JPEDAV (2015) 36:518–530
DOI: 10.1007/s11669-015-0395-1
1547-7037 ©ASM International

# Supplemental Literature Review of Binary Phase Diagrams: Al-P, B-Ga, B-Nd, Ba-Ga, Bi-Cs, Ca-Ga, Cd-Gd, Cr-Mo, Gd-Ni, Ni-Pb, Ni-Sc, and Sc-Sn

*H. Okamoto*

## Introduction

*Binary Alloy Phase Diagrams, 2nd edition*, a comprehensive collection of alloy phase diagrams for 2159 binary systems, was published in 1990 (T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak., ASM International, Materials Park, OH [Massalski2]). This review intends to provide more recent information on the binary phase diagrams for the Al-P, B-Ga, B-Nd, Ba-Ga, Bi-Cs, Ca-Ga, Cd-Gd, Cr-Mo, Gd-Ni, Ni-Pb, Ni-Sc, and Sc-Sn systems that have become available after 1990. The criteria for selecting such information for inclusion in this review are (1) systems for which no phase diagram was given in [Massalski2], (2) complete diagrams that are substantially different from the earlier version, and (3) partial diagrams that alter or clarify the earlier version. Thermodynamic consistency of the new phase diagrams was checked based on phase rules and the diagrams were modified if necessary. However, each updated phase diagram has not gone through the ordinary evaluation process. Accordingly, a newer phase diagram is not always a better diagram, especially when there is too little published data on a system. For convenience, reaction tables and crystal structure data have been added when new information was available.

## Al-P (Aluminum-Phosphorus)

The Al-P phase diagram shown in [1990Mas] was assessed by [1985Mac]. The pressure was assumed to be high enough to suppress the gas phase.

The Al-P phase diagram for the ambient pressure condition was calculated by [1994Ans] and [2013Lia]. Figure 1 shows the phase diagram reported by the latter, which is based on more detailed thermodynamic data obtained by the authors.

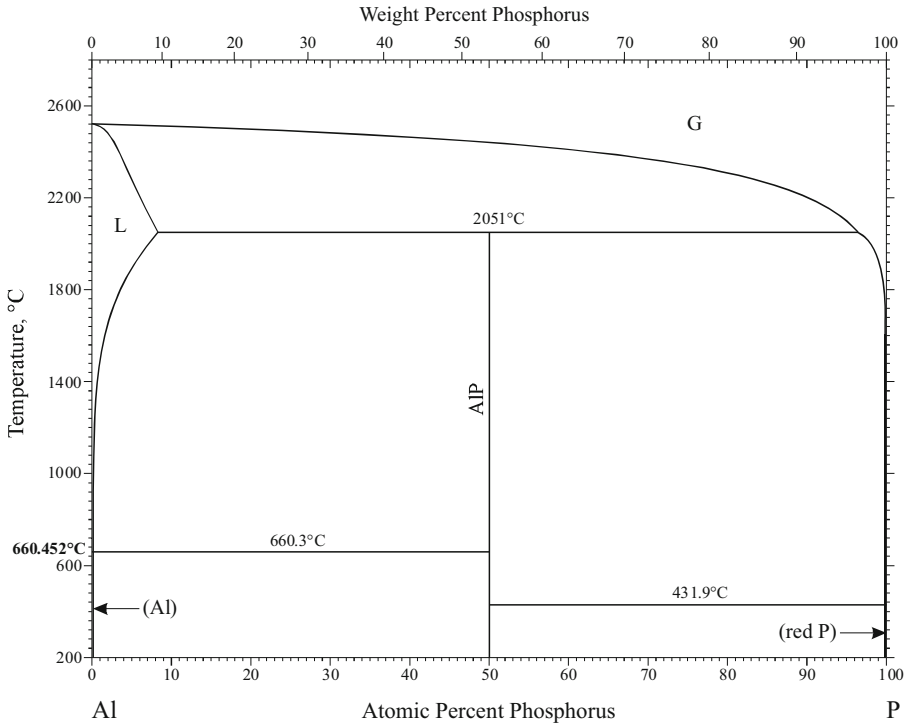


**Fig. 1** Al-P phase diagram [2013Lia]

## References

**1985Mac:** A.J. McAlister, The Al-P (Aluminum-Phosphorus) System, Bull. *Alloy Phase Diagrams*, 1985, **6**(3), p 222-234

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Al-P (Aluminum-Phosphorus), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 187-188

**1994Ans:** I. Ansara, C. Chatillon Colinet, H.L. Lukas, T. Nishizawa, H. Ohtani, K Ishida., M. Hillert, B. Sundman, B.B. Argent, A. Watson, T.G. Chart, and T.A. Anderson, A Binary Database for III-V Compound Semiconductor Systems, *CALPHAD*, 1994, **18**, p 177-222

**2013Lia:** S.M. Liang and R. Schmid-Fetzer, Thermodynamic Assessment of the Al-P System Based on Original Experimental Data, *CALPHAD*, 2013, **42**, p 76-85


## B-Ga (Boron-Gallium)

The B-Ga phase diagram in [1990Mas] was redrawn from [1991Oka]. The original diagram was proposed by [1976Mof] based on scant information that the B-Ga phase diagram is a monotectic type [1965Wal]. Accordingly the entire phase diagram was speculative.

Figure 2 shows the B-Ga phase diagram proposed by [2013Li] using first-principles calculations. This phase diagram is expected to be better than that shown in [1990Mas], but experimental confirmation is required.


## References

**1965Wal:** F. Wald and R.W. Stormont, Investigations on the Constitution of Certain Binary Boron-Metal Systems, J. Less Common Met., 1965, **9**(6), p 423-433

**1976Mof:** W.G. Moffatt, Ed., *Handbook of Binary Phase Diagrams*, General Electric Co., Schenectady, NY, 1976 and annual update

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., B-Ga (Boron-Gallium), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 483-484

**1991Oka:** H. Okamoto, B-Ga (Boron-Gallium), *J. Phase Equilib.*, 1991, **12**(4), p 501-502

**2013Li:** X. Li, K. Cheng, X. Yuan, D. Zha, J. Xin, W. Wang, C. Zhang, and Y. Du, Thermodynamic Assessment of the Ga-X (X = B, Ca, Sr, Ba) Systems Supported by First-Principles Calculations, *CALPHAD*, 2013, **43**, p 52-60


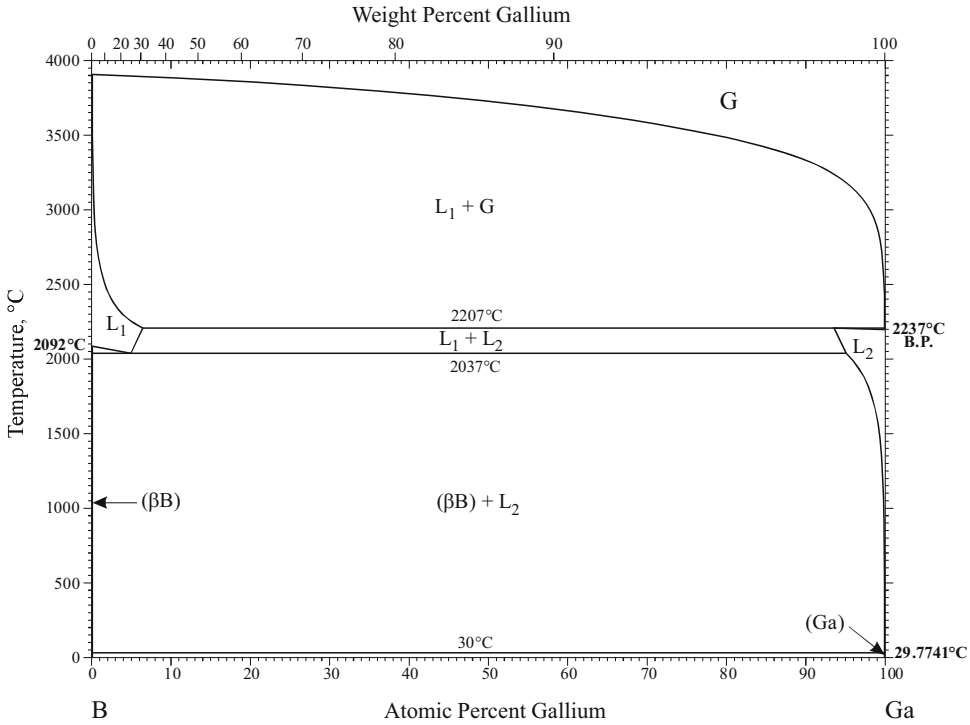


**Fig. 2** B-Ga phase diagram [2013Li]

## B-Nd (Boron-Neodymium)

The B-Nd phase diagram shown in [1990Lia] was taken from [1976Spe]. This phase diagram was updated by [1996Lia]. The $B_5Nd_2$ liquidus was drawn almost linearly to the Nd end (see [2010Oka]). Accordingly the phase diagram has become more thermodynamically unlikely by this update in view of [1991Oka].

A more plausible B-Nd phase diagram was reported by [1995Hal] by thermodynamic modeling. However, [2013 Van] disclosed that the model proposed by [1995Hal] causes formation of an unlikely inverted miscibility gap in the liquid phase. Figure 3 shows the B-Nd phase diagram calculated by [2013Van] using a problem-free thermodynamic model.

## References


**1976Spe:** K.E. Spear, Phase Diagrams: Materials Science and Engineering, Vol 4, Academic Press, New York, 1976, p 439-456

**1990Lia:** P.K. Liao, and K.E. Spear, B-Nd (Boron-Neodymium), T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 505-508

**1991Oka:** H. Okamoto and T.B. Massalski, Thermodynamically Improbable Phase Diagrams, *J. Phase Equilib.*, 1991, **12**(2), p 148-168

**1995Hal:** B. Hallemans, P. Wollants, and J.R. Roos, Thermodynamic Assessment of the Fe-Nd-B Phase Diagram, *J. Phase Equilib.*, 1995, **16**, p 137-149

**1996Lia:** P.K. Liao, K.E. Spear, and M.E. Schlesinger, The B-Nd (Boron-Neodymium) System, *J. Phase Equilib.*, 1996, **17**, p 335-339

**2010Oka:** H. Okamoto, B-Nd, *Desk Handbook, Phase Diagrams for Binary Alloys,* 2nd ed., ASM International, Materials Park, OH, 2010, p 102

**2013Van:** M.A. Van Ende and I.H. Jung, Critical Thermodynamic Evaluation and Optimization of the Fe-B, Fe-Nd, B-Nd and Nd-Fe-B Systems, *J. Alloys Compd.*, 2013, **548**, p 133-154


## Ba-Ga (Barium-Gallium)

The Ba-Ga phase diagram was first reported by [1966Bru]. Five intermediate phases ($Ba_{10-12}Ga$, $Ba_3Ga_2$, BaGa, $BaGa_2$, $BaGa_4$) were shown in this phase diagram. However, [1991Itk] concluded that there are only four equilibrium intermediate phases ($Ba_{10}Ga$, $Ba_8Ga_7$, $BaGa_2$, $BaGa_4$) in this system by reviewing the works of [1979For] and [1983For]. This phase diagram was adopted by [1990Mas].

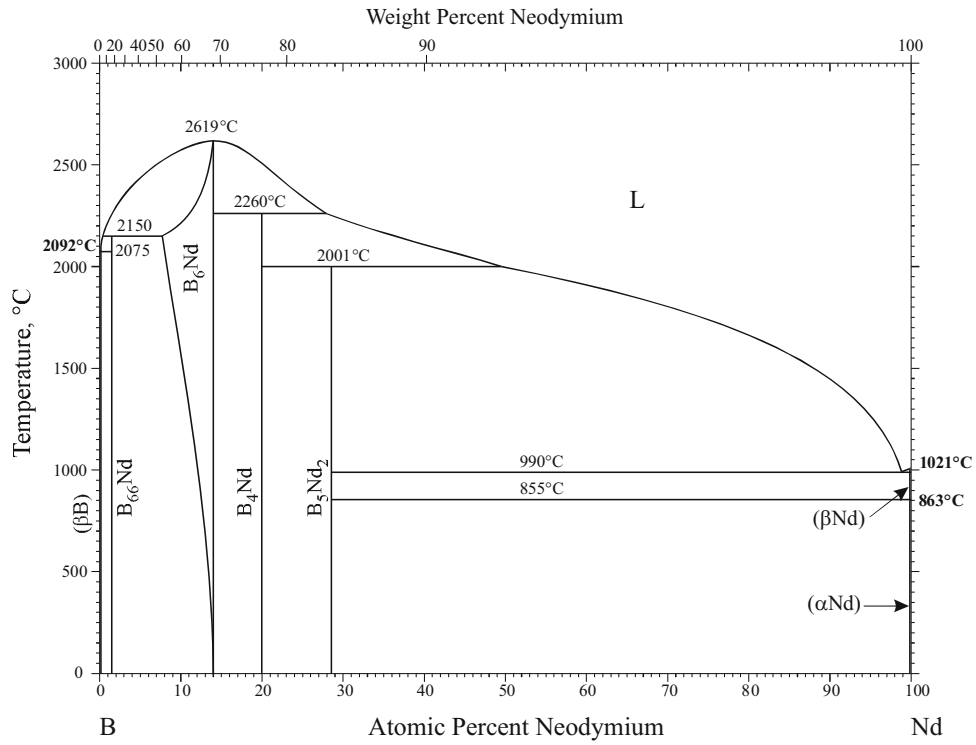


**Fig. 3** B-Nd phase diagram [2013Van]

Subsequently, [1994For] discovered a stable phase $Ba_5Ga_6$. Figure 4 shows the complete Ba-Ga phase diagram calculated by [2013Li] by taking into account the information described above.

Table 1 shows Ba-Ga crystal structure data.

## References


**1966Bru:** G. Bruzzone, Binary Systems Ca-Ga, Sr-Ga, and Ba-Ga, *Boll. Sci. Fac. Chim. Ind. Bologna*, 1966, **24**, p 113-132 in Italian

**1979For:** M.L. Fornasini and F. Merlo, The Crystal Structure of $Ba_{10}Ga$, *Rev. Chim. Mineral.*, 1979, **16**, p 458-464

**1983For:** M.L. Fornasini, Structures of $Ba_8Ga_7$, $Sr_8Ga_7$, $Sr_8Al_7$, *Acta Crystallogr. C*, 1983, **39**, p 943-946

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Ba-Ga (Barium-Gallium), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 577-579

**1991Itk:** V.P. Itkin and C.B. Alcock, The Ba-Ga (Barium-Gallium) System, *J. Phase Equilib.*, 1991, **12**(5), p 575-577

**1994For:** M.L. Fornasini and M. Pani, $Ba_5Ga_6$: A Phase with Octahedral Clusters of Gallium, *J. Alloys Compd.*, 1994, **205**, p 179-181

**2013Li:** X. Li, K. Cheng, X. Yuan, D. Zha, J. Xin, W. Wang, C. Zhang, and Y. Du, Thermodynamic Assessment of the Ga-X (X = B, Ca, Sr, Ba) Systems Supported by First-Principles Calculations, *CALPHAD*, 2013, **43**, p 52-60


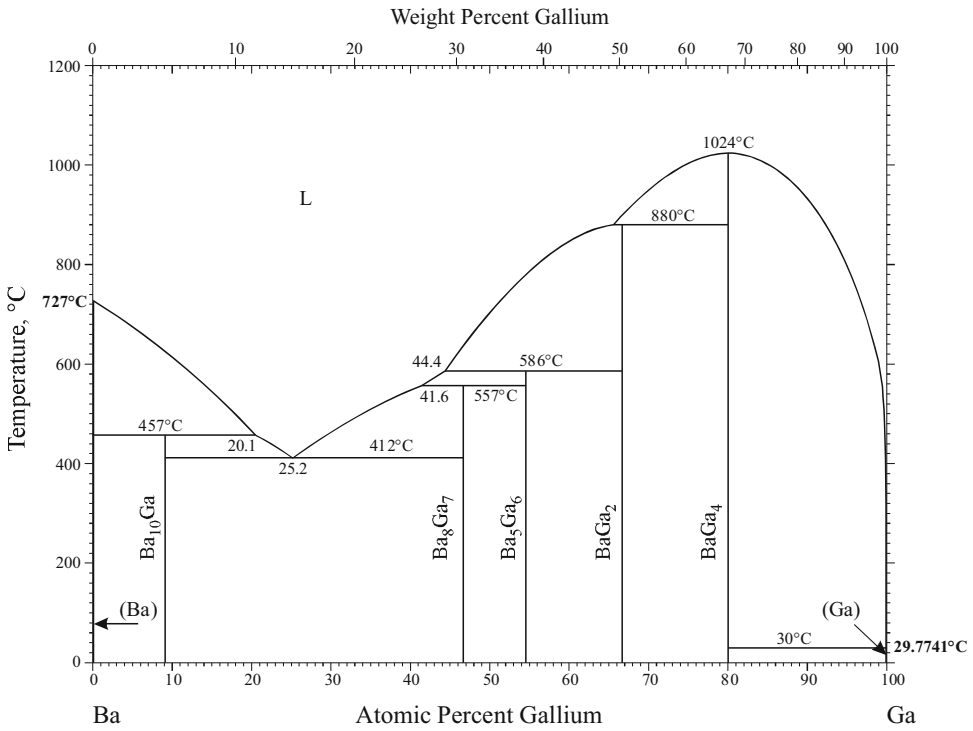


**Fig. 4** Ba-Ga phase diagram [2013Li]

**Table 1 Ba-Ga crystal structure data**

| Phase | Composition,at.% Ga | Pearson symbol | Space group | Struktur-bericht designation | Prototype |
|---|---|---|---|---|---|
| (Ba) | 0 | *cI*2 | *Im* $\bar{3}$ *m* | *A*2 | W |
| $Ba_{10}Ga$ | 9.1 | *cF*176 | *Fd* $\bar{3}$ *m* | … | $Al_{10}V$ |
| $Ba_8Ga_7$ | 46.7 | *cP*60 | $P2_13$ | … | $Al_7Sr_8$ |
| $Ba_5Ga_6$ | 54.5 | *hP*24 | *P* $\bar{6}$ *c*2 | … | … |
| $BaGa_2$ | 66.7 | *hP*3 | *P*6/*mmm* | *C*32 | $AlB_2$ |
| $BaGa_4$ | 80 | *tI*10 | *I*4/*mmm* | $D1_3$ | $Al_4Ba$ |
| (Ga) | 100 | *oC*8 | *Cmca* | *A*11 | Ga |

## Bi-Cs (Bismuth-Cesium)

The Bi-Cs phase diagram in [1990Mas] was adopted from [1991San]. The estimated error in the liquidus temperature was ±30 °C due to uncertainty in the experimental data. Figure 5 shows the Bi-Cs phase diagram obtained by thermodynamic analysis by [2015Dja]. This calculated phase diagram agrees well with the phase boundary data used for determining the phase diagram of [1991San]. However, further refinement of the thermodynamic model may be needed because the $BiCs_3$ liquidus appears to be too asymmetric according to a criterion given in [1993Oka].

## References


**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Bi-Cs (Bismuth-Cesium), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 730-731

**1991San:** J. Sangster and A.D. Pelton, The Bi-Cs (Bismuth-Cesium) System, *J. Phase Equilib.*, 1991, **12**(4), p 443-446

**1993Oka:** H. Okamoto and T.B. Massalski, Guidelines for Binary Phase Diagram Assessment, *J. Phase Equilib.*, 1993, **14**(3), p 316-335

**2015Dja:** Y. Djaballah, A. Said Amer, S. Uğur, G. Uğur, A. Hidoussi, and A. Belgacem-Bouzida, Thermodynamic Description of the Bi-Cs and Bi-Tm System Supported by First-Principles Calculations, *CALPHAD*, 2015, **48**, p 72-78


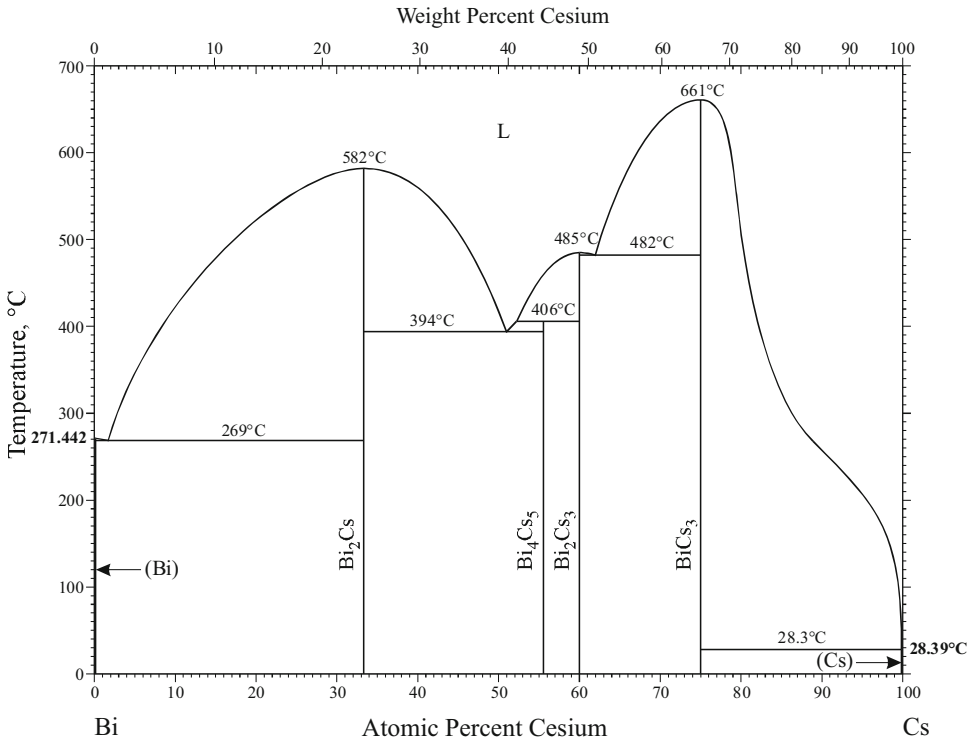


**Fig. 5** Bi-Cs phase diagram [2015Dja]

## Ca-Ga (Calcium-Gallium)

The Ca-Ga phase diagram originally reported by [1966Bru] was revised by [1989Bru]. [1990Mas] accepted the diagram of [1989Bru].

This system was analyzed thermodynamically by [2013Li]. Figure 6 shows the calculated Ca-Ga phase diagram. The $CaGa_{2+x}$ phase having an unlikely constant width (67.7 to 70.6 at.% Ga below ~900 °C) in [1990Mas] was modeled as a line compound $Ca_{25}Ga_{59}$.

## References


**1966Bru:** G. Bruzzone, Binary Systems Ca-Ga, Sr-Ga, and Ba-Ga, *Boll. Sci. Fac. Chim. Ind. Bologna*, 1966, **24,** p 113-132 in Italian

**1989Bru:** G. Bruzzone, M.L. Fornasini, and F. Merlo, Re-examination of the Ca-Ga System and Crystal Structure of $CaGa_4$, a Monoclinic Distortion of the $BaAl_4$ type, *J. Less-Common Met.*, 1989, **154**, p 67-77

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Ca-Ga (Calcium-Gallium), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 913-914

**2013Li:** X. Li, K. Cheng, X. Yuan, D. Zha, J. Xin, W. Wang, C. Zhang, and Y. Du, Thermodynamic Assessment of the Ga-X (X = B, Ca, Sr, Ba) Systems Supported by First-Principles Calculations, *CALPHAD*, 2013, **43**, p 52-60


## Cd-Gd (Cadmium-Gadolinium)

[1988Gsc] reviewed the Cd-Gd system and proposed an assessed phase diagram primarily based on [1971Bru]. This phase diagram was accepted by [1990Mas]. Six intermediate phases (one dimorphic) existing in this system were shown as line compounds. [2001Kur] attempted thermody-

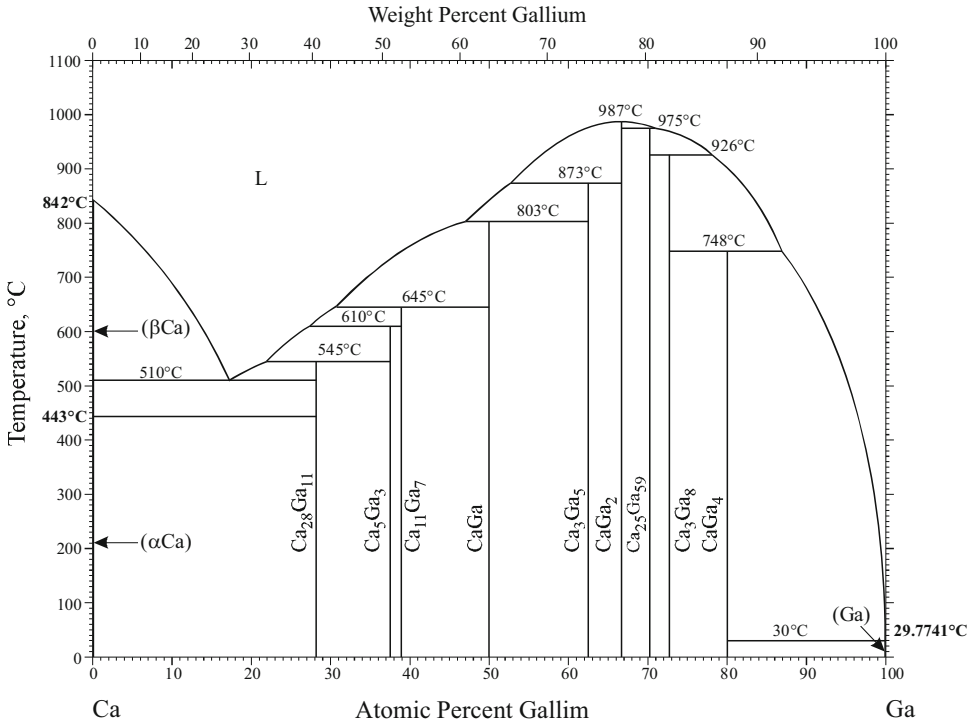


**Fig. 6** Ca-Ga phase diagram [2013Li]

namic modeling of this phase diagram for the composition range 0 to 60 at.% Gd.

[2014Rei] reinvestigated the Cd-Gd phase diagram by means of powder XRD, SEM, and DTA. The result is shown in Fig. 7. The existence of six intermediate phases was confirmed. In addition, a phase corresponding to $Cd_8Gd$ stoichiometry was found to form by a peritectic reaction at 465 °C. No crystal structure data were available for this phase.

In view of [1991Oka], the following features of this phase diagram may have to be examined further.

- Relationship between the liquidus and the solidus of (βGd): When extended to the Cd-rich direction, they would cross each other unless unlikely bends are introduced.
- Constant solid solution ranges over wide temperature range for $Cd_{45}Gd_{11}$, $\alpha Cd_2Gd$, and CdGd: Solid solution ranges usually decreases as the temperature decreases.
- Narrow two-phase field over wide temperature range between $Cd_{58}Gd_{13}$ and $Cd_{45}Gd_{11}$: One of the two phases may be unstable at low temperatures or $Cd_{45}Gd_{11}$ may have a narrower solid solution range.

## References


**1971Bru:** G. Bruzzone, M.L. Fornasini, and F. Merlo, The Gadolinium-Cadmium System, *J. Less-Common Met.*, 1971, **25**, p 295-301

**1988Gsc:** K.A. Gschneidner, Jr. and F.W. Calderwood, The Cd-Gd (Cadmium-Gadolinium) System, *Bull. Alloy Phase Diagr.*, 1988, **9**(1), p 29-31

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Cd-Gd (Cadmium-Gadolinium), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 980-983

**1991Oka:** H. Okamoto and T.B. Massalski, Thermodynamically Improbable Phase Diagrams, *J. Phase Equilib.*, 1991, **12**(2), p 148-168

**2001Kur:** M. Kurata and Y. Sakamura, Thermodynamic Assessment of Systems of Actinide or Rare Earth with Cd, *J. Phase Equilib.*, 2001, **22**, p 232-240

**2014Rei:** T.L. Reichmann and H. Ipser, Reinvestigation of the Cd-Gd Phase Diagram, *J. Alloys Compd.*, 2014, **617**, p 292-301


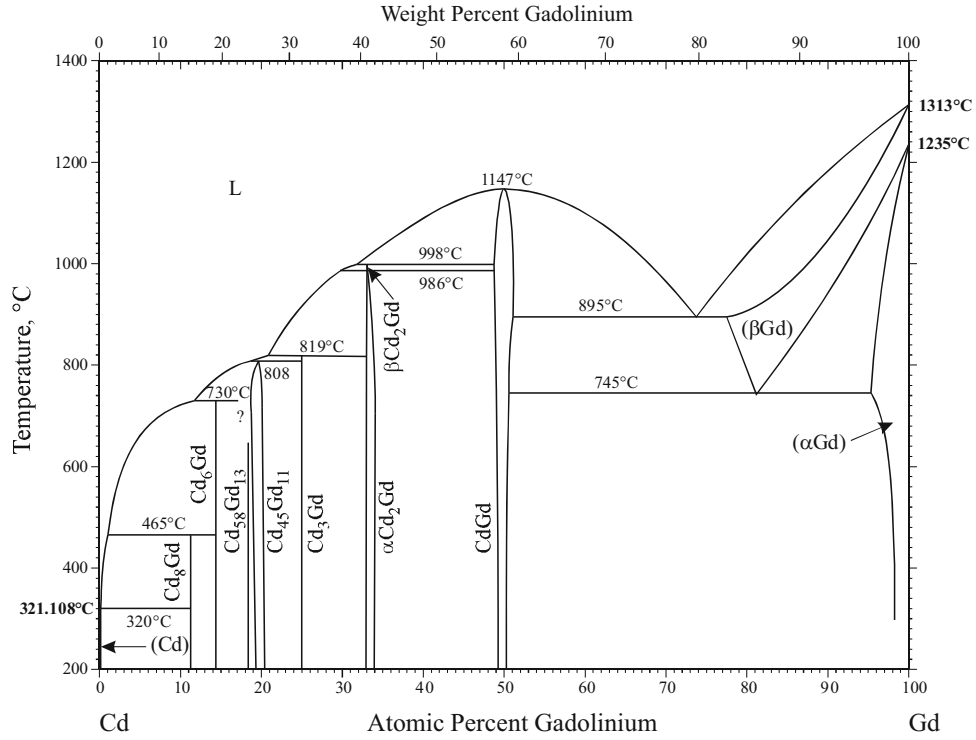


**Fig. 7** Cd-Gd phase diagram [2014Rei]

## Cr-Mo (Chromium-Molybdenum)

[1987Ven] reviewed the Cr-Mo system. The liquidus and solidus were estimated from numerous data points. The miscibility gap in the solid phase was taken from [1973Kau]. The assessed diagram was accepted in [1990Mas].

Thermodynamic modeling of the complete phase diagram was attempted by [2005Shu], [2006Tur], and [2013Jin]. Table 2 compares the minimum melting point temperature and the critical point temperature of the miscibility gap obtained by these works. It is difficult to select the most likely equilibrium diagram from these diagrams because of uncertainty in the experimental data points for the liquidus and solidus and absence of data points for the miscibility gap. Figure 8 shows the Cr-Mo phase diagram published most recently.

**Table 2 Calculated temperatures of characteristic points in the Cr-Mo phase diagram**

| Reference | Min. melting temp. (°C) | Critical temp. of miscibility gap (°C) |
|---|---|---|
| 1987Ven | 1820[a] | 880 |
| 2005Shu | 1830 | 1033 |
| 2006Tur | 1852 | 940 |
| 2013Jin | 1854 | 908 |

[a] From experimental data points

## References


**1973Kau:** L. Kaufmann and H. Nesor, Theoretical Approaches to the Determination of Phase Diagrams, Annual Review of Materials Science, 1973, 3, p 1-30

**1987Ven:** M. Venkatraman and J.P. Neumann, The Cr-Mo (Chromium-Molybdenum) System, Bull. Alloy Phase Diagrams, 1987, 8(3), p 216-220

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Cr-Mo (Chromium-Molybdenum), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 1293-1294

**2005Shu:** K.Y. Shunyaev, Calculations of Phase Diagrams in Associated Solution Model, J. Phase Equilib. Diffus., 2005, 26, p 613-615

**2006Tur:** P.E.A. Turchi, L. Kaufman, and Z.K. Liu, Modelling of Ni-Cr-Mo Based Alloys: Part I—Phase Stability, *CALPHAD* 2006, **30**, p 70-87

**2013Jin:** V. Jindal, B. Nageswara Sarma, and S. Lele, A Thermodynamic Assessment of the Cr-Mo System Using CE-CVM, *CALPHAD*, 2013, **43**, p 80-85


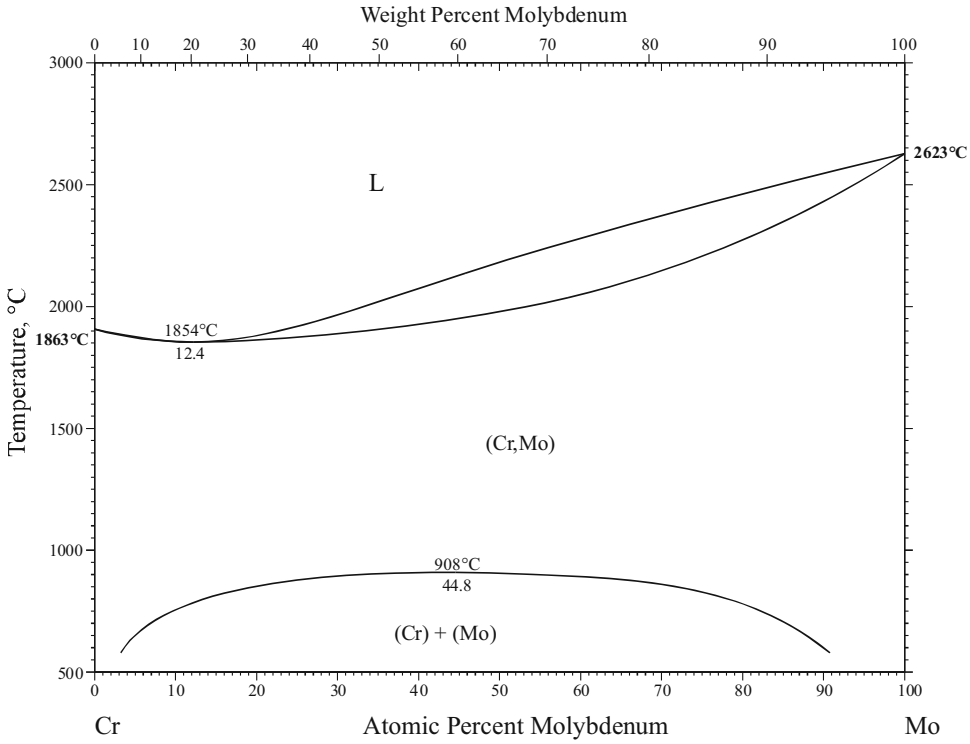


**Fig. 8** Cr-Mo phase diagram [2013Jin]

## Gd-Ni (Gadolinium-Nickel)

The Gd-Ni phase diagram in [1990Mas] was adopted from [1991Pan]. This assessed phase diagram was essentially identical to the one determined by [1986Pan]. The phase diagram of [1986Pan] in turn was in excellent agreement with [1961Nov]. Nine intermediate phases were shown ($Gd_3Ni$, $Gd_3Ni_2$, GdNi, $GdNi_2$, $GdNi_3$, $Gd_2Ni_7$, $GdNi_4$, $GdNi_5$, $Gd_2Ni_{17}$). However, [1994Oka] pointed out that further studies may be needed for this phase diagram because liquidus curves of compounds are unnaturally uneven.

[2012Xu] reexamined the Gd-Ni system and obtained the phase diagram shown in Fig. 9. A major difference from [1991Pan] is the absence of $Gd_3Ni_2$ and $GdNi_4$. This result is in good agreement with [1961Cop] and the problem pointed out by [1994Oka] has been resolved. The Gd-rich end of Fig. 9 may have to be adjusted because the melting point and allotropic transformation temperatures of pure Gd are shown fairly differently from commonly accepted values of 1313 and 1235 °C, respectively.

## References


**1961Cop:** M. Copeland and H. Kato, Gadolinium Alloys of Iron, Chromium, Nickel, and Stainless Steel, *Proc. Conf. Rare Earth Res.*, J.F. Nachman and C.E. Lundin, eds., Plenum Press, New York, 1961, p 133-141

**1961Nov:** V.F. Novy, R.C. Vickery, and E.V. Kleber, The Gadolinium-Nickel System, *Trans. Metall. Soc. AIME*, 1961, **221**, p 585-588

**1986Pan:** Y.Y. Pan, C.S. Cheng, and M. Li, A Phase Diagram of the Alloys of Gd-Ni Binary System, Wuli Xuebao, Vol 35, 1986, p 677-680 in Chinese

**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, eds., Gd-Ni (Gadolinium-Nickel), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 1901-1904

**1991Pan:** Y.Y. Pan and P. Nash, Gd-Ni (Gadolinium-Nickel), Phase Diagrams of Binary Nickel Alloys, P. Nash, Ed., ASM International, Materials Park, OH, 1991, p 140-145


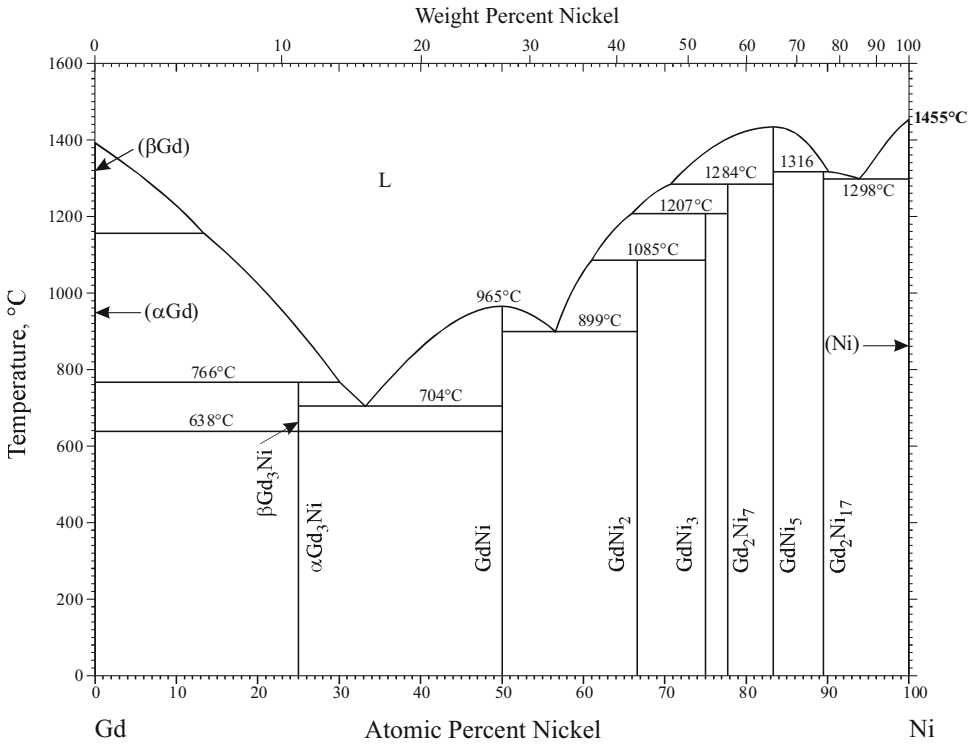


**Fig. 9** Gd-Ni phase diagram [2012Xu]

**1994Oka:** H. Okamoto and T.B. Massalski, Binary Alloy Phase Diagrams Requiring Further Studies, *J. Phase Equilib.*, 1994, **15**(5), p 500-521
**2012Xu:** G. Xu, Y.W. Cui, H. Fei, L. Zhang, F. Zheng, L. Liu, and Z. Jin, Phase Equilibria in the Gd-Ni Binary and Mg-Ni-Gd Ternary Systems, *Int. J. Mater. Res.*, 2012, **103**(10), p 1179-1187

## Ni-Pb (Nickel-Lead)

The Ni-Pb system was reviewed by [1987Nas] and the assessed phase diagram was adopted by [1990Mas]. Due to lack of experimental data, the maximum solubility of Pb in (Ni) was speculated to be ~3 at.% on the phase diagram.

[2014Oka] updated this phase diagram according to [2010Kai]. The maximum solubility was estimated to be 0.13 at.% Pb. [2013Vaa] measured the solubility of Pb in (Ni) by chemical analysis of equilibrated specimens and determined the (Ni) solvus by thermodynamic modeling. The result was quantitatively in agreement with [2010Kai]. Figure 10, 11, and 12 show the complete Ni-Pb phase diagram, Ni-rich corner, and Pb-rich corner, respectively, calculated by [2013Vaa].

## References

**1987Nas:** P. Nash, The Ni-Pb (Nickel-Lead) System, *Bull. Alloy Phase Diagrams*, 1987, **8**(3), p 264-268
**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, eds., Ni-Pb (Nickel-Lead), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 2837-2839
**2010Kai:** I. Kainulainen, P. Taskinen, and J. Gisby, A Thermodynamic Assessment of the Nickel-Lead System, *CALPHAD*, 2010, **34**, p 441-445
**2013Vaa:** Vaajamo, P. Taskinen, and J.A. Gisby, A Solubility Study and Thermodynamic Description of the System Fe-Ni-Pb, *CALPHAD*, 2013, **42**, p 66-75
**2014Oka:** H. Okamoto, Supplemental Literature Review of Binary Phase Diagrams: Al-Bi, Al-Dy, Al-Gd, Al-Tb, C-Mn, Co-Ga, Cr-Hf, Cr-Na, Er-H, Er-Zr, H-Zr, and Ni-Pb, *J. Phase Equilib. Diffus.*, 2014, **35**(3), 343-354

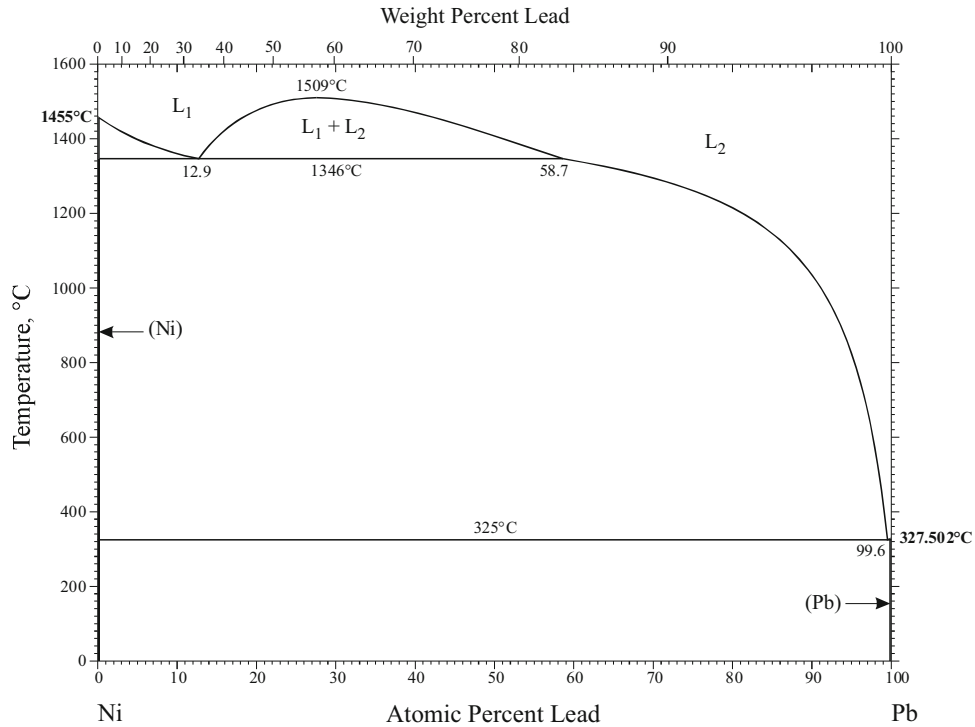


**Fig. 10** Ni-Pb phase diagram [2013Vaa]

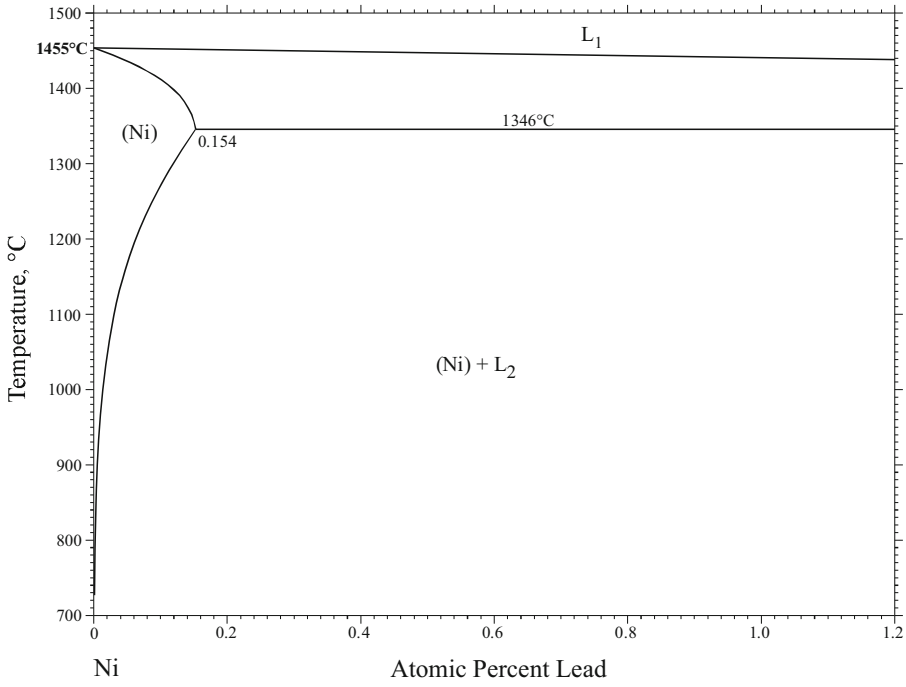


**Fig. 11** Ni-rich corner of the Ni-Pb phase diagram [2013Vaa]

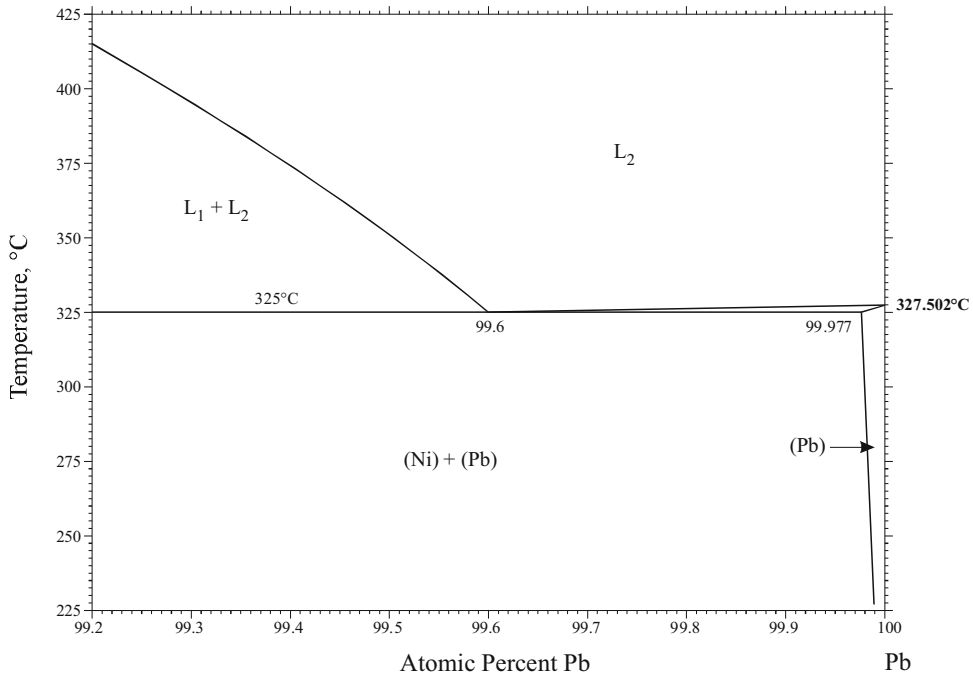


**Fig. 12** Pb-rich corner of the Ni-Pb phase diagram [2013Vaa]

## Ni-Sc (Nickel-Scandium)

The Ni-Sc phase diagram in [1990Mas] was updated by [2000Oka] based on experimental data reported by [1997Sem]. Thermodynamic modeling of this system was attempted by [2013Kar] and [2015Li]. Figure 13 shows the Ni-Sc phase diagram calculated by [2015Li]. The result of [2013Kar] seems to be less likely because the width of the $Ni_2Sc$ phase field is shown to increase as the temperature decreases, according to the guideline given by [1993Oka].

## References


**1990Mas:** T.B. Massalski, H. Okamoto, P.R. Subramanian, and L. Kacprzak, Ed., Ni-Sc (Nickel-Scandium), *Binary Alloy Phase Diagrams*, 2nd ed., ASM International, Materials Park, OH, 1990, p 2855-2857

**1993Oka:** H. Okamoto and T.B. Massalski, Guidelines for Binary Phase Diagram Assessment, *J. Phase Equilib.*, 1993, **14**(3), p 316-335

**1997Sem:** E.L. Semenova and N.Y. Rusetskaya, The Sc-Ni System, *J. Alloys Compd.*, 1997, **262/263**, p 258-262

**2000Oka:** H. Okamoto, Ni-Sc (Nickel-Scandium), *J. Phase Equilib.*, 2000, **21**(1), p 110

**2013Kar:** S. Kardellass, C. Servant, N. Selhaoui, A. Iddaoudi, M. Ait Amar, and L. Bouirden, Thermodynamic Description of the Ni-Sc System, *CALPHAD*, 2013, **42**, p 59-65

**2015Li:** C. Li, C. Guo, Z. Du, J. Li, and D. Zhu, Thermodynamic Assessment of the Ni-Sc Binary System, *CALPHAD*, 2015, **48**, p 106-112


## Sc-Sn (Scandium-Tin)

The complete Sc-Sn phase diagram was constructed by [2009Oka] by compromising two partial phase diagrams reported by [1995Pal] and [2005Pod].

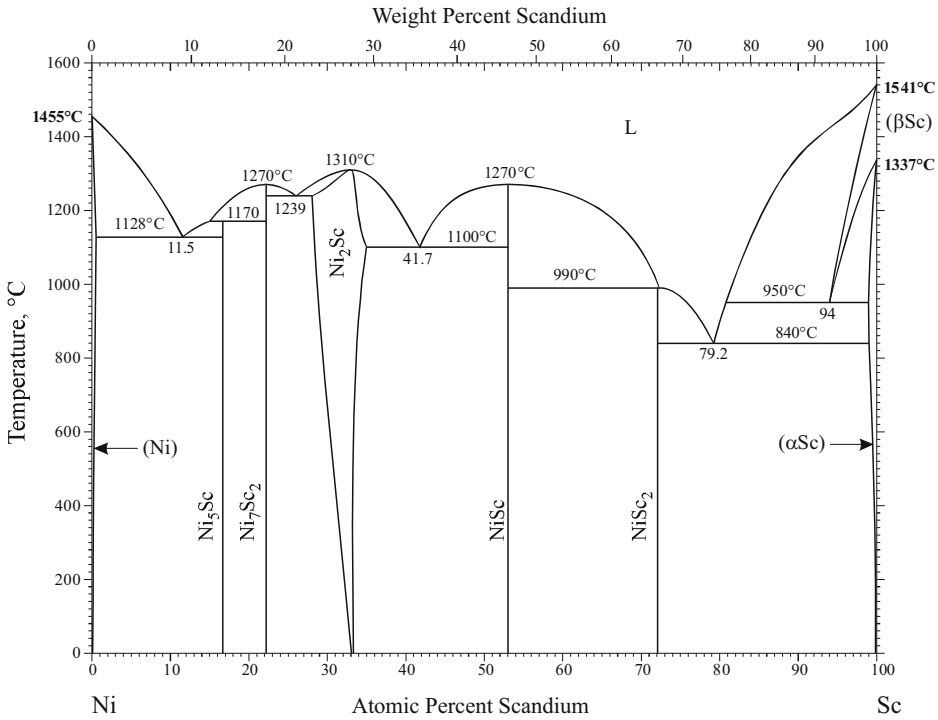


**Fig. 13** Ni-Sc phase diagram [2015Li]

This phase diagram was thermodynamically analyzed by [2013Idd]. Figure 14 shows the calculated phase diagram.

## References


**1995Pal:** A. Palenzona and P. Manfrinetti, The Phase Diagrams of the Sc-Sn and Sc-Pb Systems, 1995, **220**, p 157-160

**2005Pod:** O.V. Podarevskaya, V.G. Kudin, V.S. Zubchenko, and V.S. Sudavtsova, Phase Diagram of the Scandium-Tin System, Powder Metall. *Met. Ceram.*, 2005, **44**(9/10), p 463-466

**2009Oka:** H. Okamoto, Sc-Sn (Scandium-Tin), *J. Phase Equilib. Diffus.*, 2009, **30**(6), p 668-669

**2013Idd:** A. Iddaoudi, N. Selhaoui, M. Ait Amar, S. Kardellass, R. Karioui, and L. Bouirden, Thermodynamic Assessment of the Sc-Sn System, *CALPHAD*, 2013, **41**, p 71-75


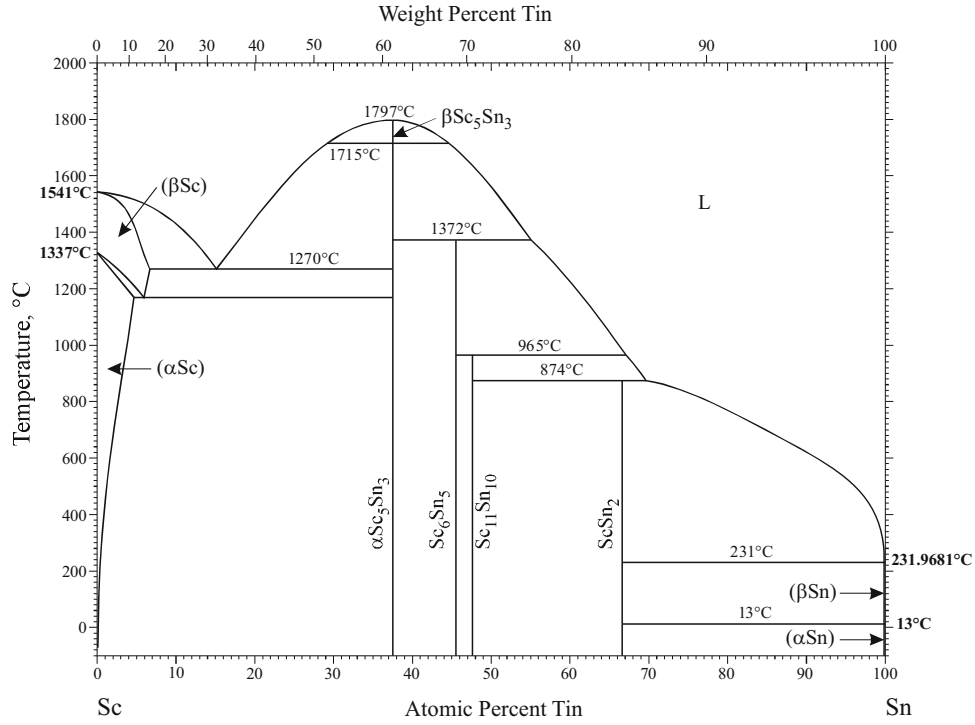


**Fig. 14** Sc-Sn phase diagram [2013Idd]