Problems to the lecture „Physical Metallurgy“ („Materialkunde“)

Chapter 4: Alloys

WS 1999/2000

Explanation:

A-question: Solve the following question with the help of the lecture notes.
B-question: solved examples
C-question: Solve the following question on your own with the help of the lecture notes and the hints given in section B

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1J=1Nm, 1Å=10^{-10} m, R=8.3144 J/molK,
k=8.62 \cdot 10^{-5} eV/K = 1.38 \cdot 10^{-23} J/K, N_L=6.023 \cdot 10^{23} mol^{-1}

Materials properties for Aluminium:
G=27 \cdot 10^9 N/m^2, a=4.04 Å, T_S=660°C, \rho=2.7 g/cm^3, A=27.0 g/mol, \nu=0.34
\gamma_{SFE}=18 \cdot 10^{-2} J/m^2, \gamma_{KG}=0.6 J/m^2

Materials properties for Copper:
G=48 \cdot 10^9 N/m^2, a=3.61 Å, T_S=1083°C, \rho=8.7 g/cm^3, A=63.5 g/mol, \nu=0.35
\gamma_{SFE}=5 \cdot 10^{-2} J/m^2, \gamma_{KG}=0.5 J/m^2, \gamma_{Ob}=1 J/m^2
A-question:
Sketch the following binary systems:
  a) with complete solubility in the solid and the liquid state
  b) without solubility in the solid and the liquid state
  c) a eutectic system
  d) and a peritectic system.

A-question:
Describe the cooling of a peritectic alloy and sketch the structure during solidification.

A-question:
Explain the concepts of „melting congruently“ and „melting incongruently“.

A-question:
Explain the lever principle.

B-question:
a) Determine the Gibbs free energy of a phase mixture under the assumption that it consists proportional of the Gibbs free energy of the individual phases (tangential law).
b) Discuss the construction of a phase diagram from the G(c)-curves by the use of the tangential law.

B-question:
Calculate the molar free enthalpy of a regular mixture of a binary system and sketch H(c), S(c) and G(c) for a fixed temperature as a function of $H_0$.

A-question:
Explain the following concepts: solid solution, substitutional solid solution and interstitial solid solution. Name possible technical applications.

A-question:
Discuss the Hume-Rothery rules for the formation of primary solid solutions. What is your expectation for the phase diagrams Au-Cu, Au-Ag and Cu-Ag ($a_{\text{Au}} = 4.0786$ Å, $a_{\text{Ag}} = 4.0863$ Å, $a_{\text{Cu}} = 3.6148$ Å)?

A-question:
Calculate the valence electron concentration for the alloys with the maximal solubility of Zn, Ga, Ge and As respectively in Cu (fig. 4.31).
A-question:
Explain the following concepts and give examples for every concept:
„intermetallic phase“ (intermediate compound), „primary solid solution“ and „intermediate solid solution“

C-question:
a) What is the lattice structure of the intermetallic phase NiAl called? What does it have in common with the body-centred cubic structure, what are the differences?
b) In an ordered cubic alloy, which is the lowest-indexed plane that, according to the Bragg law, reflects? Give an explanation!

C-question:
Draw an elementary cell of the ordered alloys \(\beta\)-CuZn, NiAl, Cu, Au, Ni, Al, FeAl and CuAu. What are their lattice structures?

B-question:
In a binary fcc-AB-alloy the binding energies of the AA-, BB- and AB-pairs be \(H_{AA}\), \(H_{BB}\) and \(H_{AB}\) respectively. Calculate the transposition work \(H_0\). If the diffusion temperature \(T_D\) is 100°C or 290°C, what is the state of the alloy at room temperature and at 400°C?

a) \(H_{AB} = -0.1\) eV
\(H_{AA} = -0.095\) eV
\(H_{BB} = -0.0957\) eV

b) \(H_{AB} = -0.030\) eV
\(H_{AA} = -0.035\) eV
\(H_{BB} = -0.033\) eV

A-question:
Explain the concepts of short range order and long range order.

B-question:
Calculate and draw the long range order parameter \(s\) for an ordered bcc-AB-alloy (\(\beta\)-brass) as a function of temperature.

A-question:
Explain the concept of antiphase boundaries. What makes them develop? What effects do they have?

A-question:
a) How are Zintl-phases characterised? (1 example)
b) How are Laves-phases characterised? (1 example)
c) How are Hägg-phases characterised? (1 example)
d) How are Hume-Rothery-phases characterised? (1 example)
B-question:
Calculate the valence electron concentrations of the stable phases $\alpha$, $\beta$, $\gamma$ and $\varepsilon$ occurring in the brass system (Cu-Zn) ($\text{VEK}=c_N N_a + (1-c)N_b$).

C-question:
Which type do the following intermetallic phases belong to?
MgCu$_2$, NiAl, MgZn$_2$, Fe,N, TaC, Ta,C, Fe,C, Cu,Ga, Ni,Al, Mg,Si, Ni,Zn$_{21}$.
(atomic diameter $/ 10^{-10}$m : Ta: 2.85; Fe: 2.48; C: 1.51; N: 1.42; Mg: 3.2; Si: 2.34; Ni: 2.49; Al: 2.86; Zn: 2.67; Cu: 2.56)