Some Conclusions from Rules on the Concentration of Valency Electrons in Binary Intermetallic Alloys

Harald Perlitz

Citation: The Journal of Chemical Physics **1**, 335 (1933); doi: 10.1063/1.1749298
View online: http://dx.doi.org/10.1063/1.1749298
View Table of Contents: http://scitation.aip.org/content/aip/journal/jcp/1/5?ver=pdfcov
Published by the AIP Publishing

Some Conclusions from Rules on the Concentration of Valency Electrons in Binary Intermetallic Alloys

HARALD PERLITZ, *University of Estonian Republic*
(Received January 12, 1933)

1. INTRODUCTION

IN 1926 W. Hume-Rothery suggested that the similarity of β-phases in Cu–Zn, Ag–Zn, Au–Zn, Ag–Cd, Au–Cd, Cu–Al, Ag–Al and Cu–Sn alloys is due to the fact that these phases are space lattices of atoms and electrons for which the ratio of electrons to atoms, the so-called concentration of valency electrons, is the same, viz., 3 : 2, according to the chemical formulae CuZn, AgZn, AuZn, AgCd, AuCd, Cu_3Al, Ag_3Al and Cu_5Sn which are usually ascribed to these β-phases.[1] At the same time, from a survey of displacements of homogeneity ranges of structurally similar phases in certain binary alloys of copper, silver and gold Arne Westgren and Gösta Phragmén concluded too that the atomic grouping of intermetallic phases is to a considerable degree regulated by their concentration of valency electrons.[2]

2. STATEMENT OF THE RULES

To-day 35 binary intermetallic alloys are known in which up to three intermediate phases are met with which are structurally similar to β-, γ- and ϵ-phases of the Cu–Zn-system.[3] As a rule these phases occur at such compositions for which the concentrations of valency electrons attain certain values peculiar to each type of structure. The characteristic values for concentrations of valency electrons are:

(1) 3 : 2 for phases with the body-centered cubic lattice of β-brass or with the cubic lattice of β-manganese with 20 atoms in the unit cube, phases which will be referred to as β-phases.

(2) 21 : 13 for phases with the cubic lattice of γ-brass with 52 atoms in the unit cube, phases which will be referred to as γ-phases.

(3) 7 : 4 for phases with the close-packed hexagonal lattice of ϵ-brass, phases which will be referred to as ϵ-phases.

3. FORMULAE FOR AND FROM THE RULES

Now, if the number of valency electrons of the first component of the binary alloy is denoted by m, and that of the second one by n; if in the phases with β-, and γ-, and ϵ-structures the number of atoms of the first component is denoted by x, and that of the second one by y, then the concentration of valency electrons, k, is defined by $(mx+ny) : (x+y) = k$. Solving this equation with respect to the ratio x/y, we have $x : y = (k-n) : (m-k)$. In this expression the left-hand side is positive, and therefore the right-hand side should be positive too. But that necessitates that m, n, and k should satisfy the inequality $m \leqq k \leqq n$.

4. CONCLUSIONS FROM THE INEQUALITY

The obtained inequality leads to following conclusions:

(1) β-, γ-, and ϵ-structures are not to be expected in binary intermetallic alloys if both components have the same number of valency electrons.

(2) A β-, γ- or ϵ-structure is to be expected in binary intermetallic alloys if the one component has less and the other component more than

[1] J. Inst. Met. **35**, 295 (1926), London.

[2] Ark. mat., astron. och fysik **B19**, 5 (1926).

[3] Arne Westgren und Gösta Phragmén, Zeits. f. Metallkde. **15**, September (1926); Metallwirtsch. **7**, 701–702 (1928); Zeits. f. anorg. allg. Chemie **175**, 84 (1928); Zeits. f. Metallkde. **18**, 279 (1929); Trans. Faraday Soc. **25**, 380–382 (1929). A. Westgren und W. Eckman, Ark. kem., mineral. och geol. **B10**, No. 11, 1–4 (1930). W. Eckman, Zeits. f. physik. Chemie **B12**, 58–59, 77 (1931). A. Westgren, Zeits. f. Metallkde., No. 11 (1930); Metallwirtsch. **9**, 922–923 (1930); Trans. Amer. Inst. min. metallurg. Engr. Institute of Metals Div. 1931 p. 35–37; J. Frank. Inst. **212**, 592–595 (1932); Zeits. f. angew. Chem. **45**, 11, 13, 15–18 (1932); Harald Perlitz, Acta et Commen. Univ. Tartuensis, **24**, tract No. 3 (1932); Metallwirtsch. 12 (1933).

3 : 2, 21 : 13 or 7 : 4 valency electrons, respectively.

(3) Since the characteristic values of concentrations of valency electrons are between two consecutive integers, it follows that in alloys in which one of the three structures referred to is met with, both other structures should be expected too. This statement accounts for the frequent coexistence of β-, γ-, and ϵ-structures.

(4) Since the lower and upper limit for the values of concentration of valency electrons are one and two, it follows that a β-, γ- or ϵ-structure is to be expected in binary intermetallic alloys if the one component has not more than one valency electron, and the other component has not less than two valency electrons.