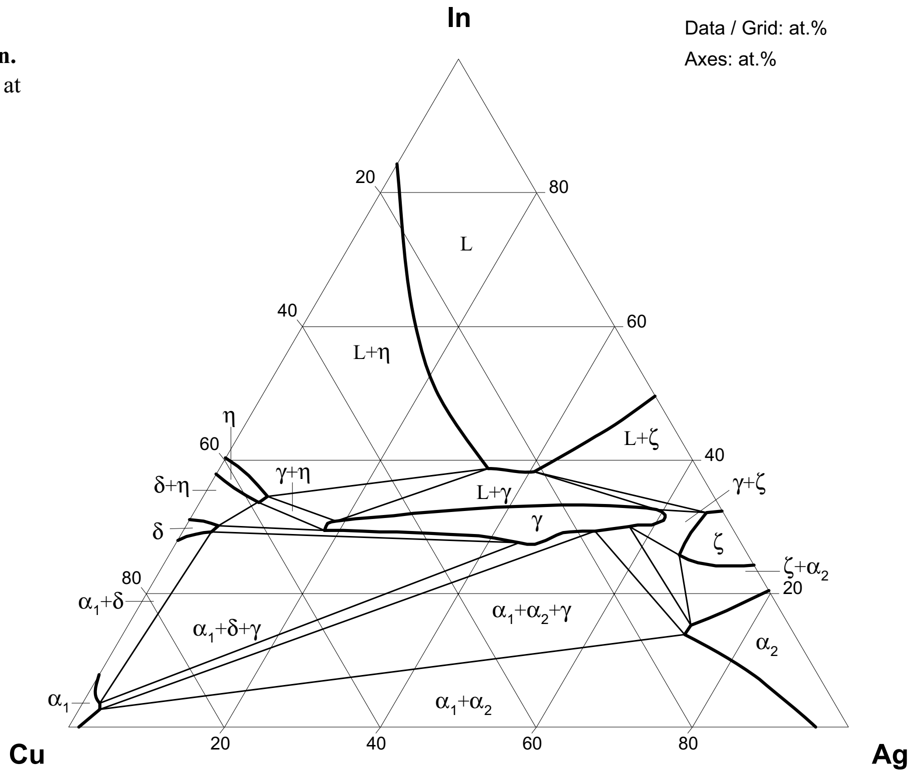


Fig. 6: Ag-Cu-In. Isothermal section at 500°C

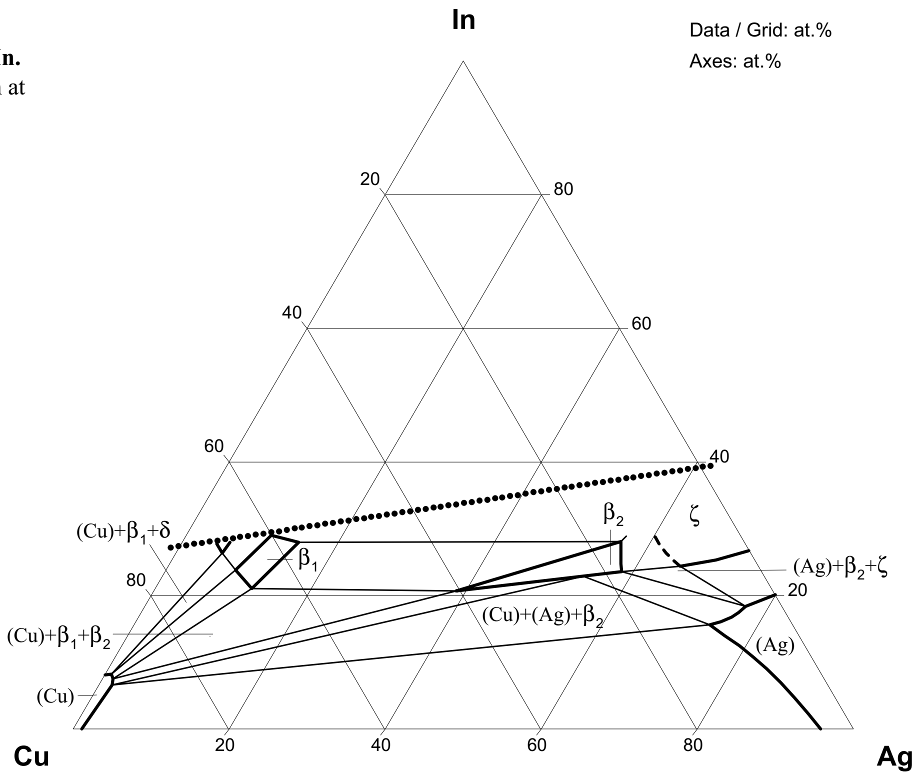
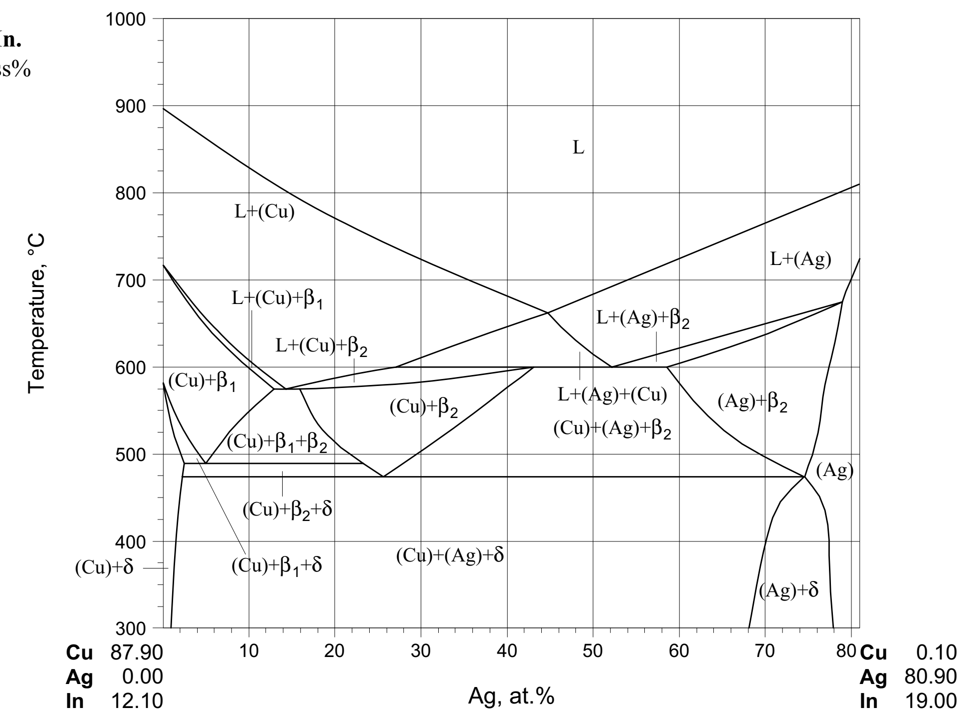


Fig. 7: Ag-Cu-In. Isopleth at 20 mass% In, plotted in at.%



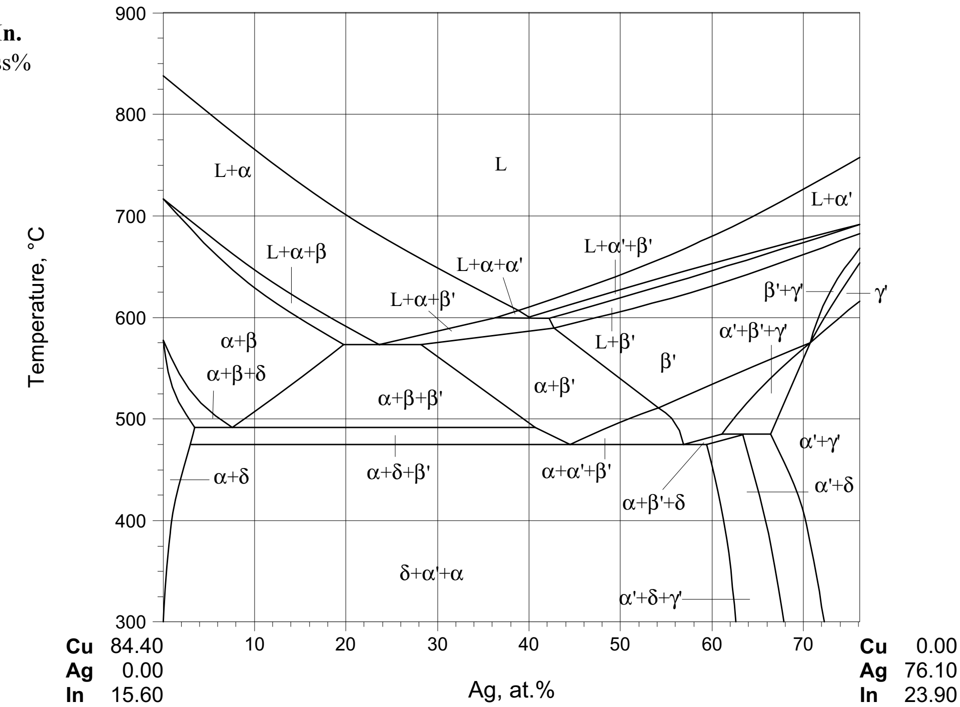


Fig. 8: Ag-Cu-In. Isopleth at 25 mass% In, plotted in at.%