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Magnetic Susceptibility of Liquid Gold-Indium-Zinc Alloys

P. Terzieff

Institut für Anorganische Chemie, Universität Wien, A-1090 Wien, Austria

Summary. Alloys of the ternary system gold-indium-zinc with a variable content of gold x_{Au} at a constant ratio of $x_{In}:x_{Zn} = 1:1$ have been investigated by susceptibility measurements from 300 K up to 1500 K with emphasis on the liquid state. The magnetic susceptibilities of the homogeneous liquids were found to vary in a non-linear manner with temperature and composition. At temperatures close to the liquid-solid transition, the susceptibilities pass through a characteristic minimum which tends to disappear with increasing temperature. The anomaly located at $x_{Au} \approx 0.6$ seems to be related to a particular valence electron concentration of $e/a \approx 1.6$.

Keywords. Liquid alloys; Gold-based alloys; Magnetic susceptibility.

Magnetische Suszeptibilität von flüssigen Gold-Indium-Zink-Legierungen

Zusammenfassung. Legierungen des ternären Systems Gold-Indium-Zink mit einem variablen Goldgehalt x_{Au} bei konstantem Indium-Zink-Verhältnis ($x_{In}:x_{Zn} = 1:1$) wurden zwischen 300 und 1500 K auf ihre magnetische Suszeptibilität untersucht. Das Hauptaugenmerk wurde dabei auf den flüssigen Zustand gelegt. Die magnetischen Suszeptibilitäten der homogenen Schmelzen variieren nichtlinear mit Temperatur und Zusammensetzung. Bei Temperaturen nahe dem übergang flüssig-fest tritt ein charakteristisches Minimum der Suszeptibilität auf, das mit steigender Temperatur verschwindet. Die Anomalie bei einem x_{Au} von *ca.* 0.6 scheint mit einer speziellen Valenzelektronenkonzentration (e/a) von etwa 1.6 verknüpft zu sein.

Introduction

Disregarding systems with extremely strong interactions, the electronic transport in liquid metals and alloys seems to be well explained by the current theoretical concepts [1, 2]. Without applying full theory, the frequent occurrence of maxima in the electrical resistivity as well as the appearance of negative temperature coefficients can be successfully analyzed in terms of the simplified condition $k_p \approx 2k_f$, which relates the first peak(s) of the structure factor(s) k_p to the diameter of the *Fermi* surface k_f [3]. This simple rule doesn't apply to the magnetic susceptibility, but it has become apparent that in many amorphous [4] and liquid systems [5–7] the susceptibilities pass through characteristic minima at very specific electron concentrations e/a.

This paper is part of a systematic study focussed on the influence of the parameter e/a on the magnetic susceptibility of liquid Au-based alloys. It was of interest to see how an alloying partner with the formal valency of 2.5 (*i.e.* InZn with $x_{In}:x_{Zn} = 1:1$) matches the conclusions drawn from previous investigations [5–7].

Results and Discussion

The compositions of the samples refer to a variable content of gold (x_{Au}) and a constant ratio of indium and zinc ($x_{In}:x_{Zn} = 1:1$) according to the notation $Au_x(InZn)_{1-x}$. Figure 1 shows the variation of the magnetic susceptibilities with the temperature for a choice of representative alloys. The marked discontinuities on the low temperature end are associated with the liquid-solid transition and comply with variation of the liquidus temperatures in the binary systems [8]. The divergencies between the heating and cooling curves are due to supercooling effects.

The magnetic susceptibility of the homogeneous liquid varies i) in a simple linear manner at the margins of the section and ii) in a non-linear manner at intermediate compositions indicating an increased temperature dependence in the range directly above the liquidus temperature. This tendency is also reflected in the isothermal representation shown in Fig. 2, for two limiting temperatures. The magnetic susceptibilities pass through a minimum located on the Au-rich side which is clearly

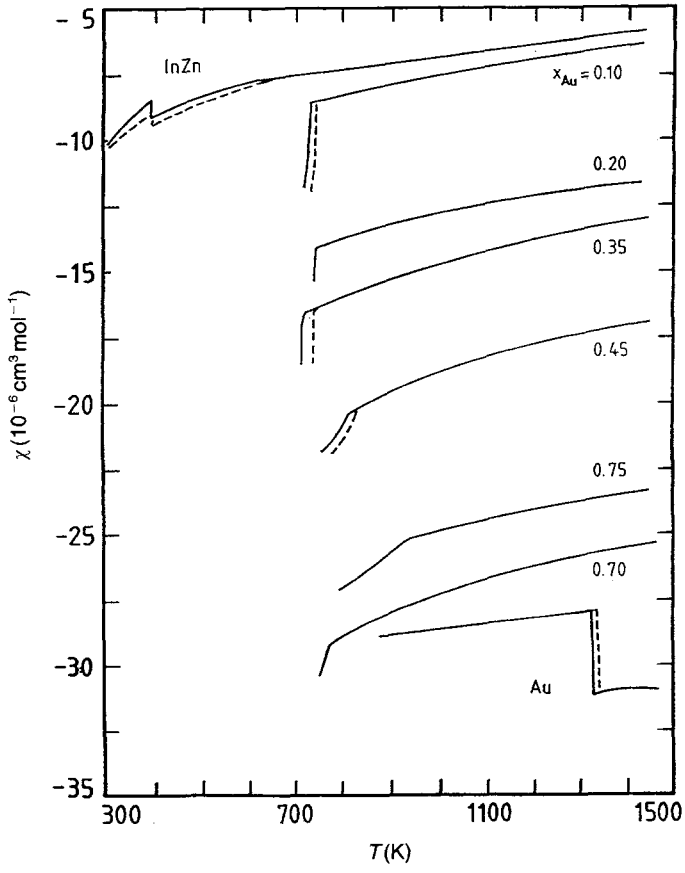

Fig. 1. Magnetic susceptibility of liquid $Au_x(InZn)_{1-x}$ ($x_{In}:x_{Zn} = 1:1$) as a function of temperature (— heating, – – cooling)

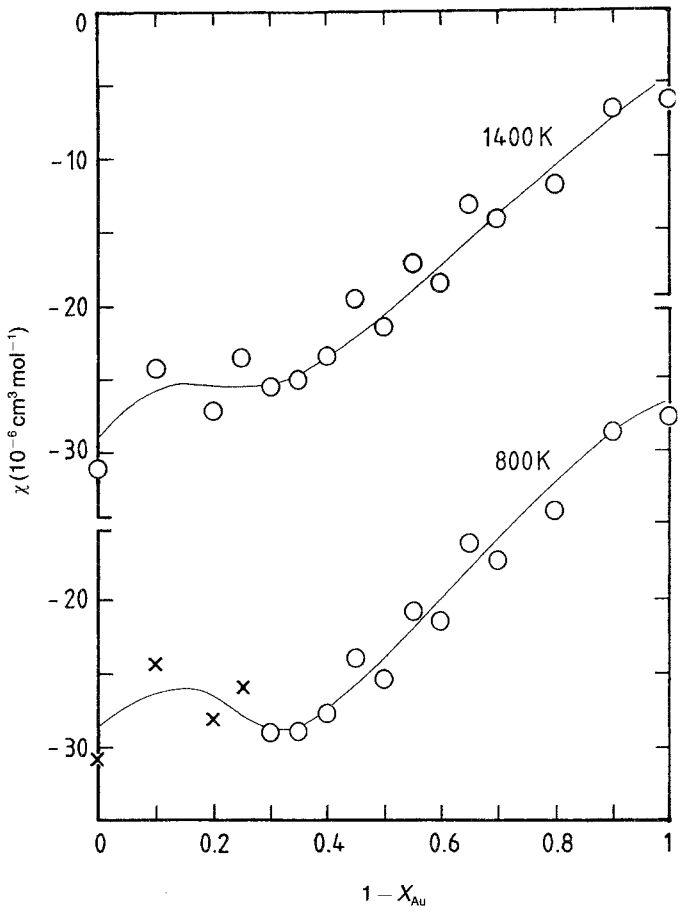

Fig. 2. Magnetic susceptibility of liquid $Au_x(InZn)_{1-x}$ ($x_{In}:x_{Zn}=1:1$) as a function of composition at 800 K and 1400 K (○ measured, × extrapolated)

indicated at 800 K (the data points given for $x_{Au} \geqq 0.75$ are extrapolated) but less pronounced 1400 K. The negative deviations from additivity turn out to be maximal around $x_{Au} \approx 0.6$ corresponding to a valence electron concentration of $e/a \approx 1.6$. This is in remarkable coincidence with the susceptibility minima in liquid Au–In [5], Au–Ge [6], and Au–Sb alloys [7] which are observed to occur at electron concentrations of 1.5–1.7.

The argumentation in terms of electron concentration is plausible but not really justified by theory. Still, applied to the series of Au-based alloys, the appearance of susceptibility minima seems to be correlated with a particular value of e/a.

Experimental

High purity gold sheet (4N, Ögussa, Austria), indium rods (5N, Asarco, USA), and zinc shot (5N, Alfa-Ventron, FRG) were used as starting materials. Samples with a total mass of *ca.* 0.6 g were prepared by direct synthesis in evacuated sealed quartz ampoules. Homogenization was achieved by thermal treatment at 1400 K for a period of 10 h.

The magnetic measurements were performed in suitable quartz containers on a self recording *Faraday*-type balance at heating and cooling rates of 2–5 $K \cdot min^{-1}$. The contributions of the individual containers inaccessible to direct measurements were taken into account in a semi-empirical manner. The total experimental error was estimated to be better than $\pm 2 \cdot 10^{-6}\,cm^3 \cdot mol^{-1}$.

References

[1] Feber TE, Ziman JM (1965) Phil Mag **11**: 153
[2] Evans R, Greenwood DA, Lloyd P (1971) Phys Lett **35A**: 57
[3] Busch G, Güntherodt HJ (1967) Phys kondens Mater **6**: 325
[4] Häussler P (1983) Z Phys B – Condensed Matter **53**: 15
[5] Terzieff P, Komarek KL, Wachtel E (1986) J Phys F: Met Phys **16**: 1071
[6] Terzieff P, Komarek KL, Wachtel E (1992) J Phys: Condensed Matter **4**: 1233
[7] Terzieff P, Komarek KL, Wachtel E, Predel B (1994) Phys Chem Liq **28**: 145
[8] Moffat WG (1984) The Handbook of Binary Phase Diagrams. Genium, New York

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