TCAL4 - TCS Al-based alloy database, Version 4.0

TCAL4 is a thermodynamic database for Al-based alloys for use with the Thermo-Calc, DICTRA and TC-PRISMA software packages. TCAL4 is based on the critical evaluation of binary, ternary and important higher-order systems which enables predictions to be made for multi-component systems and alloys of industrial importance. A hybrid approach of experiments, first-principles calculations and CALPHAD modeling has been used to obtain thermodynamic descriptions of the constituent binary and ternary systems over the whole composition and temperature ranges. The database has been validated where possible against higher-order systems and is the result of a long-term collaboration with academia that has involved extensive experimental work, theoretical calculations and critical assessments of the published literature. The database has been developed in a 34-element framework:

Al	Cu	Fe	Li	Mg	Mn	Ni	Si	Zn
B	C	Cr	Ge	Sn	Sr	Ti	V	Zr
Ag	Ca	H	Hf	K	La	Na	Sc	
Be	Bi	Cd	Ce	Co	Ga	In	Pb	

In total, 240 of the binary systems in this 34-element framework have been assessed, mostly to their full range of composition, and can be calculated with the BINARY Module in Thermo-Calc. TCAL4 also contains assessments of 62 ternaries, and these can be calculated with the TERNARY Module in Thermo-Calc. Many quaternaries with Al as one element have also been assessed.

TCAL4 contains 528 solution and intermetallic phases in total. The GAS phase is rejected by default when retrieving the data from the database. One has to manually restore it when it is required for a calculation. Phase diagrams of assessed binary and ternary systems can be conducted using the BINARY and TERNARY modules, respectively. The complete list of phases is given at the end of this document. First there is a list of all phases and then a detailed description of their models, e.g. number of sublattices and constituents on each sublattice.

TCAL4 includes nearly all stable phases in the assessed systems and most important metastable phases (or precipitates) that may form in as-cast and aged Al-based alloys. The database can be used to calculate various phase diagrams and property diagrams in the assessed systems or even extrapolated higher-order systems. The extrapolation to higher-order systems helps to understand the phase equilibria in multi-component industrial aluminum alloys, so as to predict the phase formation, phase fractions and phase compositions or to calculate the driving force of forming a phase. Note that the extrapolation to higher-order systems might not be valid beyond the Al-rich region. The database can also be used for predicting solidification behaviour of Al-alloys with the SCHEIL_GULLIVER module in Thermo-Calc and simulating multi-particle precipitation during aging treatment with the TC-PRISMA software.

Some ordered compounds with the structure of $L1_2$ or B2 were modeled as stoichiometric phases, and named as L12_FCC and B2_BCC, respectively. In general, however, the ordered B2 and $L1_2$ phases, together with bcc_A2 and fcc_A1, respectively, have been modeled with the so-called partition model, which describes an ordered phase and its disordered counterpart using a single Gibbs energy curve. This type of description is of particular importance to be able to predict second order transformations between a disordered phase and its ordered structures. Also note that there

may be several possible composition sets for the phases named FCC_L12 and BCC_B2, due to the co-existence of disordered and ordered structures or the presence of miscibility gap.

MAJOR UPDATES FROM TCAL1.0 TO TCAL1.1

The description of the Al-Zn-Mg-Cu-Fe core system has been systematically refined and validated in order to give more accurate predictions for commercial Al-based alloys, especially the 7xxx series alloys. More specifically, crucial corrections or modifications have been made for the following related ternary systems, Al-Cu-Fe, Al-Cu-Mg, Al-Cu-Zn, and Al-Mg-Zn.

Another major enhancement is that users can now get the conventional phase names in Al-based alloys for a general name used in the database by using the command LIST_SYSTEM CONSTITUENT in the TDB module.

MAJOR UPDATES FROM TCAL1.1 TO TCAL1.2

The Cu-Li, Li-Mg, Al-Cu-Li and Al-Li-Mg systems have been assessed and/or implemented in order to be able to predict the phase formation in Al-Cu-Li-Mg(-Zn) alloys (i.e. some of the 2xxx and 8xxx series alloys). The descriptions of the Al-Cu-Mg-Si and Al-Fe-Mn-Si core systems have been refined and validated, in order to give more accurate predictions for commercial Al-based alloys, including wrought alloys from series 2xxx to series 7xxx and foundry alloys series 3xx.x. The Al-Cr-Si system was tentatively assessed to include the Cr-bearing phase $Al_{13}Cr_4Si_4$.

The two compounds, AL8FEMNSI2 and AL5CU2MN3, were removed from the database since their existences were disputed. The VSI2 phase was merged into CRSI2_C40, and the AB3_L12 phase into L12_FCC. Thermodynamic models were reviewed for most phases, and many un-assessed parameters were reasonably estimated. Some phases were renamed to use their conventional names.

Additionally, the C-Mg binary description was reassessed. Now the two Mg carbides, MgC_2 and Mg_2C_3, are metastable and the C solubility in liquid Mg is greatly reduced to accord with the mostly published experimental data.

MAJOR UPDATES FROM TCAL1.2 TO TCAL2.0

Since TCAL2, all necessary volume data (including molar volume and thermal expansion) had been added for most of the solution phases and intermetallic phases. This allows for the calculation of volume fraction of phases, as well as density, thermal expansivity and lattice parameters using Thermo-Calc. However, it should be noted that the molar volume data incorporated has no pressure dependence.

21 more binary systems have been implemented: Al-Be, Al-Bi, Al-Cd, Al-Ce, Al-Co, Al-Ga, Al-In, Al-Pb, Bi-Cu, Cd-Cu, Ce-Cu, Co-Li, Cr-Li, Cu-Co, Cu-Ga, Cu-In, Cu-Pb, Cu-Sc, Li-Ni, Li-Si and Li-Zr. Some of them were reassessed in this project. Additionally, the Al-Ca and Al-Sc descriptions have been updated. The $AlLi_2$ phase was considered in Al-Li.

The three ternary systems, Al-C-Si, Al-Cu-Sc, and Al-Li-Si, have been newly implemented. The previous provisional description of the Al-Cr-Si system has been replaced by a much more reliable description, which is derived from a thorough thermodynamic modeling over the entire compositional range and a wide temperature range. The Mn-Ni-Si description is also updated.

MAJOR UPDATES FROM TCAL2.0 TO TCAL2.1.1

The Al-Fe-Mn-Si quaternary description had been systematically refined, including a deep revision of the Al-Fe-Si description and adjustments of the Al-Fe-Mn and Al-Mn-Si descriptions. It has been validated that this refinement improved the phase formation in a wide range of casting and wrought aluminum alloys, since Fe, Mn and Si are the most common additives and/or impurities in aluminum alloys.

A new Al-Ni description had been adopted and adjustments were subsequently made on the Al-Ni-based ternary systems.

The BCC_B2 description in the Ni-Zn binary system was reassessed. The Al-Ni-Zn ternary was reassessed. The Al-Mn-Ni description was improved by solving some known issues.

Both the Al-Cr and Al-V binary systems were improved in the Al-Rich corner. The Al-Si molar volume data were refined.

MAJOR UPDATES FROM TCAL2.1.1 TO TCAL3.0

19 binary systems were added, Ag-Ca, Ca-Cu, Ca-Fe, Ca-H, Ca-La, Ca-Li, Ca-Mn, Ca-Na, Ca-Ni, Ca-Sc, Ca-Si, Ca-Sr, Ca-Zn, Ag-Sc, Fe-Sc, Mn-Sc, Ni-Sc, Sc-Si and Sc-Zr.

Modeling of Al-Cu metastable precipitates: GPI Zones (described as the miscibility gap of fcc_A1), θ''-Al_3Cu (i.e. GPII Zones) and θ'-Al_2Cu.

Modeling of Al-Cu-Mg-Zn metastable phases: S'-Al_2CuMg, T'-$Al_{0.3}Mg_{0.4}Zn_{0.3}$ and η'-$Al_3Mg_{2.5}Zn_{3.5}$.

Modeling of Al-Mg-Si metastable precipitates: β''-Mg_5Si_6 (GPII zones), Al-containing β''-$Al_2Mg_5Si_4$, β'-Mg_9Si_5, U1-Al_2MgSi_2, U2-$Al_4Mg_4Si_4$ and B'-$Al_3Mg_9Si_7$.

Modeling of the metastable Al_mFe phase (modeled as Al_4Fe), which has been observed in some as-cast aluminum alloys such as AA1xxx, AA5128 and A206.

Necessary volume data were assessed for the new phases and newly introduced end-members. The Sn-Zn and Cu-Fe-Ni descriptions were updated. Some known issues were solved.

MAJOR UPDATES FROM TCAL3.0 TO TCAL4.0

The metastable Al-Cu precipitate Ω was modeled as the Al2Cu_OMEGA phase. In the Al-Cu-Mg-Zn system, the descriptions of the metastable precipitates ETA_PRIME (η') and T_PRIME (T') were refined. In the Al-Mg-Si system, the BETA_AL_DPRIME (Al-containing β'') phase was merged into BETA_DPRIME (β'') and treated as the same phase.

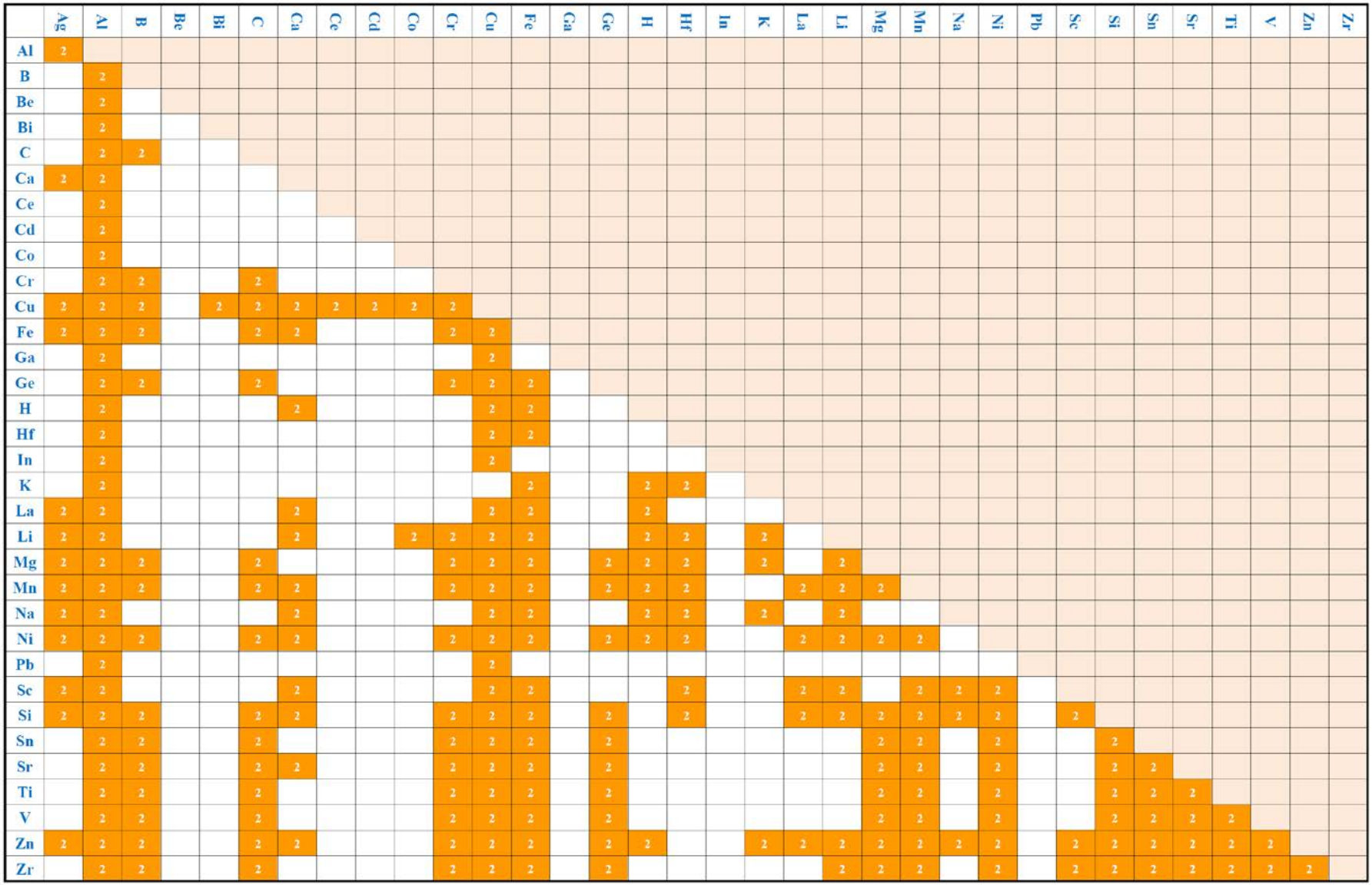
53 Ag-, H-, Hf-, K-, La-, Li-, Na- and/or Sc-containing binary systems were added, Ag-Cu, Ag-Fe, Ag-La, Ag-Li, Ag-Mg, Ag-Mn, Ag-Na, Ag-Ni, Ag-Si, Ag-Zn, Cu-H, Cu-Hf, Cu-La, Cu-Na, Fe-H, Fe-Hf, Fe-K, Fe-La, Fe-Li, Fe-Na, H-K, H-La, H-Li, H-Mg, H-Mn, H-Na, H-Ni, H-Zn, Hf-K, Hf-Li, Hf-Mg, Hf-Mn, Hf-Na, Hf-Ni, Hf-Sc, Hf-Si, K-Li, K-Mg, K-Na, K-Zn, La-Mn, La-Ni, La-Sc, La-Si, La-Zn, Li-Mn, Li-Na, Li-Sc, Li-Zn, Na-Sc, Na-Si, Na-Zn, and Sc-Zn. The previous Ag-Al binary description was replaced.

HCP_ZN was merged into HCP_A3. Necessary adjustments were made for the descriptions of Zn-containing systems in order to reproduce the phase equilibria.

Zr was introduced to Al3Ti_D022 and Ti to Al3Zr_D023. Al-Ti was updated in the Al-rich region. A preliminary assessment of the Al-Ti-Zr system was conducted. The description of Al4Mn_R in the Al-Fe-Mn system was refined.

Molar volumes and thermal expansivities were evaluated for all the newly added phases and end-members. Some existing volume data were updated as well.

Assessed binary systems in full range of composition and temperature:



Assessed ternary systems, mostly in full compositional ranges

Al-C-Si	Al-Cr-Si	Al-Cu-Fe	Al-Cu-Li	Al-Cu-Mg	Al-Cu-Mn
Al-Cu-Ni	Al-Cu-Sc	Al-Cu-Si	Al-Cu-Zn	Al-Fe-Mg	Al-Fe-Mn
Al-Fe-Ni	Al-Fe-Si	Al-Fe-Zn	Al-Li-Mg	Al-Li-Si	Al-Mg-Mn
Al-Mg-Ni	Al-Mg-Si	Al-Mg-Zn	Al-Mn-Ni	Al-Mn-Si	Al-Mn-Zn
Al-Ni-Si	Al-Ni-Zn	Al-Si-Zn	Cu-Fe-Mg	Cu-Fe-Mn	Cu-Fe-N
iCu-Fe-Si	Cu-Fe-Zn	Cu-Mg-Mn	Cu-Mg-Ni	Cu-Mg-Si	Cu-Mg-Zn
Cu-Mn-Ni	Cu-Mn-Si	Cu-Mn-Zn	Cu-Ni-Si	Cu-Ni-Zn	Cu-Si-Zn
Fe-Mg-Mn	Fe-Mg-Ni	Fe-Mg-Si	Fe-Mg-Zn	Fe-Mn-Ni	Fe-Mn-Si
Fe-Mn-Zn	Fe-Ni-Si	Fe-Ni-Zn	Fe-Si-Zn	Mg-Mn-Ni	Mg-Mn-Si
Mg-Mn-Zn	Mg-Ni-Si	Mg-Ni-Zn	Mg-Si-Zn	Mn-Ni-Si	Mn-Ni-Zn
Mn-Si-Zn	Ni-Si-Zn				

Assessed quaternary systems

Al-Cu-Mg-Zn	Al-Cu-Mg-Si	Al-Fe-Mn-Si	Al-Cu-Fe-Mn	Al-Cu-Fe-Ni	Al-Cu-Mg-Ni
Al-Cu-Mn-Si	Al-Cu-Ni-Si	Al-Fe-Mg-Mn	Al-Fe-Mg-Si	Al-Fe-Ni-Si	Al-Mg-Mn-Si

Examples of calculations[1]

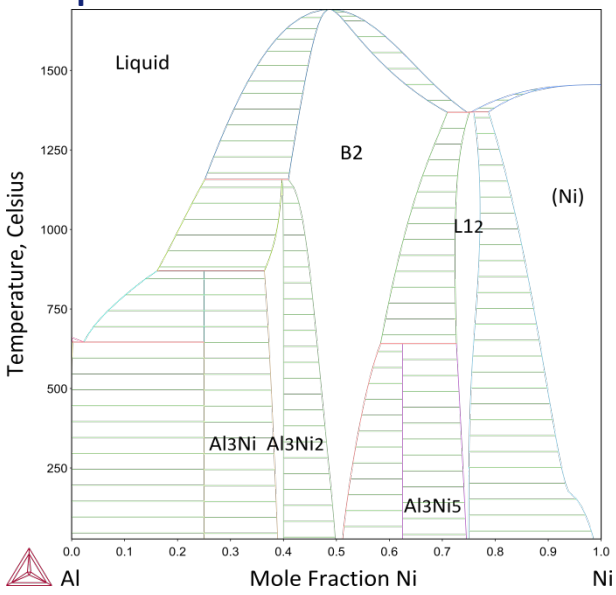


Fig.1: Calculated Al-Ni phase diagram[1]

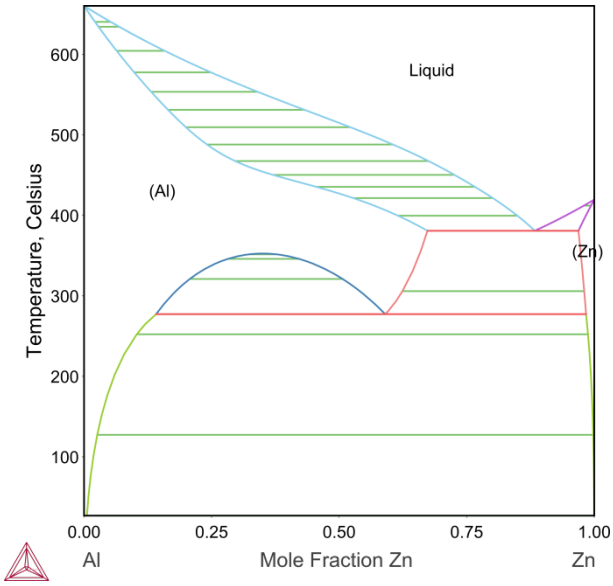


Fig.2: Calculated Al-Zn phase diagram[2]

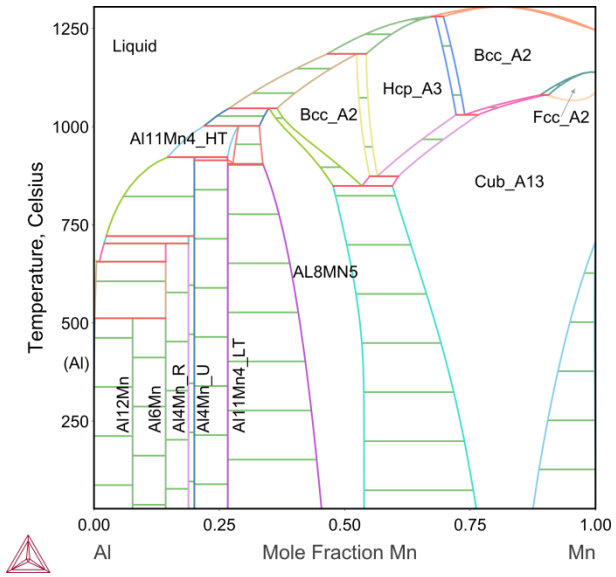


Fig.3: Calculated Al-Mn phase diagram[3]

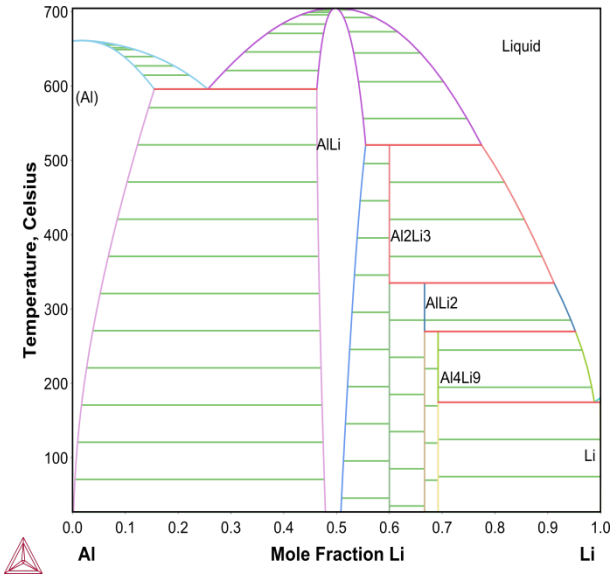


Fig.4: Calculated Al-Li phase diagram[4]

[1] Some phase diagrams had been calculated with older versions of the TCAL database, so small differences might be observed if they are recalculated with TCAL4. For the systems, which had been considerably or significantly improved, their phase diagrams were recalculated with TCAL4.

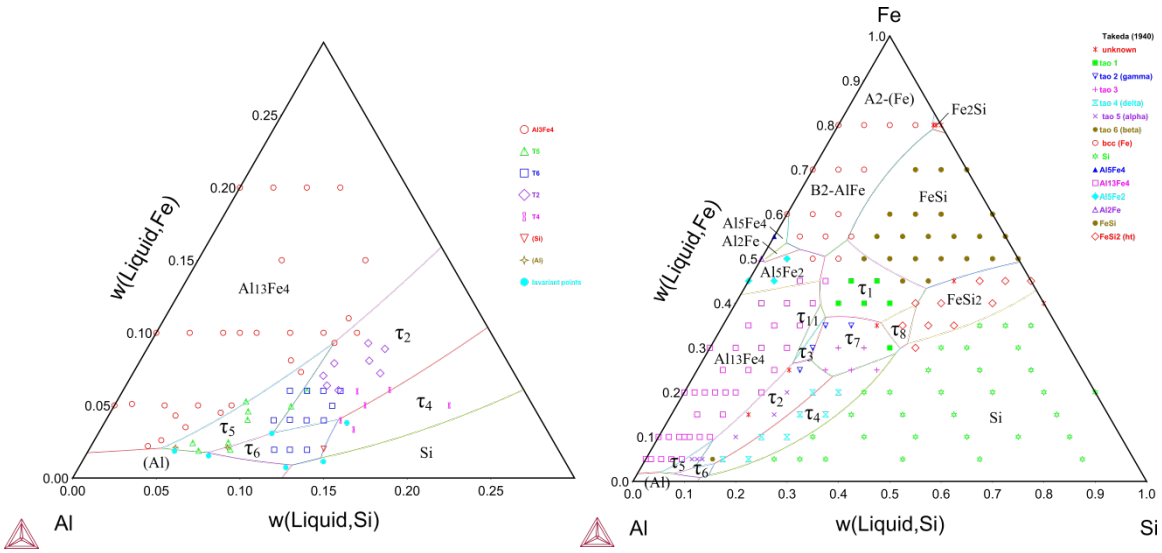


Fig.5: Calculated Al-Fe-Si liquidus projection (τ_5: α-AlFeSi; τ_6: β-AlFeSi), (a) in the Al-rich corner (the invariant points are from Pontevichi et al. [5, 6] and the remaining data from Takeda and Mutuzaki [7], Munson [8] and Zakharov et al. [9]); (b) over the entire compositional range, with the data from Takeda and Mutuzaki [7].

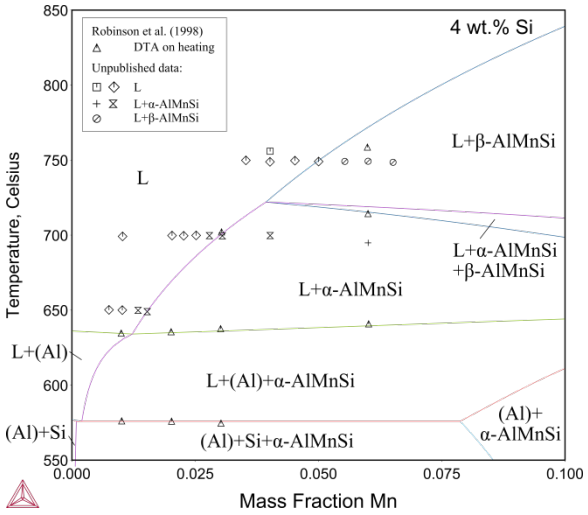


Fig.6: Al-Mn-Si vertical section at 4 wt. % Si (β-AlMnSi: τ_8; α-AlMnSi: τ_9)

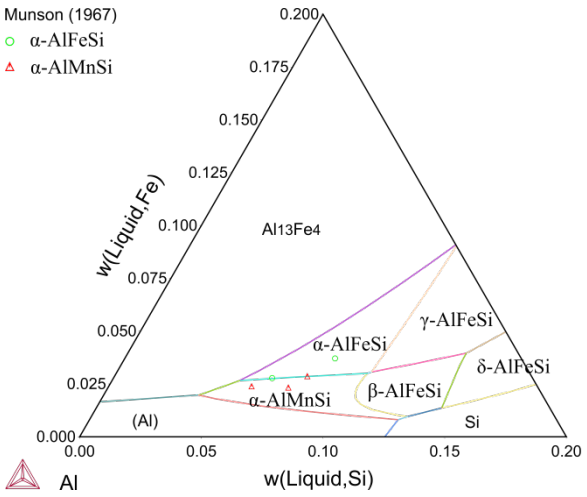


Fig.7: Al-Fe-Mn-Si liquidus surface at 0.3 wt. % Mn. (α-AlFeSi: τ_5; β-AlFeSi: τ_6; γ-AlFeSi: τ_2; δ-AlFeSi: τ_4; α-AlMnSi: τ_9)

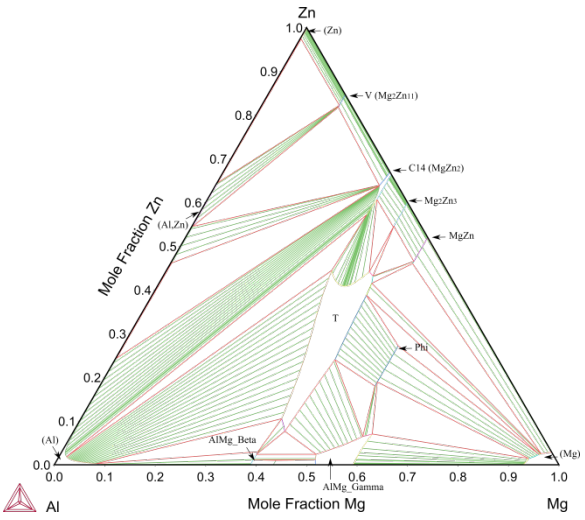


Fig.8: Isothermal section of Al-Mg-Zn[10] at 335°C

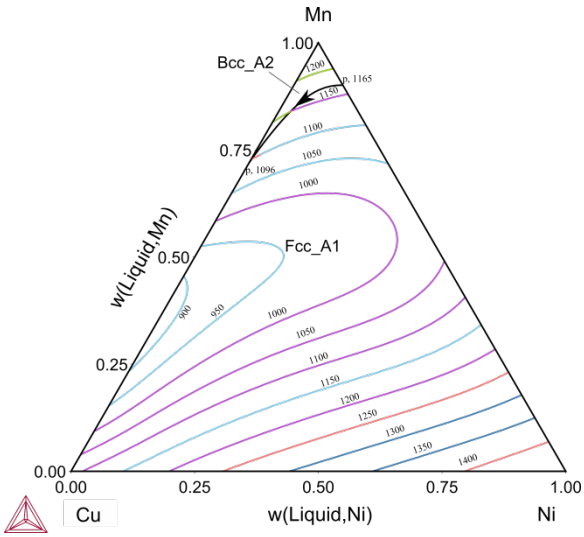


Fig.9: Liquidus projection with isothermal lines in the Cu–Mn–Ni system[11]

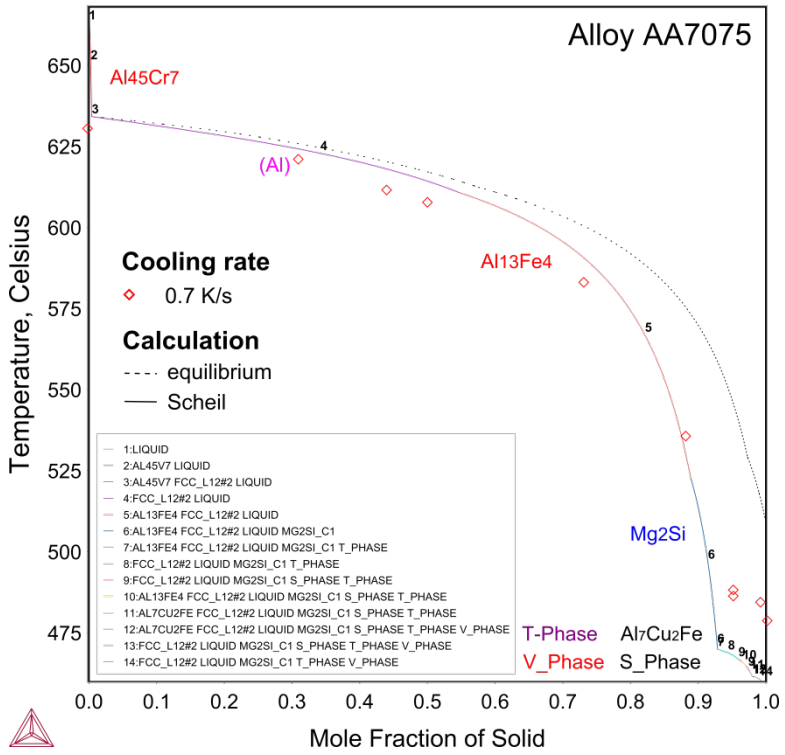


Fig.10: Equilibrium solidification and Scheil solidification simulations of alloy AA7075, compared with experimental result [12]. (Al), $Al_{13}Fe_4$, Mg_2Si, T-Phase and V-Phase ($MgZn_2$) are found in the microstructure as predicted from the calculation. $Al_{45}Cr_7$ forms primarily as a Cr-bearing phase, which may have been overlooked in experimental investigation due to its small amount. S-Phase was shown at the late stage of the Scheil solidification and its amount is small. Al_2Cu was experimentally observed but not shown in the calculation.

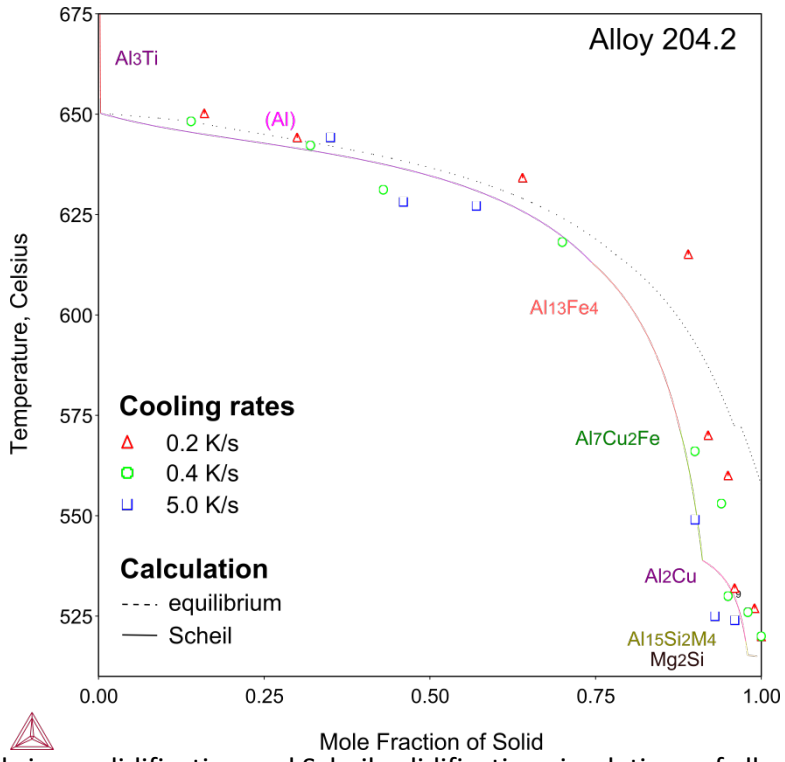


Fig.11: Equilibrium solidification and Scheil solidification simulations of alloy 204.2, compared with experimental result [12]. (Al), $Al_{13}Fe_4$, Al_7Cu_2Fe and Al_2Cu are found in the microstructure as predicted from the calculations. Al_3Ti appeared as the primary phase since this alloy contains 0.22 wt. % Ti.

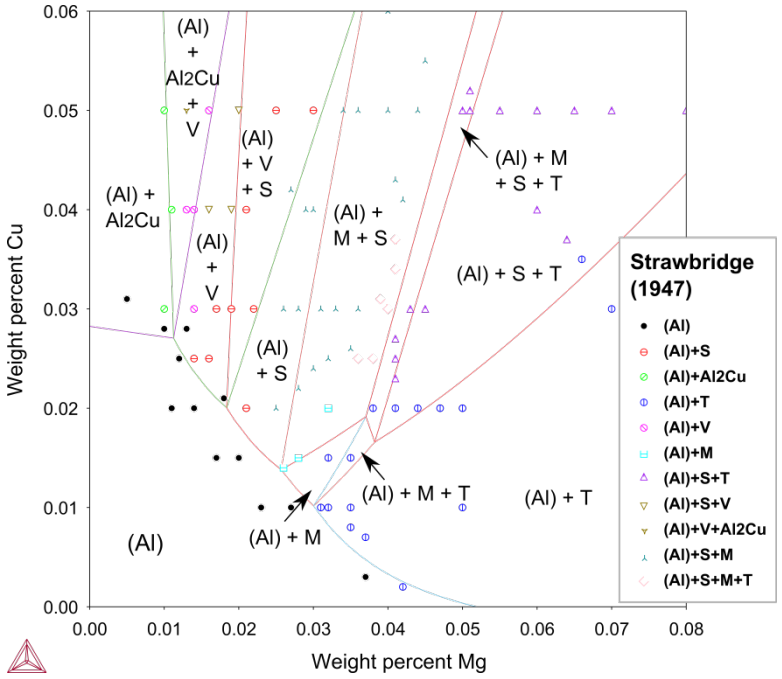


Fig.12: Calculated isothermal sections of the Al-Cu-Mg-Zn system at 460°C: at 8 wt. % Zn (experimental data are from Strawbridge et al. [13]).

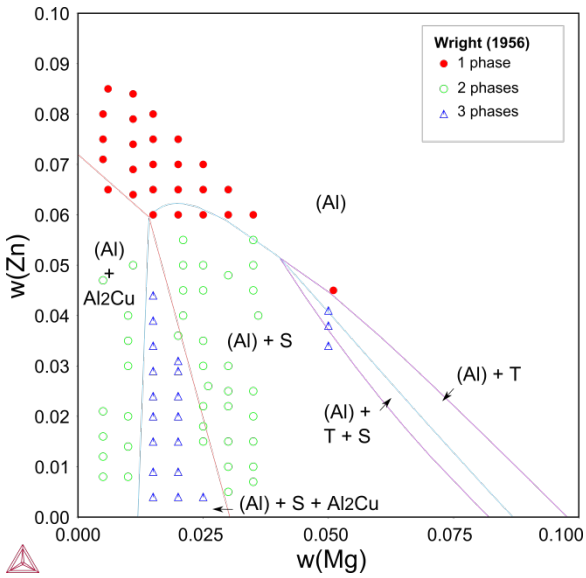


Fig.13: Calculated isothermal sections of the Al-Cu-Mg-Zn system at 90 wt.% Al (experimental data are from Wright [14]).

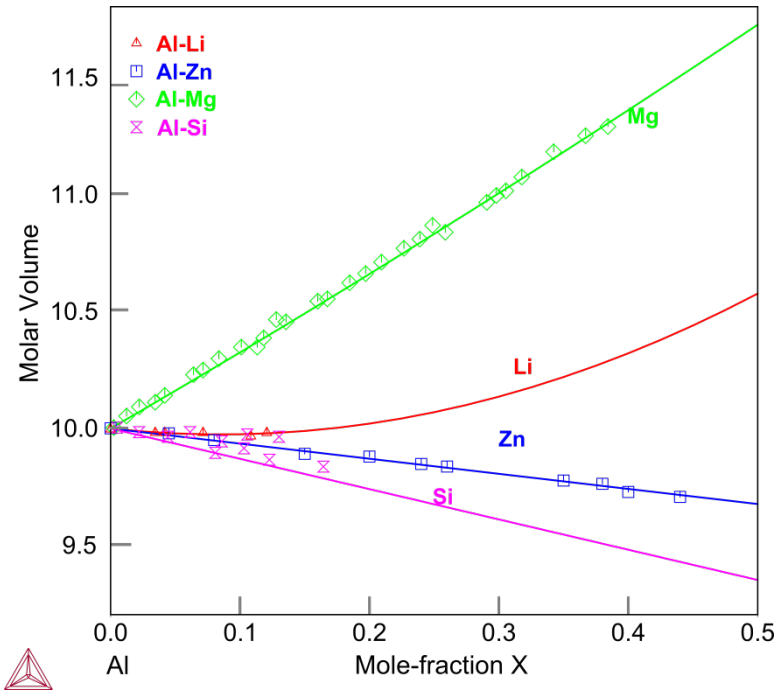


Fig.14: Calculated molar volumes of the Al-X (X=Li, Mg, Si, Zn) fcc_A1 phase

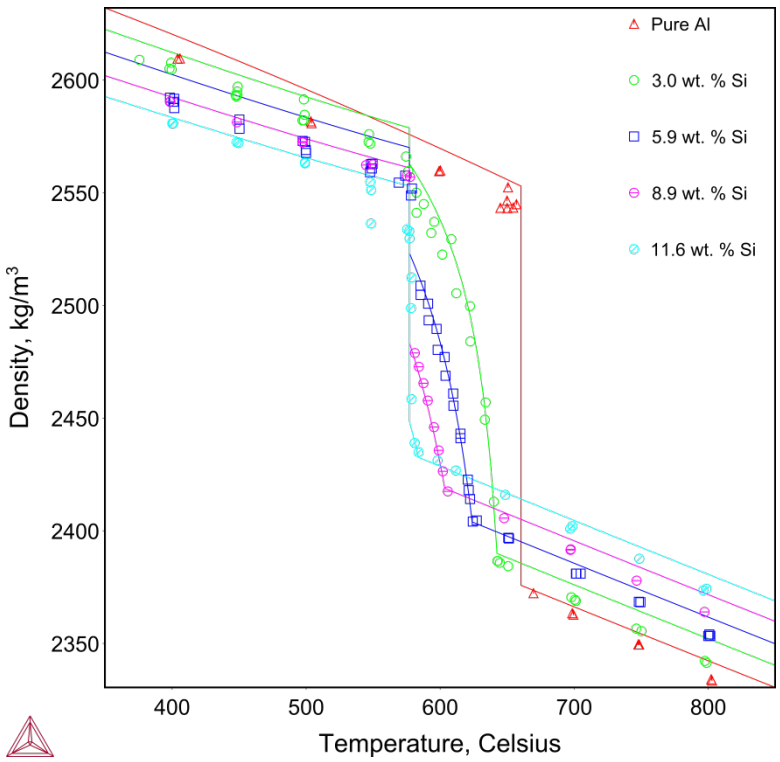


Fig.15: Calculated densities of pure Al and Al-Si alloys versus the temperature, in comparison with experimental data from Magnusson and Arnberg [15]

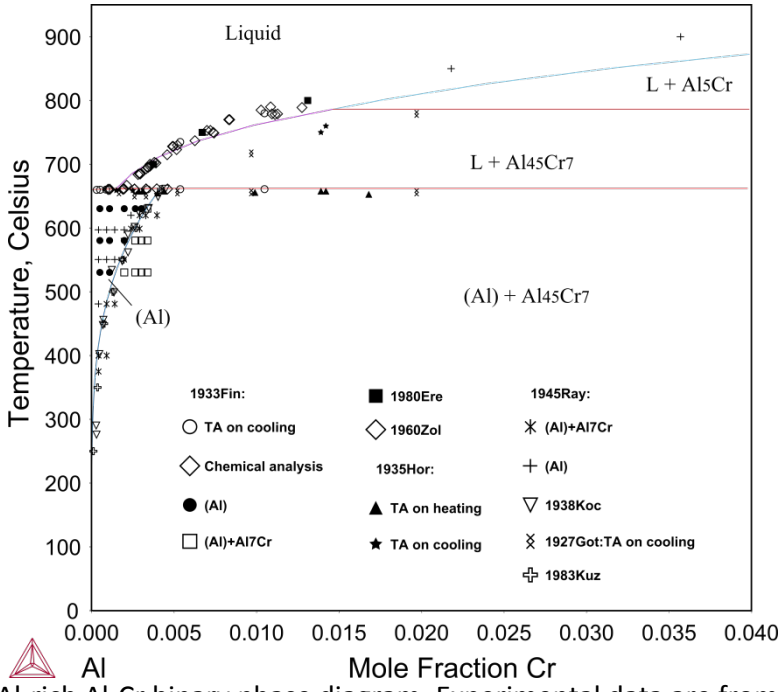


Fig.16: Calculated Al-rich Al-Cr binary phase diagram. Experimental data are from refs. [16- 18]

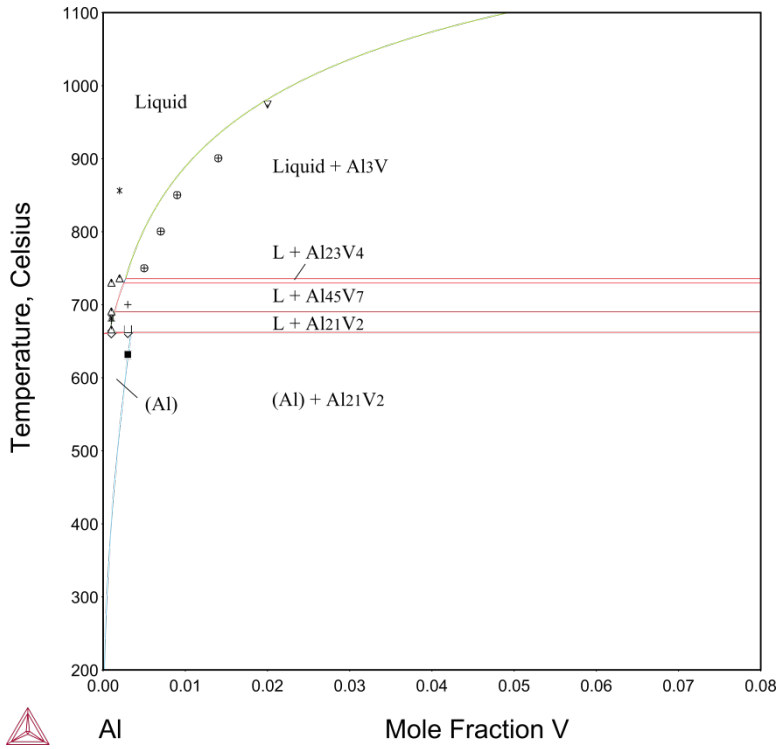


Fig.17: Calculated Al-rich Al-V binary phase diagram. Experimental data were read from ref. [19]

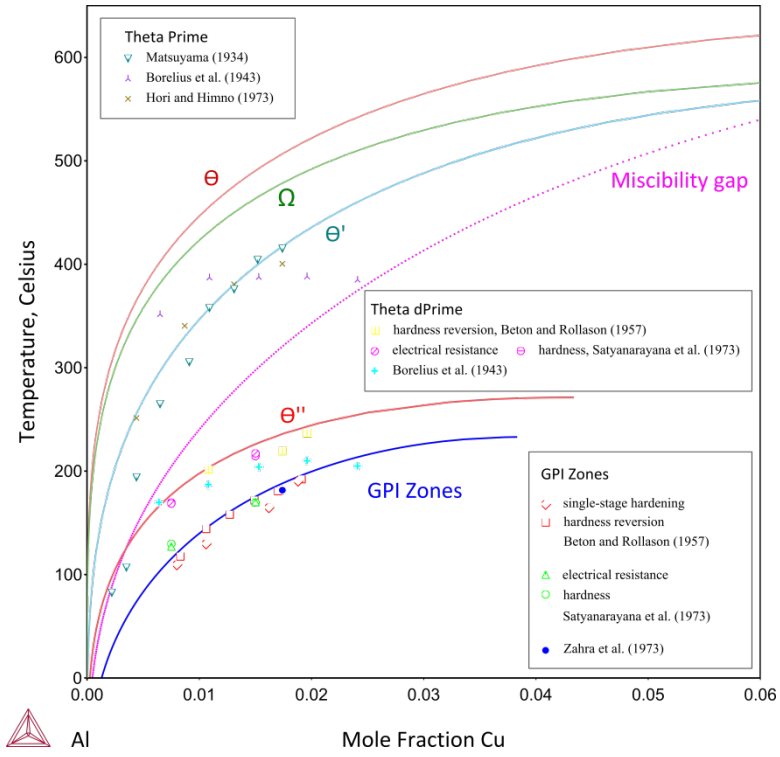


Fig.18: Calculated Al-Cu (Al) solvus curves equilibrated with θ, Ω, θ', θ'' (or GPII zones) and GPI zones, respectively. A metastable miscibility gap of fcc_A1 is shown. The GPI zones were modeled as the second composition set of fcc_A1, i.e. fcc_A1#2. It is assumed that experimentally observed GPI zones are usually tiny (say < 3 nm), so the interfacial and elastic energy has to be considered. The line for GPI zones was calculated with adding +800 J/mole-atoms to the energy of fcc_A1#2.

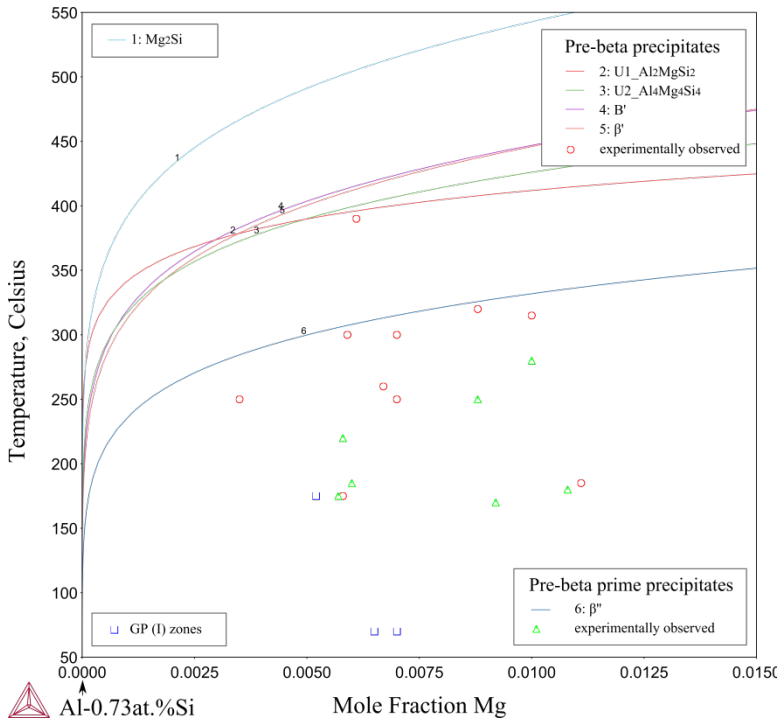


Fig.19: Calculated fcc_A1 solvi in alloys at 0.73 at.% Si and varying Mg content, relative to different Al-Mg-Si precipitates, including the stable β-Mg_2Si phase, pre-β precipitates (β', U1, U2 and B')and the pre-β' precipitate, i.e. β''. The symbols indicate certain precipitates have been experimentally observed in alloys of given compositions and aged at given temperatures.

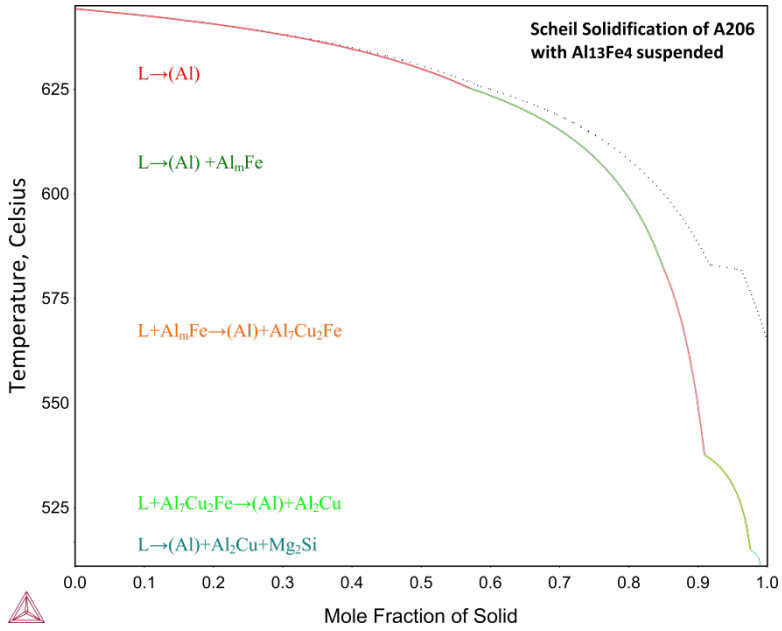


Fig.20: Scheil solidification of an A206 alloy (Al-4.58Cu-0.28Mg-0.51Fe-0.07Si-0.003Mn, wt.%) with the $Al_{13}Fe_4$ phase suspended. According Liu et al. [20], the metastable Al_mFe phase formed after (Al) during the solidification. The phase formation sequence and phase transformation temperatures can be well accounted for with this calculation.

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List of all phases included in TCAL4

The elements in phase names are rearranged in alphabetical order except for carbides and borides, where B and C are at the end. In order to designate the high- and low-temperature modifications of a phase, respectively, the suffixes "_HT" and "_LT" are used instead of "alpha-", "beta-" or "gamma".

One can list phases and constituents in the Database module and the GES module. For some phases, supplementary information has been included in their definitions. In order to show the information, it is recommended to use "List-System" or "List-Database" with the option of "Constituents" in the Database module.

LIQUID
FCC_A1
FCC_L12
BCC_A2
BCC_B2
CBCC_A12
CUB_A13
DHCP
HCP_A3
BETA_RHOMBO_B
GRAPHITE
RHOMBO_A7
TETRA_A6
C14_LAVES
C15_LAVES
C36_LAVES
DIAMOND_A4
BCT_A5
GAS
ORTHORHOMBIC_GA
SIGMA
AL45V7
CUZR2_C11B
B2_BCC
ALB2_C32
FEB_B27
AL3TI_D022
ALZR2_B82
CAZN13_CF112
NI3SN_D019
CRB_B33
AL3ZR5_D8M
AL2SR_OI12
CACU5_D2D
M3B4_D7B
SI2ZR3_D5A
CO2SI_C23
CR5B3_D81

M11GE8_OP76
SIZR3_TP32
SI4ZR5_TP36
SI2ZR_C49
SI2TI_C54
ZRM5_C15B
FEM_B35
SN5TI6_OI44
M7C3_D101
M23C6_D84
V_PHASE
AGLA
AG2LA
AG51LA14
AG5LA
AGMG3
AGMG4
AG2NA
AGZN3
AGZN
AG5ZN8
ALCU_DEL
ALCU_EPS
ALCU_ETA
AL2CU_C16
AL2CU_OMEGA
THETA_PRIME
THETA_DPRIME
ALCU_ZETA
GAMMA_D83
GAMMA_H
AL2FE1
AL5FE2
AL5FE4
AL13FE4
AL4FE
ALMG_BETA
ALMG_EPS

ALMG_GAMMA
ALMGZN_PHI
AL12MN
AL6MN
AL4MN_R
AL4MN_U
AL11MN4_LT
AL11MN4_HT
AL8MN5
AL3NI_D011
AL3NI2
AL3NI5
CA2CU
CACU
HCP_CA
CAH2_LT
CAH2_HT
CALI2
CA2NI7
CANI3
CA3SI4
CA14SI19
CASI2
CA3ZN
CA5ZN3
CAZN
CAZN2
CAZN3
CAZN11
CU9GA4_0
CU9GA4_1
CU9GA4_2
CU9GA4_3
CUGA2
CUGA_THETA
CU5HF
CU51HF14
CU8HF3

CU10HF7
CU1HF2
CUIN_GAMMA
CUIN_THETE
CU2IN_HT
CU2IN_LT
CU11IN9
CU37LA3
CU6LA1_LT
CU6LA1_HT
CU5LA1
CU4LA1
CU2LA1
CU1LA1
CUMG2
CU4SC
CU2SC_C11B
CUSC
CU33SI7_DELTA
CU15SI4_EPSILON
CU56SI11_GAMMA
CUSI_ETA
EPSILON
C14_FE2HF
C36_FE2HF
C15_FE2HF
FE1HF2
FE2SC_C15
FE6SC29
FE2SI
FESI2_H
FESI2_L
FESI_B20
MN5SI3_D88
GAMMA_D82
FEZN_GAMMA1
FEZN_DELTA
FEZN_ZETA
LAH3
MGH2
HFMN
KNA2
KZN13
LA3NI
LA7NI3
LANI
LA2NI3

LA7NI16
LANI3
LA2NI7_LT
LA2NI7_HT
LANI5
LA3SI2
LA5SI3
LA5SI4
LASI
LASI2_A1
LASI2_A2
LAZN2
LAZN4
LAZN5
LA3ZN22
LAZN11
LAZN13
LA2ZN17
LI2ZN3_L
LI2ZN3_H
LI2ZN5_L
LI2ZN5_H
LIZN4_L
LIZN4_H
LIZN2
BCC_B32
MG2NI
MG2SI_C1
MG7ZN3
MGZN
MG2ZN3
FCC_L10
MNNI2
MNSC4
MN11SI19
MN3SI
MN6SI
MN9SI2
MNZN9
NASI_LT
NASI_HT
NAZN13
NI5HF
NI7HF2
NI3HF_LT
NI3HF_HT
NI21HF8

NI7HF3
NI10HF7
NI11HF9
NIHF_LT
NIHF_HT
NIHF2
HF2SI
HF3SI2
HF5SI3
HFSI
HF5SI4
HFSI2
NI2SI_HT
NI3SI2
NI3SI_HT
L12_FCC
NI3SI_MT
NI5SI2
NISI_B31
NISI2
NIZN_LT
NIZN8
ALB12
AL4C3
AL5CR
AL4CR
ALCR_GAMMA1
GAMMA_D810
AL7SR8
AL4M_D13
AL2TI
AL18TI7
ALTI3_DO19
AL21V2
AL23V4
AL8V5
AL2ZR
AL4ZR5
AL3ZR2_OF40
AL2ZR3_TP20
AL3ZR_D023
CU6SN5_HT
CUSN_GAMMA
CU10SN3
CU3SN
CU41SN11
CU6SN5_LT

CUSR
CU2TI
CU3TI2
CU4TI1
CU4TI3
CUTI_B11
CUTI3
CU10ZR7
CU51ZR14
CU8ZR3
FE2GE1
FEGE_ETA
FE6GE5
FE2GE3
FE5SN3_D82
FE3SN2
FEZR3
MGB4
MGB7
MG2C3
MGC2
MG2SR
MG38SR9
MG23SR6
MG17SR2
MN2B_D1F
MNB4
M5C2
CR3MN5
HIGH_SIGMA
GEMN3_HT
GE2MN3
GE2MN5
GE3MN7
MN2SN
MN3SN2
MNTI_LT
MNTI_HT
MN3TI
MN4TI
MNV_SIGMA
NI4B3_ORTH
NI4B3_MONO
GENI2
GE3NI5_HT
GE2NI3
GENI3_GAMMA

GE2NI5
GE3NI5_LT
GE12NI19
NI7SC2
NISC_B2
NISC2
NI3SN2_LT
NI3SN_HT
NI3SN2_HT
NI3SN4
NISR
NI3TI_D024
NITI2
NI2V7
NI2V1
NI10ZR7
NI21ZR8
NI11ZR9
NI7ZR2
SC5SI3
SCSI
SC3SI5_LT
SC3SI5_HT
SCZN
SCZN2
SC13ZN58
SC3ZN17
SCZN12
SIB3
SIB6
SIBX
SIC
CR3SI
CRSI2_C40
SI2SR_HT
SI2SR_LT
SI3TI5
V3SI
CRZN13
CRZN17
SRZN5_LT
TIZN2
TIZN5
TIZN10
TIZN15
V4ZN5
ZN2ZR

ZN22ZR
ZN39ZR5
ZN3ZR_LT
ZN3ZR_HT
B4C
CR2B_ORTH
CRB4
SRB6
V2B3
V5B6
ZRB12
CU6CE
CU5CE
CU4CE
CU2CE
CUCE
CR3C2
V3C2
CDCU2
CD3CU4
CD8CU5
CD10CU3
CR3GE
CR5GE3_HT
CR5GE3_LT
CR11GE19
GE2SR
GE3TI5
V3GE
V17GE31
SR3SN5
SRSN3
SRSN4
SN3TI2
V3SN
VSN2
SN3ZR5
SNZR3_A15
V2ZR
AL14CA13
AL3CA8
AL4CE
AL11CE3
AL3CE_H
AL3CE_L
ALCE
ALCE2

ALCE3_H
ALCE3_L
AL13CO4
AL3CO
AL5CO2
AL9CO2
AL3LA
ALLA
AL53LA22
AL11LA3_LT
AL11LA3_HT
AL2LI3
ALLI2
AL4LI9
ALLI_B32
AL3SC
AL2SC
ALSC
ALSC2
AL3HF4
LI22SI5
LI13SI4
LI7SI3
LI12SI7
AG9CA2
AG7CA2
AG2CA
AGCA3
AG4SC
AGSC
AL4C4SI
AL8C7SI
AL13CR4SI4
AL9CR3SI
ALCRSI_T3
ALCRSI_T4
AL23CUFE4
AL62CU25FE13
AL7CU2FE
AL10CU10FE
AL2CULI
ALCULI_T2
ALCULI_R
ALCULI_B

Q_PHASE
S_PHASE
S_PRIME
T_PHASE
AL28CU4MN7
AL11CU5MN3
ALCU3MN2
AL7CU4NI
ALCUSC_TAU
AL9FENI
AL10FE3NI
AL71FE5NI24
ALFESI_T1
ALFESI_T2
ALFESI_T3
ALFESI_T4
AL8FE2SI
AL9FE2SI2
ALFESI_T7
ALFESI_T8
ALFESI_T10
ALFESI_T11
ALFEZN_GAMMA
ALLIMG_T
ALLISI
AL3LI8SI5
ALLI5SI2
AL18MG3MN2
ALMG3NI2
BETA_PRIME
B_PRIME
U1_AL2MGSI2
U2_AL4MG4SI4
BETA_DPRIME
ETA_PRIME
T_PRIME
AL31MN6NI2
AL2MN2SI3
AL5MN6SI7
AL1MN1SI1
AL3MNSI2
AL3MN4SI2
ALMNSI_T6
ALMNSI_T8

AL15SI2M4
AL2MNSI3
AL24MN5ZN
AL9MN2ZN
AL11MN3ZN2
ALNI2SI
AL6NI3SI
ALNI16SI9
ALNI2ZN
AL13NI38ZN49
CU16MG6SI7
CU3MG2SI
CU5MN4SI
CUMNZN
CU6NISI3
CU46NI25SI29
FE5NI3SI2
ZN13M2
MG6MN3NI
MGNI6SI6
MG2NI3SI
MG10NI55SI35
MG2NI16SI11
MG5NI9SI
MG9NI29SI16
MGNI6ZN6
MN15NI45SI40
MN15NI50SI35
MN6NI16SI7
MN1NI1SI1
MNNISI_T5
MNNISI_T6
MN3NI2SI
MN2NISI
MN6NISI3
MN66NI4SI30
MN52NI29SI19
MN7NI7ZN86
NI2SIZN_T1
NI9SI2ZN_T2
NI2SIZN3_T3
NISIZN_T4
Q_ALCUMGSI
AL18FE2MG7SI10

List of models for all the phases included in TCAL4

LIQUID :AL CU FE MG MN NI SI ZN B C CR GE SN SR TI V ZR MG2GE MG2SN1 ZN2ZR AG CA HF H LIH K LA LI NA SC CO PB BE BI CE CD GA IN: > Metallic LIQUID solution phase
FCC_A1 2 SUBL 1 1 :AL CU FE MG MN NI SI ZN CR GE SN SR TI V ZR AG CA HF K LA LI NA SC CO PB BE BI CE CD GA IN: B C H VA: > Metallic FCC_A1 solution, e.g. (Al), (Cu), and MC carbides
FCC_L12 3 SUBL 0.75 0.25 1 :AL CU FE MG MN NI SI ZN CR GE SN SR TI V ZR AG CA HF K LA LI NA SC CO PB BE BI CE CD GA IN: AL CU FE MG MN NI SI ZN CR GE SN SR TI V ZR AG CA HF K LA LI NA SC CO PB BE BI CE CD GA IN: B C H VA: > Solution of ordered FCC_L12, having Gibbs energy contribution from FCC_A1
BCC_A2 2 SUBL 1 3 :AL CU FE MG MN NI SI ZN VA GE CR SN SR TI V ZR AG CA HF K LA LI NA SC CO PB BE BI CE CD GA IN: B C H VA: > Metallic BCC_A2 solution
BCC_B2 3 SUBL 0.5 0.5 3 :AL CU FE MG MN NI SI TI ZN VA GE CR SN SR V ZR AG CA HF K LA LI NA SC CO PB BE BI CE CD GA IN: AL CU FE MG MN NI SI TI ZN VA GE CR SN SR V ZR AG CA HF K LA LI NA SC CO PB BE BI CE CD GA IN: B C H VA: > Solution of ordered BCC_B2, having Gibbs energy contribution from BCC_A2
CBCC_A12 2 SUBL 1 1 :AL CO CU FE LI MG MN NI SI ZN CR GE SN SR TI V ZR: B C H VA:
CUB_A13 2 SUBL 1 1 :AL CU FE HF LI MG MN NI SI ZN CR GE SN SR TI V ZR AG: B C H VA:
DHCP :CU LA NI SC:

HCP_A3 2 SUBL 1 0.5

:AG AL CU FE K LI MG MN NA NI SI ZN GE CR SN SR TI V ZR HF LA SC CO PB BE BI CA CE CD GA IN: B C H VA: > Metallic HCP_A3 solution, alpha_Mg/Hf/Sc/Ti/Zr, epsilon_CuZn, etc.
BETA_RHOMBO_B 2 SUBL 93 12 :B: CU SI B C:
GRAPHITE :B C:
RHOMBO_A7 :BI IN:
TETRA_A6 :IN:
C14_LAVES 2 SUBL 2 1 :AL CU CR FE HF MG MN NI TI ZN ZR: AL CU CR FE HF MG MN SC TI ZN ZR: > Solution of MgZn2-type phases, including MgZn2 (Eta, aka M or sigma)
C15_LAVES 2 SUBL 2 1 :AL CA CU FE MG NI SC SI ZN CR TI ZR LA HF: AL CA CE CU FE MG NI SC SI ZN CR TI ZR LA HF: > Solution of Cu2Mg-type phases, cF24, Fd-3m
C36_LAVES 2 SUBL 2 1 :AL CU CR FE HF MG MN NI ZN ZR: AL CU CR FE HF MG NI SC ZN ZR: > Solution of MgNi2-type phases, hP24, P63/mmc
DIAMOND_A4 :AL SI ZN B C GA GE SR SN TI: > Pure C, Ge, Si or solution phases based on them
BCT_A5 :AL B CU GA GE IN ZN SN TI: > Pure Sn or its solution

GAS :AL AL2 B B2 C C2 C3 C4 C5 C60 CA CA2 CO CO2 CR CR2 CU CU2 FE FE2 GE GE2 LI LI2 MG MG2 MN NI NI2 SC SI SI2 SI3 SN SN2 SR SR2 TI TI2 V ZN K K2 NA NA2 H H2 AL1H1 AL1H2 AL1H3 CA1H1 CU1H1 H1LI1 H1NA1 K1LI1:
ORTHORHOMBIC_GA :GA:
SIGMA 3 SUBL 8 4 18 :FE MN NI: CR V: FE CR MN NI V:
AL45V7 2 SUBL 45 7 :AL: CR V: > Al45Cr7, Al45V7
CUZR2_C11B 2 SUBL 1 2 :AL CR CU SI ZN: AL CR TI ZR: > AlCr2, CuTi2, CuZr2, Ti2Zn, ZnZr2
B2_BCC 2 SUBL 1 1 :AL CO FE CU ZN: CO MN TI VA ZR: > CuZr, FeTi, TiZn, ZnZr, MnZn(rt), AlCo
ALB2_C32 2 SUBL 1 2 :MG AL MN CR ZR TI V: B: > AlB2, B2Cr, B2Mg, B2Mn, B2Ti, B2V, B2Zr
FEB_B27 2 SUBL 1 1 :FE MN TI ZR SR: B SI ZN GE: > BFe, BMn, BTi, GeZr, SiTi, SrZn, SiZr
AL3TI_D022 2 SUBL 3 1 :AL MN NI: GE MN TI V ZR: > Al3Ti, Ni3V, GeMn3, Al3V
ALZR2_B82 2 SUBL 1 2 :AL GE MN SN VA: ZR MN TI VA: > SnTi2, GeMn2, AlZr2
CAZN13_CF112 2 SUBL 1 13 :CA SR: ZN: > CaZn13, SrZn13
NI3SN_D019 2 SUBL 1 3 :AL SN GE VA: LA MN FE NI TI: > Ni3Sn, SnTi3, SnMn3, AlLa3
CRB_B33 2 SUBL 1 1 :AL CA CR NI SR V: AG B SI GE SN ZR HF: > AgCa, AlHf, AlZr, BNi, BV, GeSr, NiZr, SiSr, SnSr
AL3ZR5_D8M 2 SUBL 3 5 :AL SI GE: ZR CR V: > Al3Zr5, Cr3Si5, Ge3V5, Si3V5
AL2SR_OI12 2 SUBL 2 1 :AL ZN: SR:
> Al2Sr, SrZn2

CACU5_D2D 2 SUBL 1 5 :CA SC SR: CU NI ZN: > CaCu5, CaNi5, CaZn5, Cu5Sr, ScNi5, SrZn5
M3B4_D7B 2 SUBL 4 3 :B: MN CR TI V: > V3B4, Ti3B4, Mn3B4, Cr3B4
SI2ZR3_D5A 2 SUBL 2 3 :SI B: ZR V: > Si2Zr3, B2V3
CO2SI_C23 2 SUBL 2 1 :CA CU FE NI SR: AL SI ZN GE SN: > Ca2Si, Ni2Si, SiSr2, SnSr2, GeSr2
CR5B3_D81 2 SUBL 0.625 0.375 :CA CR SR: AG SI B GE SN: > Ca5Si3, Sn3Sr5, Si4Sr5, Ge3Sr5, B3Cr5
M11GE8_OP76 2 SUBL 0.579 0.421 :CR V: GE: > Cr11Ge8, V11Ge8
SIZR3_TP32 2 SUBL 1 3 :SI GE: ZR TI: > SiZr3, SiTi3, GeZr3
SI4ZR5_TP36 2 SUBL 4 5 :SI GE: TI ZR: > Si4Zr5, Si4Ti5, Ge4Zr5
SI2ZR_C49 2 SUBL 2 1 :SI GE: ZR: > Si2Zr, Ge2Zr
SI2TI_C54 2 SUBL 2 1 :GE SI SN: TI ZR: > Ge2Ti, Si2Ti, Sn2Zr
ZRM5_C15B 2 SUBL 5 1 :CU NI: ZR: > Cu5Zr, Ni5Zr
FEM_B35 2 SUBL 1 1 :FE: SN GE: > FeSn, FeGe
SN5TI6_OI44 2 SUBL 5 6 :GE SN SI: V TI: > Sn5Ti6, Si5V6, Ge5Ti6
M7C3_D101 2 SUBL 7 3 :MN CR: C: > Cr7C3, Mn7C3
M23C6_D84 2 SUBL 23 6 :MN CR: C SC: > Cr23C6, Mn23C6, Mn23SC6

V_PHASE :AL SI ZN: CU ZN: MG: > solution of Mg2Zn11, Al5Cu6Mg2; aka Z	3 SUBL 5 6 2
AGLA :LA: AG:	2 SUBL 1 1
AG2LA :LA: AG:	2 SUBL 1 2
AG51LA14 :LA: AG:	2 SUBL 14 51
AG5LA :LA: AG:	2 SUBL 1 5
AGMG3 :AG: MG: > Ag17Mg54	2 SUBL 0.23 0.77
AGMG4 :AG: MG: > Ag9Mg37	2 SUBL 0.2 0.8
AG2NA :AG: NA:	2 SUBL 2 1
AGZN3 :AG ZN:	
AGZN :ZN: AG ZN:	2 SUBL 1 2
AG5ZN8 :AG ZN: AG: AG ZN: AG ZN:	4 SUBL 2 2 3 6
ALCU_DEL :AL ZN: CU FE:	2 SUBL 2 3
ALCU_EPS :AL CU ZN NI: CU FE:	2 SUBL 1 1
ALCU_ETA :AL CU: CU FE ZN NI:	2 SUBL 1 1
AL2CU_C16 :AL FE GE SN ZR MN NI HF: AL CU FE NI B MN SI: > Al2Cu, AlHf2, Fe2B, FeGe2, FeZr2, FeSn2, Mn2B, MnSn2,NiB2,NiZr2,SiZr2	2 SUBL 2 1
AL2CU_OMEGA :AL: CU: > Al2Cu-OMEGA metastable precipitate	2 SUBL 2 1
THETA_PRIME :AL: CU:	2 SUBL 2 1
THETA_DPRIME :AL: CU:	2 SUBL 3 1
ALCU_ZETA :AL: CU FE:	2 SUBL 9 11
GAMMA_D83 :AL FE NI SI ZN: AL CU NI SI ZN: CU MN FE NI ZN:	3 SUBL 4 1 8
> solution between Al8Cu5 (rt) and Cu5Zn8	

GAMMA_H :AL ZN: AL CU ZN: CU MN FE NI: > Cu5Zn8-type Al8Cu5 (ht) phase	3 SUBL 4 1 8
AL2FE1 :AL CU SI ZN: FE MN NI:	2 SUBL 2 1
AL5FE2 :AL CU SI ZN: FE MN NI:	2 SUBL 5 2
AL5FE4 :AL CU FE MN:	
AL13FE4 :AL CU: FE MN NI ZN: AL SI VA ZN: > solution phases based on Al13Fe4, aka Al3Fe	3 SUBL 0.6275 0.235 0.1375
AL4FE :AL: FE:	2 SUBL 4.2 1
ALMG_BETA :MG LI: AL ZN:	2 SUBL 89 140
ALMG_EPS :MG: AL ZN:	2 SUBL 23 30
ALMG_GAMMA :LI MG: AL MG ZN: AL MG ZN:	3 SUBL 5 12 12
ALMGZN_PHI :MG: AL ZN: > a Al-Mg-Zn ternary phase know as PHI	2 SUBL 6 5
AL12MN :AL: MN:	2 SUBL 12 1
AL6MN :AL ZN: MN FE:	2 SUBL 6 1
AL4MN_R :AL: MN FE: > AL461MN107	2 SUBL 0.81162 0.18838
AL4MN_U :AL ZN: MN:	2 SUBL 4 1
AL11MN4_LT :AL ZN: MN FE:	2 SUBL 11 4
AL11MN4_HT :AL MN: MN:	2 SUBL 29 10
AL8MN5 :AL ZN: MN: AL MN SI CU:	3 SUBL 12 5 9
AL3NI_D011 :AL MN NI: FE NI B C:	2 SUBL 0.75 0.25
AL3NI2 :AL SI ZN: AL CU FE MG NI:NI VA:	3 SUBL 3 2 1
AL3NI5	2 SUBL 0.375 0.625

:AL: NI:
CA2CU 2 SUBL 2 1 :CA: CU:

CACU 2 SUBL 1 1 :CA: CU:
HCP_CA 2 SUBL 1 0.5 :CA: H VA:
CAH2_LT 2 SUBL 1 2 :CA: H:
CAH2_HT 2 SUBL 1 2 :CA: H:
CALI2 2 SUBL 2 1 :LI: CA:
CA2NI7 2 SUBL 2 7 :CA: NI:
CANI3 2 SUBL 0.25 0.75 :CA: NI:
CA3SI4 2 SUBL 0.428571 0.571429 :CA: SI:
CA14SI19 2 SUBL 0.424242 0.575758 :CA: SI:
CASI2 2 SUBL 0.333333 0.666667 :CA: SI:
CA3ZN 2 SUBL 3 1 :CA: ZN:
CA5ZN3 2 SUBL 5 3 :CA: ZN:
CAZN 2 SUBL 1 1 :CA: ZN:
CAZN2 2 SUBL 1 2 :CA: ZN:
CAZN3 2 SUBL 1 3 :CA: ZN:
CAZN11 2 SUBL 1 11 :CA: ZN:
CU9GA4_0 3 SUBL 6 6 1 :CU: CU GA: GA:
CU9GA4_1 4 SUBL 6 3 3 1 :CU: CU GA: CU GA: GA:
CU9GA4_2 4 SUBL 3 3 3 4 :CU: CU VA: CU GA: GA:
CU9GA4_3 3 SUBL 6 3 4 :CU VA: CU GA: GA:
CUGA2 2 SUBL 1 2 :CU: GA:
CUGA_THETA 2 SUBL 0.778 0.222 :CU: GA:

CU5HF 2 SUBL 5 1 :CU: HF:
CU51HF14 2 SUBL 51 14 :CU: HF:
CU8HF3 2 SUBL 8 3 :CU: HF:
CU10HF7 2 SUBL 10 7 :CU: HF:
CU1HF2 2 SUBL 1 2 :CU: HF:
CUIN_GAM 4 SUBL 2 2 3 6 :CU: CU IN: CU: CU IN:
CUIN_THETE 2 SUBL 0.7 0.3 :CU: IN:
CU2IN_HT 3 SUBL 0.545 0.122 0.333 :CU: CU IN: IN:
CU2IN_LT 2 SUBL 0.64 0.36 :CU: IN:
CU11IN9 2 SUBL 0.55 0.45 :CU: IN:
CU37LA3 2 SUBL 37 3 :CU: LA:
CU6LA1_LT 2 SUBL 6 1 :CU: LA:
CU6LA1_HT 2 SUBL 6 1 :CU: LA:
CU5LA1 2 SUBL 5 1 :CU: LA:
CU4LA1 2 SUBL 4 1 :CU: LA:
CU2LA1 2 SUBL 2 1 :CU: LA:
CU1LA1 2 SUBL 1 1 :CU: LA:
CUMG2 2 SUBL 1 2 :CU NI: MG:
CU4SC 2 SUBL 4 1 :CU: SC:
CU2SC_C11B 2 SUBL 2 1 :AG CU: SC:
CUSC 2 SUBL 1 1 :CU: SC:
CU33SI7_DELTA 2 SUBL 0.825 0.175 :CU ZN: SI:
CU15SI4_EPSILON 2 SUBL 0.789474 0.210526 :CU MG MN ZN: AL SI:

CU56SI11_GAMMA 2 SUBL 0.835821 0.164179 :CU MG MN NI SI ZN: SI:
CUSI_ETA 2 SUBL 0.76 0.24 :CU MN NI ZN: SI:
EPSILON :CU MN ZN:
C14_FE2HF 2 SUBL 0.6667 0.3333 :FE: HF FE:
C36_FE2HF 2 SUBL 0.6667 0.3333 :FE: HF:
C15_FE2HF 2 SUBL 0.6667 0.3333 :FE: HF:
FE1HF2 2 SUBL 0.3333 0.6667 :FE: HF:
FE2SC_C15 2 SUBL 0.64 0.36 :FE: SC:
FE6SC29 2 SUBL 0.17 0.83 :FE: SC:
FE2SI 2 SUBL 2 1 :FE NI: AL SI:
FESI2_H 2 SUBL 3 7 :FE NI: AL MG SI:
FESI2_L 2 SUBL 1 2 :FE NI: AL SI:
FESI_B20 2 SUBL 1 1 :FE MN NI CR: AL MG SI GE: > FeSi, MnSi, CrSi, CrGe
MN5SI3_D88 2 SUBL 5 3 :CU FE MN NI CR ZR TI: AL CR SI GE SN: > Mn5Si3, Cr3Si5, Fe5Si3, Ge3Mn5, Ge3Zr5, Si3Zr5, Sn3Ti5
GAMMA_D82 4 SUBL 2 2 3 6 :FE MN ZN: FE MN NI ZN: AL CU FE MN NI SI ZN: AL ZN:
FEZN_GAMMA1 3 SUBL 0.137 0.118 0.745 :FE: AL CU FE NI SI ZN: MN ZN:
FEZN_DELTA 4 SUBL 5.8E-2 0.18 0.525 0.237 :FE: AL CU FE MN NI SI ZN: ZN: ZN:
FEZN_ZETA 3 SUBL 7.2E-2 0.856 7.2E-2 :FE MN NI VA: AL ZN: AL CU SI VA ZN:
LAH3 3 SUBL 0.25 0.5 0.25 :LA: H VA: H VA:
MGH2 2 SUBL 1 2 :MG: H:
HFMN 2 SUBL 0.5 0.5 :HF: MN:
KNA2 2 SUBL 1 2 :K: NA:
KZN13 2 SUBL 1 13 :K: ZN:
LA3NI 2 SUBL 3 1 :LA: NI:
LA7NI3 2 SUBL 7 3 :LA: NI:
LANI 2 SUBL 1 1 :LA: NI:
LA2NI3 2 SUBL 2 3 :LA: NI:
LA7NI16 2 SUBL 7 16 :LA: NI:
LANI3 2 SUBL 1 3 :LA: NI:
LA2NI7_LT 2 SUBL 2 7 :LA: NI:
LA2NI7_HT 2 SUBL 2 7 :LA: NI:
LANI5 2 SUBL 1 5 :LA: NI:
LA3SI2 2 SUBL 0.6 0.4 :LA: SI:
LA5SI3 2 SUBL 0.625 0.375 :LA: SI:
LA5SI4 2 SUBL 0.5556 0.4444 :LA: SI:
LASI 2 SUBL 0.5 0.5 :LA: SI:
LASI2_A1 2 SUBL 0.36 0.64 :LA: SI:
LASI2_A2 2 SUBL 0.3333 0.6667 :LA: SI:
LAZN2 2 SUBL 0.333 0.667 :LA: ZN:
LAZN4 2 SUBL 0.2 0.8 :LA: ZN:
LAZN5 2 SUBL 0.1667 0.8333 :LA: ZN:
LA3ZN22 2 SUBL 0.12 0.88 :LA: ZN:
LAZN11 2 SUBL 8.3E-2 0.917

:LA: ZN:
LAZN132 SUBL 7.1E-2 0.929 :LA: ZN:
LA2ZN17 2 SUBL 0.105 0.895 :LA: ZN:
LI2ZN3_L 2 SUBL 2 3 :LI: LI ZN:
LI2ZN3_H 2 SUBL 2 3 :LI ZN: LI ZN:
LI2ZN5_L 2 SUBL 2 5 :LI ZN: ZN:
LI2ZN5_H 2 SUBL 2 5 :LI ZN: ZN:
LIZN4_L 2 SUBL 1 4 :LI ZN: LI ZN:
LIZN4_H 2 SUBL 0.2 0.8 :LI ZN: LI ZN:
LIZN2 2 SUBL 1 2 :LI: ZN:
BCC_B32 2 SUBL 1 1 :LI ZN: LI ZN:
MG2NI 2 SUBL 2 1 :MG ZN: CU NI ZN:
MG2SI_C1 2 SUBL 2 1 :MG: GE SI SN: > solution phase of Mg2Si, GeMg2, Mg2Sn
MG7ZN3 2 SUBL 51 20 :MG: ZN:
MGZN 2 SUBL 12 13 :MG: AL CU ZN:
MG2ZN3 2 SUBL 2 3 :MG: AL CU ZN:
FCC_L10 2 SUBL 0.5 0.5 :AL CU MN NI TI: AL CU MN NI TI:
MNNI2 2 SUBL 1 2 :MN NI: NI:
MNSC4 2 SUBL 0.2 0.8 :MN:SC:
MN11SI19 2 SUBL 11 19 :MN: AL SI:
MN3SI 2 SUBL 3 1 :FE MN NI: AL SI:
MN6SI 2 SUBL 17 3 :AL MN: SI ZN:
MN9SI2 2 SUBL 33 7 :MN: SI:
MNZN92 SUBL 0.1 0.9 :MN: ZN:

NASI_LT 2 SUBL 1 1 :NA: SI:
NASI_HT 2 SUBL 1 1 :NA: SI:
NAZN13 2 SUBL 1 13 :NA: ZN:
NI5HF 2 SUBL 0.833 0.167 :NI: HF:

NI7HF2 2 SUBL 0.778 0.222 :NI: HF NI:
NI3HF_LT 2 SUBL 0.75 0.25 :NI: HF:
NI3HF_HT 2 SUBL 0.75 0.25 :NI: HF:
NI21HF8 2 SUBL 0.724 0.276 :NI: HF:
NI7HF3 2 SUBL 0.7 0.3 :NI: HF:
NI10HF7 2 SUBL 0.588 0.412 :NI: HF:
NI11HF9 2 SUBL 0.55 0.45 :NI: HF:
NIHF_LT 2 SUBL 0.5 0.5 :NI: HF:
NIHF_HT 2 SUBL 0.5 0.5 :NI: HF:
NIHF2 2 SUBL 1 2 :NI VA: HF:
HF2SI 2 SUBL 0.6666667 0.3333333 :HF: SI:
HF3SI2 2 SUBL 0.6 0.4 :HF: SI:
HF5SI3 2 SUBL 0.625 0.375 :HF: SI:
HFSI 2 SUBL 0.5 0.5 :HF: SI:
HF5SI4 2 SUBL 0.555556 0.444444 :HF: SI:
HFSI2 2 SUBL 0.333333 0.666667 :HF: SI:
NI2SI_HT 3 SUBL 1 1 1 :CU NI: NI VA: AL SI:
NI3SI2 2 SUBL 3 2 :FE NI: SI:
NI3SI_HT 2 SUBL 3 1 :FE NI: AL SI:

L12_FCC 2 SUBL 1 3 :AL GE NI SI TI V: AL FE ZR NI ZN: > L12 phase, Ni3Si_rt, AlZr3, GeNi3, TiZn3, VZn3
NI3SI_MT 2 SUBL 1 3 :SI: NI:
NI5SI2 2 SUBL 5 2 :CU FE NI: AL SI:

NISI_B31 2 SUBL 1 1 :FE NI: GE SI ZN: > GeNi, NiSi
NISI2 2 SUBL 2 1 :AL CU SI ZN: CU FE MN NI:
NIZN_LT 2 SUBL 0.5 0.5 :AL FE MN NI SI ZN: AL FE MG MN NI SI ZN:
NIZN8 2 SUBL 0.1111111 0.8888889 :NI: AL MN ZN:
ALB12 2 SUBL 1 12 :AL: B:
AL4C3 2 SUBL 4 3 :AL SI: C:
AL5CR 2 SUBL 5 1 :AL SI: CR:
AL4CR 2 SUBL 1 4 :CR: AL SI VA:
ALCR_GAMMA1 4 SUBL 2 2 3 6 :AL CR SI: CR: AL CR: AL SI:
GAMMA_D810 3 SUBL 12 5 9 :AL SI: CR: AL CR SI:
AL7SR8 2 SUBL 7 8 :AL: SR:
AL4M_D13 2 SUBL 4 1 :AL: CA SR: > Al4Ca, Al4Sr
AL2TI 2 SUBL 2 1 :AL: TI:
AL18TI7 2 SUBL 0.72 0.28 :AL: TI:
ALTI3_DO19 2 SUBL 3 1 :AL TI: AL TI:
AL21V2 2 SUBL 21 2 :AL: V:
AL23V4 2 SUBL 23 4 :AL: V:
AL8V5 4 SUBL 2 2 3 6 :AL V: V: AL V: AL:
AL2ZR 2 SUBL 2 1 :AL: ZR:
AL4ZR5 2 SUBL 4 5 :AL: ZR:
AL3ZR2_OF40 2 SUBL 3 2 :AL: HF ZR: > Al3Zr2, Al3Hf2
AL2ZR3_TP20 2 SUBL 2 3 :AL ZN: HF ZR:

> Al2Zr3, Al2Hf3, ZN2Zr3
AL3ZR_D023 2 SUBL 3 1 :AL: HF TI ZR: > Al3Zr, Al3Hf
CU6SN5_HT 3 SUBL 1 1 1 :CU: CU SN: SN:
CUSN_GAMMA :CU SN:
CU10SN3 :CU SN:
CU3SN 2 SUBL 3 1 :CU SN: CU SN:
CU41SN11 2 SUBL 41 11 :CU SN: CU SN:
CU6SN5_LT 3 SUBL 1 1 1 :CU: CU SN: SN:
CUSR 2 SUBL 1 1 :SR: CU:
CU2TI 2 SUBL 2 1 :CU: TI:
CU3TI2 2 SUBL 3 2 :CU: TI:
CU4TI1 2 SUBL 4 1 :CU TI: CU TI:
CU4TI3 2 SUBL 4 3 :CU: TI:
CUTI_B11 2 SUBL 1 1 :CU TI: CU TI:
CUTI3 2 SUBL 1 3 :CU TI: TI:
CU10ZR7 2 SUBL 10 7 :CU: ZR:
CU51ZR14 2 SUBL 51 14 :CU: ZR:
CU8ZR3 2 SUBL 8 3 :CU: ZR:
FE2GE1 3 SUBL 1 1 1 :FE: FE VA: GE:
FEGE_ETA 2 SUBL 13 9 :FE: GE:
FE6GE52 SUBL 6 5 :FE: GE:
FE2GE32 SUBL 2 3 :FE: GE:
FE5SN3_D82 2 SUBL 5 3 :FE: SN:
FE3SN22 SUBL 3 2 :FE: SN:

FEZR3 :FE: ZR:	2 SUBL 1 3
MGB4 :MG: B:	2 SUBL 1 4
MGB7 :MG: B:	2 SUBL 1 7
MG2C3 :MG: C:	2 SUBL 2 3
MGC2 :MG: C:	2 SUBL 1 2
MG2SR :MG: SR:	2 SUBL 2 1
MG38SR9 :MG: SR:	2 SUBL 38 9
MG23SR6 :MG: SR:	2 SUBL 23 6
MG17SR2 :MG: SR:	2 SUBL 17 2
MN2B_D1F :MN: B:	2 SUBL 0.6707 0.3293
MNB4 :MN: B:	2 SUBL 0.2 0.8
M5C2 :MN: C:	2 SUBL 5 2
CR3MN5 :CR: MN:	2 SUBL 3 5
HIGH_SIGMA :MN: CR: CR MN:	3 SUBL 8 4 18
GEMN3_HT :GE MN: MN:	2 SUBL 1 3
GE2MN3 :GE: MN:	2 SUBL 2 3
GE2MN5 :GE MN: MN:	2 SUBL 2 5
GE3MN7 :GE: MN:	2 SUBL 3 7
MN2SN2 :MN: SN: > Mn(2-x)Sn	SUBL 0.643 0.357
MN3SN2 :MN: SN:	2 SUBL 3 2
MNTI_LT :MN: TI:	2 SUBL 1 1
MNTI_HT :MN: TI:	2 SUBL 0.515 0.485
MN3TI :MN: TI:	2 SUBL 3 1
MN4TI :MN: TI:	2 SUBL 0.815 0.185
MNV_SIGMA :MN V: V: MN V:	3 SUBL 10 4 16
NI4B3_ORTH :NI: B:	2 SUBL 0.586 0.414
NI4B3_MONO :NI: B:	2 SUBL 0.564 0.436
GENI2 :NI: GE:	2 SUBL 0.665 0.335
GE3NI5_HT :GE NI: GE NI:	2 SUBL 0.625 0.375
GE2NI3 :GE NI: GE:	2 SUBL 0.6 0.4
GENI3_GAMMA :NI: GE:	2 SUBL 0.744 0.256
GE2NI5 :NI: GE:	2 SUBL 0.72 0.28
GE3NI5_LT :NI: GE:	2 SUBL 0.63 0.37
GE12NI19 :GE NI: GE NI:	2 SUBL 0.613 0.387
NI7SC2 :SC: NI:	2 SUBL 0.222222 0.777778
NISC_B2 :SC: NI:	2 SUBL 1 1
NISC2 :SC: NI:	2 SUBL 0.72 0.28
NI3SN2_LT :SN: NI SN: NI:	3 SUBL 0.2 0.4 0.4
NI3SN_HT :NI SN: NI SN: NI:	3 SUBL 0.25 0.25 0.5
NI3SN2_HT 0.33333 :NI: NI SN: SN:	3 SUBL 0.33333 0.33334
NI3SN4 :NI: NI SN: SN:	3 SUBL 0.25 0.25 0.5
NISR :NI: SR:	2 SUBL 0.5 0.5
NI3TI_D024 :NI TI: NI TI:	2 SUBL 0.75 0.25
NITI2 :NI TI: NI TI:	2 SUBL 1 2
NI2V7 :NI: V:	2 SUBL 2 7
NI2V1 :NI: V:	2 SUBL 2 1

NI10ZR7 :NI: ZR:	2 SUBL 23 17
NI21ZR8 :ZR: NI:	2 SUBL 8 21
NI11ZR9 :NI: ZR:	2 SUBL 11 9
NI7ZR2 :NI: ZR:	2 SUBL 7 2
SC5SI3 :SC: SI:	2 SUBL 0.625 0.375
SCSI :SC: SI:	2 SUBL 0.5 0.5
SC3SI5_LT :SC: SI:	2 SUBL 0.375 0.625
SC3SI5_HT :SC: SI:	2 SUBL 0.375 0.625
SCZN :SC: ZN:	2 SUBL 0.5 0.5
SCZN2 :SC: ZN:	2 SUBL 0.3333 0.6667
SC13ZN58 :SC: ZN:	2 SUBL 0.1831 0.8169
SC3ZN17 :SC: ZN:	2 SUBL 0.15 0.85
SCZN122 :SC: ZN:	SUBL 7.7E-2 0.923
SIB3 :B: SI: B SI:	3 SUBL 6 2 6
SIB6 :B: SI: B SI:	3 SUBL 210 23 48
SIBX :B: SI: B SI:	3 SUBL 61 1 8
SIC :C: SI:	2 SUBL 1 1
CR3SI :CR SI: AL CR SI:	2 SUBL 3 1
CRSI2_C40 :CR SI V: AL CR SI:	2 SUBL 1 2
SI2SR_HT :SI VA: SR:	2 SUBL 2 1
SI2SR_LT :SI: SR:	2 SUBL 2 1
SI3TI5 :SI TI: SI TI: TI: VA:	4 SUBL 2 3 3 1
V3SI :V SI: SI V:	2 SUBL 0.75 0.25
CRZN13 :CR: ZN:	2 SUBL 1 13
CRZN17 :CR: ZN:	2 SUBL 1 17
SRZN5_LT :SR: ZN:	2 SUBL 1 5
TIZN2 :TI: ZN:	2 SUBL 1 2
TIZN5 :TI: ZN:	2 SUBL 1 5
TIZN10 :TI: ZN:	2 SUBL 1 10
TIZN15 :TI: ZN:	2 SUBL 1 15
V4ZN5 :V: ZN:	2 SUBL 4 5
ZN2ZR :ZN: ZR:	2 SUBL 2 1
ZN22ZR :ZN: ZR:	2 SUBL 22 1
ZN39ZR5 :ZN: ZR:	2 SUBL 39 5
ZN3ZR_LT :ZN: ZR:	2 SUBL 3 1
ZN3ZR_HT :ZN: ZR:	2 SUBL 3 1
B4C :B11C B12: B2 C2B CB2:	2 SUBL 1 1
CR2B_ORTH :CR: B:	2 SUBL 0.666667 0.333333
CRB4 :CR: B:	2 SUBL 0.2 0.8
SRB6 :SR: B:	2 SUBL 1 6
V2B3 :V: B:	2 SUBL 0.4 0.6
V5B6 :V: B:	2 SUBL 0.454545 0.545455
ZRB12 :B: ZR:	2 SUBL 12 1
CU6CE :CU: CE:	2 SUBL 6 1
CU5CE :CU: CE:	2 SUBL 5 1
CU4CE :CU: CE:	2 SUBL 4 1
CU2CE :CU: CE:	2 SUBL 2 1
CUCE	2 SUBL 1 1

:CU: CE:	
CR3C2	2 SUBL 3 2
:CR: C:	
V3C2	2 SUBL 3 2
:V: C:	
CDCU2	2 SUBL 1 2
:CD: CU:	
CD3CU4	2 SUBL 0.4286 0.5714
:CD: CU:	
CD8CU5	4 SUBL 2 3 2 6
:CU: CD CU: CU: CU CD:	
CD10CU3	2 SUBL 0.7692 0.2308
:CD: CU:	
CR3GE	2 SUBL 0.75 0.25
:CR GE: CR GE:	
CR5GE3_HT	2 SUBL 0.625 0.375
:CR GE: GE CR:	
CR5GE3_LT	2 SUBL 0.625 0.375
:CR GE: GE CR:	
CR11GE19	2 SUBL 0.367 0.633
:CR: GE:	
GE2SR	2 SUBL 2 1
:GE: SR:	
GE3TI5	2 SUBL 5 3
:TI: GE:	
V3GE	2 SUBL 0.75 0.25
:V: GE:	
V17GE31	2 SUBL 0.354 0.646
:V: GE:	
SR3SN52 SUBL 0.375 0.625	
:SR: SN:	
SRSN3	2 SUBL 0.25 0.75
:SR: SN:	
SRSN4	2 SUBL 0.2 0.8
:SR: SN:	
SN3TI2	2 SUBL 3 2
:SN: TI:	
V3SN	2 SUBL 0.205 0.795
:SN: V:	
VSN2	2 SUBL 0.6 0.4
:SN: V:	
SN3ZR5	3 SUBL 5 3 1
:ZR: SN: SN VA:	
> aka eta	
SNZR3_A15	2 SUBL 3 1
:SN ZR: SN ZR:	
V2ZR	2 SUBL 2 1
:V: ZR:	

AL14CA13	2 SUBL 14 13
:AL MG ZN: CA:	
AL3CA8	2 SUBL 3 8
:AL: CA MG:	
AL4CE	2 SUBL 0.8 0.2
:AL: CE:	
AL11CE3	2 SUBL 0.7857 0.2143
:AL: CE:	
AL3CE_H	2 SUBL 0.75 0.25
:AL: CE:	
AL3CE_L	2 SUBL 0.75 0.25
:AL: CE:	
ALCE	2 SUBL 0.5 0.5
:AL: CE:	
ALCE2	2 SUBL 0.3333 0.6667
:AL: CE:	
ALCE3_H	2 SUBL 0.25 0.75
:AL: CE:	
ALCE3_L	2 SUBL 0.25 0.75
:AL: CE:	
AL13CO4	2 SUBL 13 4
:AL: CO:	
AL3CO	2 SUBL 3 1
:AL: CO:	
AL5CO2	2 SUBL 5 2
:AL: CO:	
AL9CO2	2 SUBL 9 2
:AL: CO:	
AL3LA	2 SUBL 3 1
:AL: LA:	
ALLA	2 SUBL 1 1
:AL: LA:	
AL53LA22	2 SUBL 0.707 0.293
:AL: LA:	
AL11LA3_LT	2 SUBL 11 3
:AL: LA:	
AL11LA3_HT	2 SUBL 11 3
:AL: LA:	
AL2LI3	2 SUBL 2 3
:AL MG: LI:	
ALLI2	2 SUBL 1 2
:AL: LI:	
AL4LI9	2 SUBL 4 9
:AL: LI:	
ALLI_B32	2 SUBL 1 1
:AL LI MG: LI MG VA:	
AL3SC	2 SUBL 1 3

:SC: AL:
AL2SC 2 SUBL 1 2 :SC: AL:
ALSC 2 SUBL 1 1 :SC: AL:
ALSC2 2 SUBL 2 1 :SC: AL:
AL3HF4 2 SUBL 3 4 :AL: HF:
LI22SI5 2 SUBL 22 5 :LI: SI:
LI13SI4 2 SUBL 13 4 :LI: SI:
LI7SI3 2 SUBL 7 3 :LI: SI:
LI12SI7 2 SUBL 12 7 :LI: SI:
AG9CA2 2 SUBL 0.818182 0.181818 :AG: CA:
AG7CA2 2 SUBL 0.777778 0.222222 :AG: CA:
AG2CA 2 SUBL 0.666667 0.333333 :AG: CA:
AGCA3 2 SUBL 0.25 0.75 :AG: CA:
AG4SC 2 SUBL 0.8 0.2 :AG: SC:
AGSC 2 SUBL 0.5 0.5 :AG: SC:
AL4C4SI 3 SUBL 4 1 4 :AL: SI: C:
AL8C7SI 3 SUBL 8 1 7 :AL: SI: C:
AL13CR4SI4 3 SUBL 13 4 4 :AL: CR: SI: > Al-Cr-Si, tao 1
AL9CR3SI 3 SUBL 9 3 1 :AL: CR: SI: > Al-Cr-Si, tao 2
ALCRSI_T3 2 SUBL 11 4 :AL SI: CR: > Al-Cr-Si, tao 3
ALCRSI_T4 3 SUBL 58 31.5 10.5 :AL: CR: SI: > Al-Cr-Si, tao 4, AL58CR32SI11
AL23CUFE4 3 SUBL 23 1 4 :AL: CU: FE:

AL62CU25FE13 3 SUBL 0.125 0.255 0.62 :FE: AL CU: AL:
AL7CU2FE 3 SUBL 1 2 7 :FE NI: CU: AL: > Solution phase of the ternary compound Al7Cu2Fe
AL10CU10FE 3 SUBL 1 10 10 :FE: AL CU: AL:
AL2CULI 3 SUBL 0.5 0.25 0.25 :AL: CU: LI: > Al-Cu-Li ternary phase, i.e. T1
ALCULI_T2 3 SUBL 0.57 0.11 0.32 :AL: CU: LI: > Al-Cu-Li ternary phase, T2
ALCULI_R 3 SUBL 0.55 0.117 0.333 :AL: CU: LI: > Al-Cu-Li ternary phase, R
ALCULI_B 3 SUBL 0.6 0.32 8E-2 :AL: CU: LI: > Al-Cu-Li ternary phase, TB
Q_PHASE 3 SUBL 7 3 6 :AL: CU: MG: > Al7Cu3Mg6, Al-Cu-Mg ternary phase
S_PHASE 3 SUBL 2 1 1 :AL SI: CU: MG: > Solution phase based on Al2CuMg
S_PRIME 3 SUBL 2 1 1 :AL: CU: MG: > metastable precipitate, related to S_PHASE
T_PHASE 4 SUBL 26 6 48 1 :MG: AL MG: AL CU MG ZN: AL: > Solution (Al,Cu,Zn)49Mg32, stable in Al-Mg-Zn, Al-Cu-Mg, Al-Cu-Mg-Zn
AL28CU4MN7 3 SUBL 28 7 4 :AL: MN: CU:
AL11CU5MN3 3 SUBL 11 3 5 :AL: MN: CU:
ALCU3MN2 3 SUBL 1 2 3 :AL: MN: CU:
AL7CU4NI 2 SUBL 1 1 :AL: FE CU NI VA:
ALCUSC_TAU 3 SUBL 0.6154 0.3077 7.69E-2 :AL CU: AL CU: SC:

AL9FENI 2 SUBL 9 2 :AL: FE NI:
AL10FE3NI 2 SUBL 5 2 :AL: FE NI:
AL71FE5NI24 3 SUBL 0.71 5E-2 0.24 :AL: FE: NI:
ALFESI_T1 2 SUBL 5 3 :AL SI: FE: > Al-Fe-Si ternary phase, tao 1 / tao 9
ALFESI_T2 4 SUBL 0.5 0.2 0.1 0.2 :AL: FE: SI: AL SI: > Al-Fe-Si ternary phase, tao 2, gamma_AlFeSi
ALFESI_T3 3 SUBL 0.56 0.24 0.2 :AL: FE: SI: > Al-Fe-Si ternary phase, AL56FE24SI10, tao 3
ALFESI_T4 4 SUBL 0.4166 0.1667 0.25 0.1667 :AL: FE: SI: AL SI: > Al-Fe-Si ternary phase, tao 4, delta_AlFeSi
AL8FE2SI 4 SUBL 0.6612 0.19 4.96E-2 9.92E-2 :AL: FE: SI: AL SI: > solution of the Al-Fe-Si ternary phase, tao 5, alpha_AlFeSi
AL9FE2SI2 4 SUBL 0.598 0.152 0.1 0.15 :AL: FE: SI: AL SI: > Al-Fe-Si ternary phase, tao 6, aka Al5FeSi, beta_AlFeSi
ALFESI_T7 2 SUBL 3 1 :AL SI: FE: > Al-Fe-Si ternary phase, AL9FE5SI6, tao 7
ALFESI_T8 2 SUBL 2 1 :AL SI: FE: > Al-Fe-Si ternary phase, AL2FE3SI4, tao 8
ALFESI_T10 3 SUBL 0.6 0.25 0.15 :AL: FE: SI: > Al-Fe-Si ternary phase, AL60FE25SI15, tao 10
ALFESI_T11 3 SUBL 0.65 0.25 0.1 :AL: FE: SI: > Al-Fe-Si ternary phase, AL85FE30SI15, tao 11
ALFEZN_GAMMA 2 SUBL 0.255 0.745 :AL FE ZN: ZN: > Al-Fe-Zn ternary phase, aka gamma 2, no detailed structure
ALLIMG_T 3 SUBL 0.53 0.33 0.14 :AL: LI: MG:
ALLISI 3 SUBL 0.333333 0.333333 0.333334 :LI: AL: SI:

AL3LI8SI5 3 SUBL 0.5 0.1875 0.3125 :LI: AL: SI:
ALLI5SI2 3 SUBL 0.6625 8.75E-2 0.25 :LI: AL: SI:
AL18MG3MN2 3 SUBL 18 3 2 :AL: MG: MN:
ALMG3NI2 3 SUBL 1 2 3 :AL: NI: MG: > Ternary phase AlMg3Ni2, cF96, Fd-3m, Ti2Ni type
BETA_PRIME 2 SUBL 1.8 1 :MG: SI: > metastable precipitate, Mg9Si5/Mg1.8Si, related to Mg2Si
B_PRIME 3 SUBL 3 9 7 :AL: MG: SI: > metastable precipitate, B_Prime, Al-containing Pre-beta phase
U1_AL2MGSI2 3 SUBL 2 1 2 :AL: MG: SI: > metastable precipitate, U1_Al2MgSi2, Al-containing Pre-beta phase
U2_AL4MG4SI4 3 SUBL 1 1 1 :AL: MG: SI: > metastable precipitate, U2_Al4Mg4Si4, Al-containing Pre-beta phase
BETA_DPRIME 3 SUBL 2 5 4 :AL SI: MG: SI: > metastable beta double prime, related to Mg2Si, Mg5Si6, Al2Mg5Si4
ETA_PRIME 3 SUBL 3 2.5 3.5 :AL: MG: ZN: > metastable precipitate, related to MgZn2-based Eta phase
T_PRIME 3 SUBL 0.3 0.4 0.3 :AL: MG: ZN: > metastable precipitate, related to T_PHASE
AL31MN6NI2 3 SUBL 31 6 2

:AL: MN: NI: > Orthorhombic, ternary Al-Mn-Ni phase
AL2MN2SI3 3 SUBL 2 2 3 :AL: MN: SI: > the Al-Mn-Si ternary phase, tao1
AL5MN6SI7 3 SUBL 5 6 7 :AL: MN: SI: > the Al-Mn-Si ternary phase, tao2

AL1MN1SI1 3 SUBL 1 1 1 :AL: MN: SI: > the Al-Mn-Si ternary phase, tao3
AL3MNSI2 3 SUBL 3 1 2 :AL: MN: SI: > the Al-Mn-Si ternary phase, tao4
AL3MN4SI2 3 SUBL 3 4 2 :AL: MN: SI: > the Al-Mn-Si ternary phase, tao5
ALMNSI_T6 2 SUBL 4 1 :AL MN: SI: > the Al-Mn-Si ternary phase, tao6
ALMNSI_T8 4 SUBL 6 3 3 1 :AL: MN: AL MN SI: AL SI: > the Al-Mn-Si ternary phase, tao 8
AL15SI2M4 4 SUBL 16 4 1 2 :AL: FE MN: SI: AL SI: > Solution of Al-Mn-Si ternary phase, tao 9, Al15(Mn,Fe)3Si2
AL2MNSI3 3 SUBL 2 1 3 :AL: MN: SI: > the Al-Mn-Si ternary phase, tao10
AL24MN5ZN 3 SUBL 5 1 24 :MN ZN: ZN: AL:
AL9MN2ZN 3 SUBL 2 1 9 :MN: ZN: AL:
AL11MN3ZN2 3 SUBL 3 2 11 :MN: ZN: AL:
ALNI2SI 2 SUBL 1 1 :AL SI VA: NI:
AL6NI3SI 3 SUBL 6 3 1 :AL: NI: SI:
ALNI16SI9 3 SUBL 1 16 9 :AL: NI: SI:
ALNI2ZN 3 SUBL 0.25 0.5 0.25 :AL: NI: ZN:
AL13NI38ZN49 3 SUBL 0.13 0.38 0.49 :AL: NI: ZN: > Al-Ni-Zn ternary phase
CU16MG6SI7 3 SUBL 16 6 7 :CU: MG: SI:
CU3MG2SI 3 SUBL 2.74 2 1.26 :CU: MG: SI:
CU5MN4SI 3 SUBL 0.5 0.37 0.13 :CU: MN: SI:
CUMNZN 3 SUBL 0.334 0.333 0.333 :CU: MN: ZN:

CU6NISI3 2 SUBL 0.732 0.268 :CU NI: SI:
CU46NI25SI29 3 SUBL 0.458 0.25 0.292 :CU: NI: SI:
FE5NI3SI2 2 SUBL 4 1 :FE NI: SI:
ZN13M2 2 SUBL 1 6.5 :FE NI: ZN:
MG6MN3NI 3 SUBL 0.5 0.1666667 0.3333333 :MG: MN: NI:
MGNI6SI6 3 SUBL 1 6 6 :MG: NI: SI:
MG2NI3SI 3 SUBL 2 3 1 :MG: NI: SI:
MG10NI55SI35 3 SUBL 2 11 7 :MG: NI: SI:
MG2NI16SI11 3 SUBL 1 8 5.5 :MG: NI: SI:
MG5NI9SI 3 SUBL 1 1.8 0.2 :MG: NI: SI:
MG9NI29SI16 3 SUBL 9 29 16 :MG: NI: SI:
MGNI6ZN6 4 SUBL 3 4 1 2 :MG ZN: MG NI ZN: NI: ZN:
MN15NI45SI40 3 SUBL 0.15 0.45 0.4 :MN: NI: SI: > Mn-Ni-Si ternary phase, T1 or N
MN15NI50SI35 3 SUBL 0.15 0.5 0.35 :MN: NI: SI: > Mn-Ni-Si ternary phase, T2 or PHI
MN6NI16SI7 3 SUBL 0.206897 0.551724 0.241379 :MN: NI: SI: > Mn-Ni-Si ternary phase, T3 or G
MN1NI1SI1 3 SUBL 1 1 1 :MN: NI: SI: > Mn-Ni-Si ternary phase, T4 or E
MNNISI_T5 2 SUBL 1 2 :MN: NI SI: > Mn-Ni-Si ternary phase, T5 or "tao 1"
MNNISI_T6 2 SUBL 1 2 :MN: NI SI: > Mn-Ni-Si ternary phase, T6 or "tao 2"
MN3NI2SI 3 SUBL 3 2 1 :MN: NI: SI: > Mn-Ni-Si ternary phase, T7 or Omega

MN2NISI :MN NI: SI: > Mn-Ni-Si ternary phase, T8 or S	2 SUBL 3 1
MN6NISI3 0.27 :MN: NI: SI: > Mn-Ni-Si ternary phase, T9 or R	3 SUBL 0.61 0.12
MN66NI4SI30 :MN: NI: SI: > Mn-Ni-Si ternary phase, T10 or U	3 SUBL 0.66 4E-2 0.3
MN52NI29SI19 0.19 :MN: NI: SI: > Mn-Ni-Si ternary phase, T11 or W	3 SUBL 0.52 0.29
MN7NI7ZN86 0.86 :MN: NI: ZN:	3 SUBL 7E-2 7E-2
NI2SIZN_T1 :NI: SI: ZN:	3 SUBL 0.5 0.25 0.25
NI9SI2ZN_T2 8.25E-2 :NI: SI: ZN:	3 SUBL 0.75 0.1675
NI2SIZN3_T3 :NI: SI: ZN:	3 SUBL 2 1 3
NISIZN_T4 :NI: SI: ZN: > Ni-Si-Zn tao 4, Ni3Si2Zn1	3 SUBL 3 2 1
Q_ALCUMGSI :AL: CU: MG: SI: > Quaternary phase, aka Q, Al5Cu2Mg8Si6, Al3Cu2Mg9Si7 & Al4Cu2Mg8Si7	4 SUBL 5 2 8 6
AL18FE2MG7SI10 :AL: FE: MG: SI: > Quaternary phase, aka Al8FeMg3Si6 and Q_/PHI/H_PHASE	4 SUBL 18 2 7 10

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