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MAGNETIC BEHAVIOUR OF $U_{1-x}Dy_xNi_5$ SYSTEMS

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The magnetic properties of $(U_{1-x}Dy_x)Ni_5$ compounds were studied in the temperature range 2–800 K and fields up to 7 T. The compounds having $x \geq 0.2$ are magnetically ordered. Above the Curie points, the reciprocal susceptibilities follow a modified Curie–Weiss behaviour. UNi_5 is a paramagnet. A peak in the temperature dependence of the magnetic susceptibility is evidenced at $T \approx 20$ K. For $T > 140$ K the UNi_5 susceptibility is temperature independent.

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1. Introduction

UNi_5 crystallizes in a cubic structure of $AuBe_5$ type [1]. The compound is not magnetically ordered down to 2 K. A peak in the temperature dependence of the magnetic susceptibility is evidenced at $T = 20$ K. Over $T^* = 140$ K the susceptibility is temperature independent [2]. $DyNi_5$ crystallizes in a hexagonal structure of $CaCu_5$ type. A ferromagnetic type ordering is evidenced having the Curie temperature $T_C = 11.6$ K [3].

As a part of an ongoing investigation of uranium intermetallic compounds, we studied the magnetic behaviour of $(U_{1-x}Dy_x)Ni_5$ systems where uranium is gradually substituted by dysprosium.

2. Experimental

The samples were obtained by melting the constituent elements in an arc furnace, in purified argon atmosphere. In order to ensure a good homogeneity, the buttons were remelted several times. The samples were thermally treated in vacuum, during one weak, at 850°C and then annealed. X-ray analyses show that $(U_{1-x}Dy_x)Ni_5$ systems crystallize in a cubic type structure for $x \leq 0.6$.

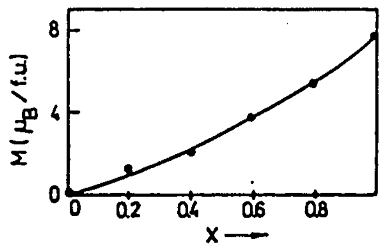
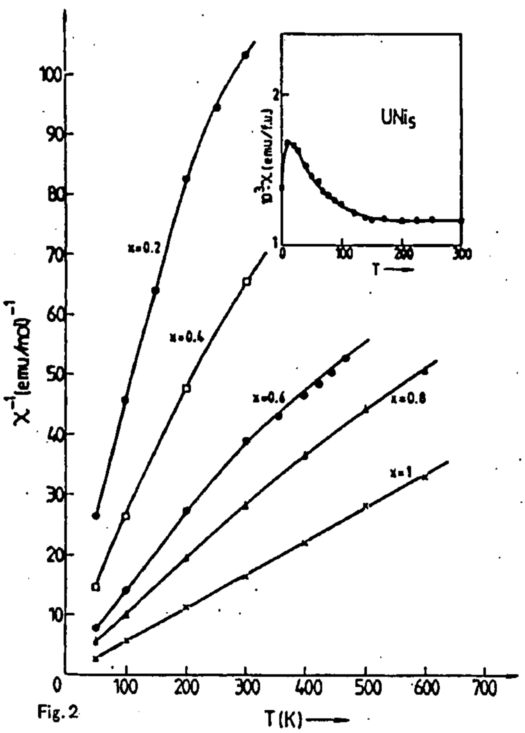


Fig. 1. The composition dependence of spontaneous magnetizations for $(U_{1-x}Dy_x)Ni_5$ system.



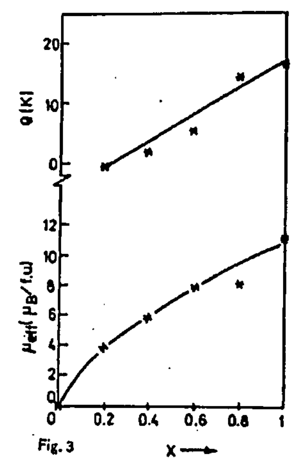


Fig. 2. The thermal variation of the reciprocal susceptibilities for $(U_{1-x}Dy_x)Ni_5$. In the inset the thermal dependence of UNi_5 susceptibility is presented.

Fig. 3. The dysprosium composition dependence of θ, μ_{eff}/fu values for $(U_{1-x}Dy_x)Ni_5$ compounds.

The magnetic measurements were performed in the temperature range 2–700 K and fields up to 7 T. The studied systems present a ferromagnetic order in the composition range $x \geq 0.2$. The spontaneous magnetizations were determined according to $M = M_0(1 - a/H) + \chi'_0 H$, where a is the coefficient of magnetic hardness and χ'_0 is the field independent susceptibility. The ferromagnetic Curie temperatures are slowly increasing as Dy content is greater up to 11.6 K, the T_C value corresponding to $DyNi_5$. The spontaneous magnetizations calculated per formula unit are increasing when Dy concentration becomes higher. The composition dependence of these values are presented in Fig. 1.

Above the Curie temperatures T_C the accurate susceptibility χ values were obtained from their field dependence according to Honda–Owen plots [4], $\chi_m = \chi + cM_s' H^{-1}$, while extrapolating to $H^{-1} \to 0$. A presumed content of magnetic impurity is denoted by c, M_s' is its saturation magnetization and χ_m is the measured susceptibility.

UNi_5 is reported as a spin fluctuation system presented a maximum in the thermal variation of the magnetic susceptibility. The χ values are decreasing up to $T^* = 140$ K. Over this temperature the susceptibility is temperature independent evidencing a Pauli type paramagnetism as it is seen in the inset, in Fig. 2.

The thermal variations of the reciprocal susceptibilities for $(U_{1-x}Dy_x)Ni_5$, which are represented in Fig. 2, follow a modified Curie–Weiss law: $\chi = \chi_0 + C(T - \theta)^{-1}$. C represents the Curie constants, θ is the paramagnetic Curie temperatures and χ_0 — the temperature independent contribution to the susceptibility. According to this behaviour we calculated C, θ, χ_0 and the effective magnetic moments μ_{eff}.

The paramagnetic Curie temperatures θ are presented in Fig. 3. They are increasing as x is greater. χ_0 values are nearly the same in all studied compounds $\chi_0 \approx 5 \times 10^{-3}$ emu/mol.

The effective magnetic moments corresponding to formula unit are increasing with increasing x up to $10.85\mu_B$, the value of dysprosium free ion (Fig. 3). Since the composition dependence of μ_{eff}/fu is linear, the effective magnetic moments per dysprosium atom remain close to $10.85\mu_B$.

3. Discussion

UNi_5 shows an exchange enhanced paramagnetism. This compound presents a maximum in the thermal variation of the susceptibility which is followed by a Pauli type paramagnetism. These facts lead to the conclusion that UNi_5 is, according to Ikeda criteria [5], a spin fluctuator. A small content of dysprosium determines an increase in exchange interactions and the appearance of ferromagnetic order. As Dy composition is higher an increase in spontaneous magnetizations up to $7.7\mu_B$ is evidenced. The ferromagnetic Curie temperatures are close to that of $DyNi_5$ presenting a slow increase as x is greater. Over the transition temperature all systems with $x \geq 0.2$ obey a Curie–Weiss law. The paramagnetic Curie temperatures are almost linearly increasing and the effective magnetic moments are also increasing up to that corresponding to $DyNi_5$ compound. A transition from the spin fluctuation behaviour to an ordered state (antiferromagnetic one) is previously reported for $U_{1-x}R_xAl_3$ systems with R = Gd and Dy [6].

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