

CRYSTAL STRUCTURE AND MAGNETIC PROPERTIES OF RHOMBOHEDRAL Y-CO-NI COMPOUNDS

E. BURZO,¹ Ileana CREANGĂ²

Compușii $Y_2Co_{7-x}Ni_x$ cu $x \leq 3$ cristalizează într-o rețea de tip rombroedric. Magnetizarea de saturație și temperatura Curie descresc rapid atunci când crește conținutul de nichel. Deasupra punctelor Curie susceptibilitatea urmează o dependența de tipul Curie-Weiss. Comportamentul magnetic al metalelor de tranziție a fost analizat cu ajutorul modelului fluctuațiilor de spin.

The $Y_2Co_{7-x}Ni_x$ compounds with $x \leq 3$ crystallize in a rhombohedral type lattice. The saturation magnetizations and Curie temperatures decrease rapidly when increasing nickel content. Above the Curie points, the reciprocal susceptibilities follow a Curie-Weiss-type dependence. The magnetic behaviour of transition metals was analysed in spin fluctuation model.

1. Introduction

The Y-Co intermetallic compounds show a wide variety of magnetic behaviour as determined by cobalt contributions. These cover the situation in which Co has a well localized moment as in Y_2Co_{17} , or at opposite side, when an exchange enhanced magnetic susceptibility was shown, as in YCo_2 [1]. In Y_2Co_7 compound, cobalt has interesting magnetic properties as function of stoichiometry. For a lower cobalt content than the stoichiometric one, random substitutions of Co by some Y atoms take place. Consequently, some Co atoms have higher Y coordination. It results a decrease of the magnetic correlations and the Co atoms situated in the neighborhood of these substitutions are unstable from the magnetic point of view [2]. Thus, the saturation moment per formula unit can decrease from $8.56 \mu_B$ to $6.34 \mu_B$ as function of cobalt deficit. This suggests a high sensitivity of cobalt moment to the exchange interactions.

The Y_2M_7 with $M = Co$ or Ni crystallizes in a rhombohedral type lattice having $R\bar{3}m$ space group [1]. The nickel in Y_2Ni_7 shows a weak ferromagnetic behaviour. The magnetic moment per formula unit is $0.56 \mu_B$ and the Curie temperature is $T_C \cong 54$ K [3]. Previous study on $Y_2Co_{7-x}Ni_x$ [4] showed that the magnetizations decrease very fast when cobalt is replaced by nickel.

¹ Prof., Faculty of Physics Babes-Bolyai University Cluj-Napoca, ROMANIA

² Lecturer, Dept. of Physics, University "Politehnica" of Bucharest, ROMANIA

As an on going work on intermetallic compounds we studied the crystal structure and the magnetic properties of $Y_2Co_{7-x}Ni_x$ compounds in a large temperature range including the paramagnetic region. We show that the degree of itinerancy of transition metal moments increases as the nickel content is higher.

2. Experimental

The $Y_2Co_{7-x}Ni_x$ compounds with $x \leq 3$ were prepared in arc furnace, in purified argon atmosphere. The samples were remelted several times to ensure a good homogeneity. A small excess of yttrium ($\cong 1\%$) was added to compensate for the weight loss during melting. The samples were thermally treated in vacuum, at $1000\text{ }^\circ\text{C}$, for one week. The X-ray analyses show the presence of only one phase having rhombohedral type structure. The lattice parameters decrease when increasing nickel content (Fig. 1).

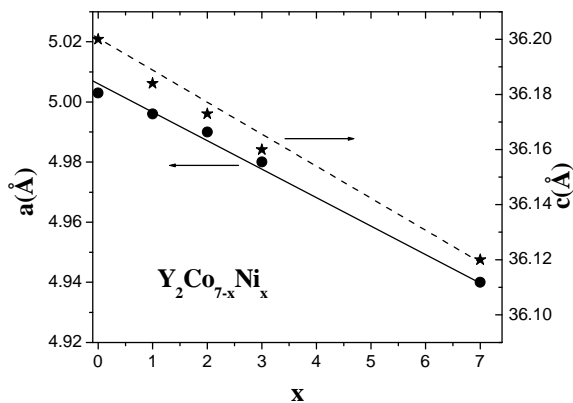


Fig.1. Composition dependence of lattice parameters

Magnetic measurements were performed in the temperature range 4.2-1000 K in field up to 7 T. The paramagnetic data were obtained by using a Faraday type balance. For measurements at $T > 300\text{ K}$, the samples were sealed in quartz tubes under vacuum.

3. Experimental results

The composition dependence of the saturation moment, at 4.2 K, is plotted in Fig. 2. A value of $7.6\text{ }\mu_B/\text{f.u.}$ was obtained in Y_2Co_7 . This value suggests that the compound is not fully stoichiometric. We appreciate that the deviation from stoichiometry is of order of 3%. The saturation magnetizations decrease rather fast when cobalt is replaced by nickel. The same behaviour can be observed for

the Curie temperatures T_C (Fig.3). The above behaviour can be correlated with the diminution of the exchange interactions. The nickel moment in Y_2Ni_7 has a very small value of $\cong 0.08 \mu_B/\text{atm}$. Thus, the exchange interactions are considerable diminished as result of the presence of nickel. This effect can be evidenced by plotting the saturation magnetizations as function of Curie temperature. A linear relation was shown in agreement with the above supposition (Fig.4).

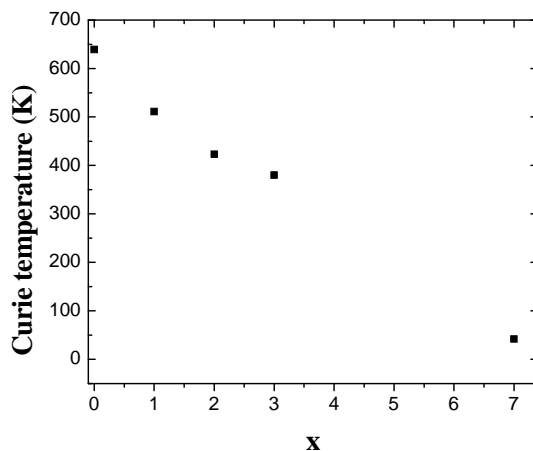


Fig.2. Saturation moments at 4.2 K

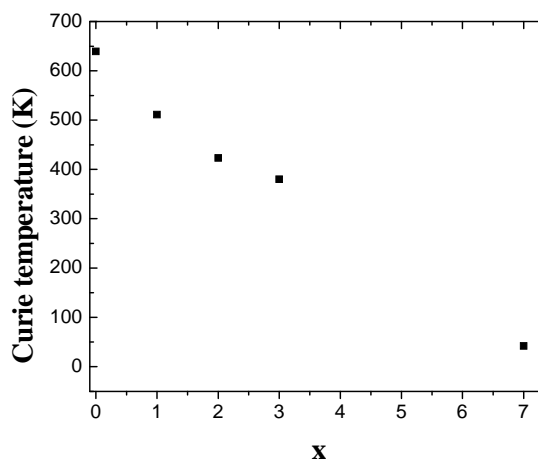


Fig.3. Composition dependence of the Curie temperatures

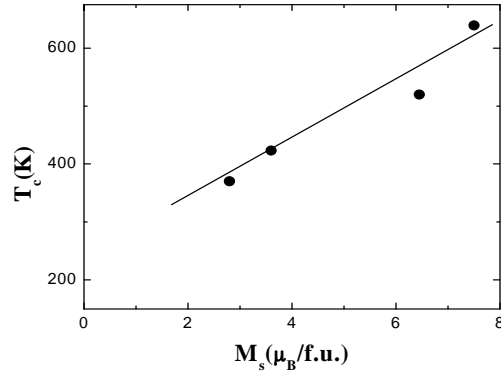


Fig. 4. Correlation of Curie temperature and saturation magnetizations

The thermal variations of reciprocal susceptibilities are given in Fig.5. A Curie-Weiss law is shown, described by the relation:

$$\chi = C(T - \theta)^{-1} \quad (1)$$

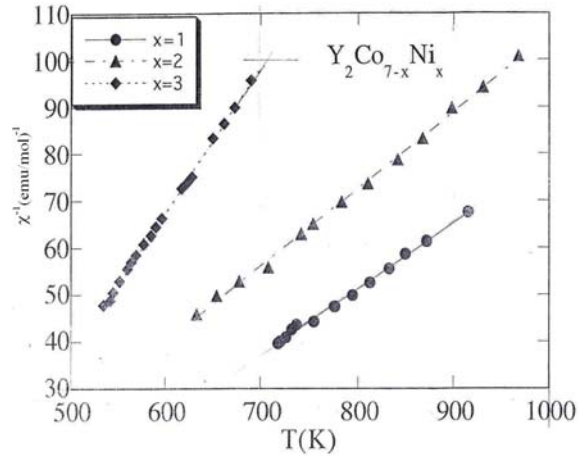


Fig. 5. Thermal variations of reciprocal susceptibilities

We denoted by C the Curie constant and θ is the paramagnetic Curie temperature.

From Curie constant we determined the, M_{eff} , effective mean transition metal moment. The M_{eff} values decrease from $\cong 3 \mu_B$ ($x = 0$) to $\cong 2 \mu_B$ ($x = 3$) (Fig.6). This decrease is not so high as for saturation transition metal moments.

4. Discussion

In the present system at 4.2 K there are two types of magnetic atoms: cobalt and nickel both sensitive to the exchange interactions. Their contributions to magnetization are not possible to be separated. Thus in the analysing the data we can consider a mean value for transition metal moment.

The experimental data show a diminution of the mean transition metal moment when the nickel content increase, suggesting an increase of the itinerancy degree. The itinerancy degree can be evaluated from the ratio between the number of spins determined from effective transition metal moment, S_p and those obtained from saturation data S_0 [5,6], $r = S_p / S_0$. Their values increase from $r = 2$ ($x = 0$) to $r = 3.8$ ($x = 3$) (Fig.6). In the local moment limit, $r = 1$, and for the opposite weakly ferromagnetic limit, a divergence of this ratio is expected as $S_0 \rightarrow 0$.

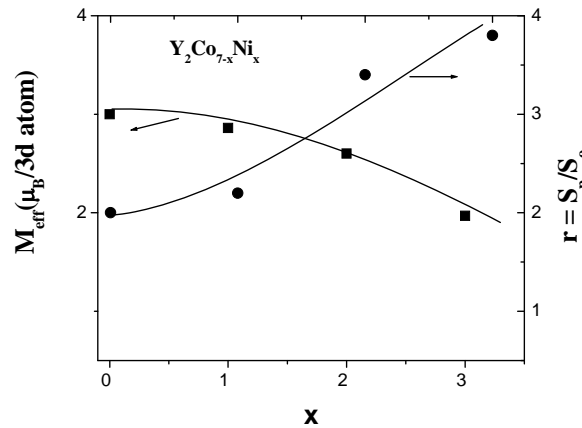


Fig. 6. Composition dependences of effective moments per 3d atom and of the ratio r

The transition metal moment may be analysed in spin fluctuation model [7,8]. When the amplitude of local spin fluctuations (LSF) is large and fixed, there is a local moment limit, where only the transverse components of LSF are important. On the other hand when the amplitude of LSF is small there is the

weakly ferromagnetic limit, where the longitudinal components of LSF or temperature variation of amplitude of LSF play an important role. In $Y_2Co_{7-x}Ni_x$ system both the transverse and longitudinal components of LSF seem to be present, their relative contributions being dependent on nickel content as evidenced by increase of r values.

Conclusions

We conclude that in $Y_2Co_{7-x}Ni_x$ compounds the nature of spin fluctuations is changed continuously as a function of composition. The contributions of longitudinal components of local spin fluctuations or the variation with temperature of the local spin fluctuations increase rapidly and dominate the magnetic properties of samples having high nickel content.

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