(βZr) and (αZr) Terminal Solid Solutions

The melting point of βZr and the βZr ↔ αZr allotropic transformation temperature are 1855 and 863 °C, respectively [Massalski]. The maximum solubility of Bi in (βZr) is about 15 at.% [64Ham]. The peritectoid transformation temperature of (βZr) to (αZr) is about 900 °C [63Bad, 64Ham]. It is shown at 901 °C in Fig. 1 as in [Metals], because the βZr ↔ αZr transition temperature in [64Ham] was assumed to be 862 °C. The solubility of Bi in (αZr) at the peritectoid temperature is about 4 at.% [63Bad, 64Ham].

Crystal Structures and Lattice Parameters

Crystal structure and lattice parameter data for Bi-Zr phases are given in Tables 2 and 3, respectively.

Thermodynamics

According to emf measurements, the activity coefficient of infinitely dilute Zr solution can be expressed as: $\ln\gamma_{Zr} = 5.190 - 7631/T$ for T = 750 to 1000 K [79Leb].

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* Indicates key paper.

\# Indicates presence of a phase diagram.

Bi-Zr evaluation contributed by **H. Okamoto,** ASM INTERNATIONAL, Materials Park, OH 44073. This work was supported by ASM INTERNATIONAL. Literature searched through early 1987. Dr. Okamoto is the ASM/NIST Data Program Category Editor for miscellaneous binary alloys.

The Br-In (Bromine-Indium) System

By H. Okamoto
ASM INTERNATIONAL

Equilibrium Diagram

In-Br phase diagrams were proposed by [61Wal] and [62Mor] for the composition range between 50 and 75 at.% Br. Although the assessed In-Br phase diagram (Fig. 1) is based on the data of [62Mor] because of the larger number of data points used to determine the diagram, the disagreement between [61Wal] and [62Mor] is minor. Five intermediate phases exist in the In-Br system—InBr, In_5Br_7, In_4Br_7, $InBr_2$, and $InBr_3$. Special points of the assessed diagram are given in Table 1. The existence of InBr, $InBr_2$, and $InBr_3$ was known early in this century [04Thi].

(In) Terminal Solid Solution

The melting point of In is 156.634 °C [Melt]. In(L) and InBr(L) are immiscible [62Mor].

InBr

The melting point is 280 [61Wal] or 285.2 °C [62Mor]. The latter value is accepted in this assessment.

In_5Br_7

The congruent melting point of In_5Br_7 is 234.6 °C [62Mor]. [65Bra] confirmed the existence of this compound by determining the crystal structure, and the "In_2Br_3" in [61Wal] corresponds to this phase.

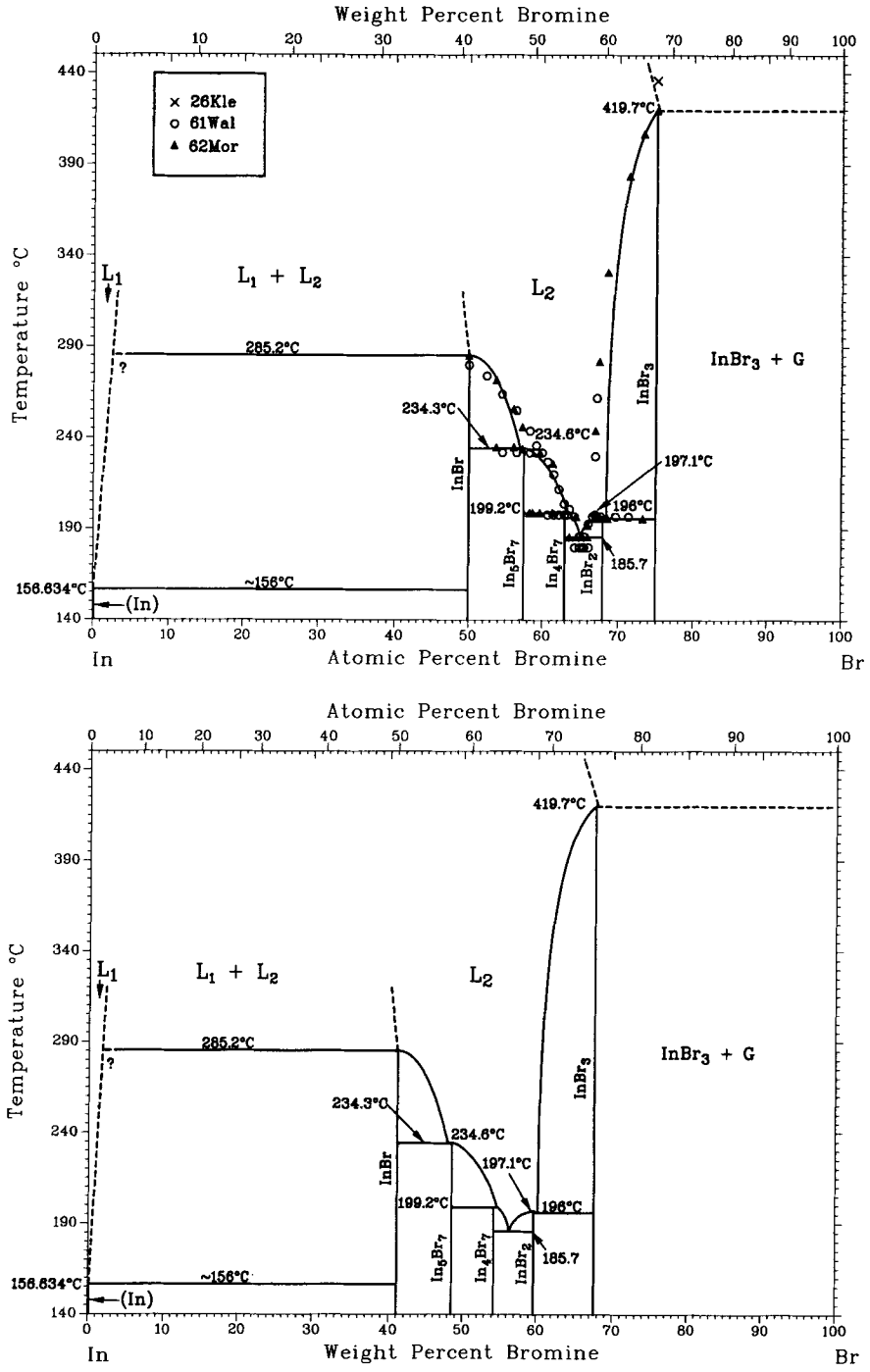
In_4Br_7

The peritectic melting temperature of In_4Br_7 is 199.2 °C [62Mor]. The composition is displaced to 63.4 at.% Br from the ideal position of 63.6 at.% Br, apparently due to vacancies at the In lattice sites. [61Wal] considered In_4Br_7 to melt congruently at 201 °C.

L ↔ In_4Br_7 + $InBr_2$ Eutectic Reaction

The eutectic point was reported at 65.3 at.% Br and 180 °C [61Wal] or 65.4 at.% Br and 185.7 °C [62Mor]. The disagreement of 5.7 °C in the eutectic temperature is exceptionally large, comparing the data sets of [61Wal] and

Fig. 1 Assessed In-Br Phase Diagram



H. Okamoto, 1990.

Table 1 Special Points of the Assessed In-Br Phase Diagram

Reaction	Compositions of the respective phases, at.% Br			Temperature, °C	Reaction type
L ⇔ In		0		156.634	Melting point
L ⇔ (In) + InBr	~0	0	50	~156	Eutectic?
L ⇔ InBr		50		285.2	Congruent
L ⇔ InBr + In_5Br_7	58.2	50	58.3	234.3	Eutectic
L ⇔ In_5Br_7		58.3		234.6	Congruent
L + In_5Br_7 ⇔ In_4Br_7	63.7	58.3	63.4	199.2	Peritectic
L ⇔ In_4Br_7 + $InBr_2$	65.4	63.4	66.7	185.7	Eutectic
L ⇔ $InBr_2$		66.7		197.1	Congruent
L ⇔ $InBr_2$ + $InBr_3$	66.8	66.7	75	196.0	Eutectic
L ⇔ $InBr_3$		75		419.7	Congruent
Br_2(g) ⇔ L		100		59.10	Boiling point
L ⇔ Br		100		-7.25	Triple point

Table 2 In-Br Crystal Structure Data

Phase	Composition, at.% Br	Pearson symbol	Space group	Strukturbericht designation	Prototype	Reference
(In)	0	*tI*2	*I*4/*mmm*	*A*6	In	[King1]
InBr	50	*oC*8	*Cmcm*	*B*33	TlI	[50Ste]
In_5Br_7	58.3	*tP*192	$P4_22_12$		...	[65Bra]
In_4Br_7	63.4	...	...	...	...	[61Wal]
$InBr_2$	66.7	...	...	...	...	[04Thi]
$InBr_3$	75	...	...	...	...	[04Thi]
(Br)	100	*oC*8	*Cmca*	...	Cl	[Massalski]

Table 3 In-Br Lattice Parameter Data

Phase	Composition, at.% Br	Lattice parameters, nm *a*	*b*	*c*	Comment	Reference
(In)	0	0.32512	...	0.49467	...	[Pearson3]
InBr	50	0.446	1.239	0.473	...	[50Ste]
In_5Br_7	58.3	1.322	...	3.727	...	[65Bra]
In_4Br_7	63.4	...	...	...	...	...
$InBr_2$	66.7	...	...	...	...	...
$InBr_3$	75	...	...	...	...	...
(Br)	100	0.668	0.449	0.874	At -150 °C	[King1]

[62Mor]. The result of [62Mor] is accepted in Fig. 1, because it is based on 18 well-defined data points (for clarity, not all points are shown in Fig. 1).

$InBr_2$

The congruent melting point of $InBr_2$ is 197.1 °C [62Mor]. Due to limited data, the type of melting is not clear in the diagram of [61Wal].

$InBr_3$

The melting point of $InBr_3$ is 436 [26Kle] or 419.7 °C [62Mor]. The latter value is accepted.

(Br) Terminal Phase

The triple point and boiling point temperatures of Br_2 are -7.25 and 59.1 °C, respectively [Massalski].

Crystal Structures and Lattice Parameters

In-Br crystal structure and lattice parameter data are summarized in Tables 2 and 3, respectively. The structures of InBr and In_5Br_7 are known. [40Bro] attempted to determine the Br-Br interatomic distance in $InBr_3$, but because the crystal structure is uncertain, a few different values were reported to be possible.

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* Indicates key paper.

\# Indicates presence of a phase diagram.

Br-In evaluation contributed by **H. Okamoto,** ASM INTERNATIONAL, Materials Park, OH 44073. This work was supported by ASM INTERNATIONAL. Literature searched through 1987. Dr. Okamoto is the ASM/NIST Data Program Category Editor for miscellaneous binary alloys.

The Cl-In (Chlorine-Indium) System

By H. Okamoto
ASM INTERNATIONAL

Equilibrium Diagram

The assessed In-Cl phase diagram (Fig. 1) is based primarily on the works of [63Pal], [68Fed], and [87Dmi]. The data of [58Cla], [66Cha], and [77Saf] are in reasonable agreement (Fig. 1). The intermediate phases existing in the assessed diagram are (1) βInCl and αInCl; (2) In_3Cl_4; (3) βIn_2Cl_3 and αIn_2Cl_3; (4) In_5Cl_9 with a possible polymorphic transition; (5) $\beta InCl_2$ and $\alpha InCl_2$; and (6) $InCl_3$. Special points of the assessed diagram are given in Table 1.

(In) Terminal Solid Solution

The melting point of In is 156.634 °C [Melt]. In(L) and InCl(L) are immiscible [63Pal]. The monotectic temperature is 216 °C [63Pal].

βInCl(red) and αInCl(yellow)

Two modifications exist in solid InCl, with a transition temperature of 120 °C [66Ber]. Syntectic melting point of InCl is 212 °C [87Dmi]. [64Fed] and [68Fed] proposed diagrams with a congruent melting point at about 225 °C. Because a critical data point in a diagram of [68Fed] does not agree with the tabulated value, the result of [87Dmi] is accepted.

On the Cl-rich side of InCl, [63Pal] observed a monotectic reaction at about 254 °C (see data points in Fig. 1). However, [58Cla] and [68Fed] observed the L/(L + In_3Cl_4) liquidus in the same composition range. The latter relationship is shown in Fig. 1. The L ⇔ βInCl + In_3Cl_4 eutectic point is 50.5 at.% Cl and 210 °C [87Dmi].

In_3Cl_4

The peritectic melting point of In_3Cl_4 is shown at 265 °C in Fig. 1, based on thermal arrest data given by [63Pal] and [68Fed]. However, [63Pal] considered this temperature to correspond to a polymorphic transformation of an unknown compound (In_xCl_y).

Table 1 Special Points of the Assessed In-Cl Phase Diagram

Reaction	Compositions of the respective phases, at.% Cl			Temperature, °C	Reaction type
L ⇔ In		0		156.634	Melting point
L ⇔ (In) + βInCl	~0	0	50	156	Eutectic
$L_1 + L_2 \Leftrightarrow \beta$InCl	?	50.24	50	212	Syntectic
βInCl ⇔ αInCl		50		120	Polymorphic
L ⇔ βInCl + In_3Cl_4	50.5	50	57.1	210	Eutectic
L + $\alpha In_2Cl_3 \Leftrightarrow In_3Cl_4$	55	60	57.1	265	Peritectic
L ⇔ βIn_2Cl_3		60		325	Congruent
L + $\beta In_2Cl_3 \Leftrightarrow \alpha In_2Cl_3$	57	60	60	302	Peritectic?
$\beta In_2Cl_3 \Leftrightarrow$ L + αIn_2Cl_3	?	63	60	284	Catatectic
L + $\alpha In_2Cl_3 \Leftrightarrow \beta In_5Cl_9$	64.5	60	64.3	258	Peritectic
$\beta In_5Cl_9 \Leftrightarrow \alpha In_5Cl_9$		64.3		224	Polymorphic
L ⇔ βIn_5Cl_9 + $\beta InCl_2$	65.8	64.3	66.7	236	Eutectic
L + $InCl_3 \Leftrightarrow \beta InCl_2$	66	75	66.7	239	Peritectic
$\beta InCl_2 \Leftrightarrow \alpha InCl_2$		66.7		186	Polymorphic
L ⇔ $InCl_3$		75		580	Congruent
$Cl_2(g) \Leftrightarrow Cl_2(L)$		100		-100.97	Boiling point
L ⇔ Cl		100		-34.05	Triple point