Magnetic properties and resonance studies of some pseudobinary gadolinium or yttrium compounds

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Résumé. — Les mesures magnétiques et l'étude par résonance des composés pseudobinaires cubiques, suggèrent que les électrons 3d des atomes des éléments de transition ne forment pas une bande 3d commune.

Abstract. — The magnetic measurements and resonance studies on pseudobinary cubic compounds suggest that the 3d electrons of transition metal atoms do not share a common 3d band.

Although the magnetic properties of pseudobinary rare-earth (yttrium)-transition metal (T) compounds of $R(T'_xT''_{1-x})_2$-type have been studied generally [1] we have no information on the individual magnetic behaviour of T′ and T″ atoms. In order to obtain further data on this matter we have investigated $Gd(Co_xNi_{1-x})_2$ and $R(Fe_xT_{1-x})_2$ compounds, where R = Gd or Y and T = Co, Ni, Mn or Al. To determine the separate magnetic contributions from the transition metal atoms, we make two assumptions :

(*a*) The Mössbauer effect measurements can indirectly supply information on the iron magnetic contribution. This can be justified analysing the data plotted in figure 1. The hyperfine field per unit spin (H_n/M_{Fe}) is the same for a wide range of M_{Fe} values and also for various types of crystalline structures.

(*b*) Nickel has no magnetic moment in

$$Gd(Co_xNi_{1-x})_2$$

system as in case of RNi_2 compounds.

The magnetic measurements, ferromagnetic and electron paramagnetic resonance studies, in a large temperature range show some interesting features :

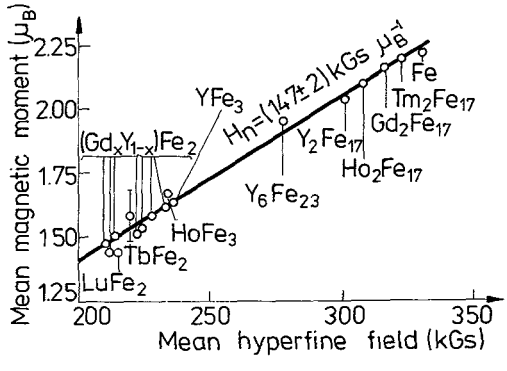

Fig. 1. — The relationship between Fe^{57} hyperfine field values and the iron moments.

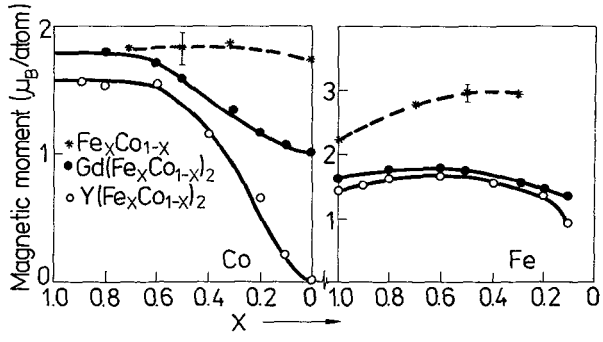

Fig. 2. — The composition dependence of the Co and Fe moment per atom in $R(Fe_xCo_{1-x})_2$ compounds and Fe_xCo_{1-x} solid solutions.

(I) The composition dependence of the magnetic moment of T′ and T″ atoms behave in a different manner. We present in figure 2 as an example the magnetic moment of Fe and Co atoms in $R(Fe_xCo_{1-x})_2$ compounds, as well as in Fe_xCo_{1-x} solid solutions [2]. The composition dependence of mean cobalt moment in $R(Fe_xCo_{1-x})_2$ compounds can be analysed in the local environment model, considering the interactions with the next neighbours (NN) iron atoms. The results of experimental data are well described if we suppose that cobalt has a magnetic moment M_{Co} $(x = 1)$ if there are at least $n_c = 2$ iron atoms as NN in $\bar{3}m$ site or M_{Co} $(x = 0)$ if $n_c < 2$. These data suggest that the magnetic interactions involving cobalt atoms are essentially of short-range. The observed peak in the composition dependence of the transition metal sublattice is attributed only to the magnetic behaviour of iron.

The composition dependence of Fe moment in $R(Fe_xT'_{1-x})_2$ where T′ = Al, Ni, Mn, can be justified only if we consider the magnetic interactions with the atoms of more than one coordination shell, these interactions being also dependent on the distances between atoms.

(II) The reciprocal susceptibility for $T > T_c$ in case of ferromagnetic compounds follows a Curie — Weiss behaviour, while in case of ferrimagnetic compounds a hyperbolic variation is observed — figure 3. The ratio between the number of spins determined from the Curie constant and that obtained from saturation measurements is dependent on the Curie temperature following the trend reported previously [3].

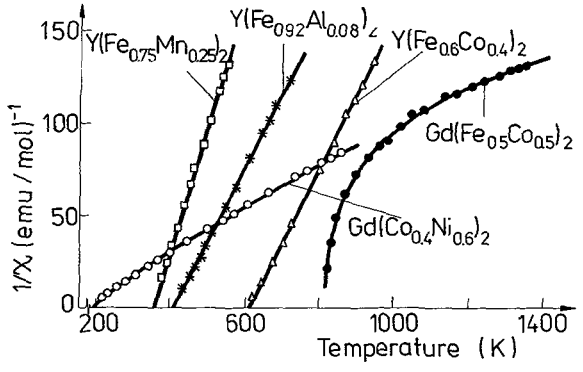

Fig. 3. — Thermal variation of reciprocal susceptibilities for some representative compounds.

(III) The ferromagnetic resonance study of compounds where only one type of magnetic T atoms is present, reveals that the spectroscopic splitting factor is not dependent on composition as in case of $Y(Fe_xAl_{1-x})_2$ system. In pseudobinary compounds where there are two magnetic atoms, the g_T values can be described by mean of their individual g values :

$$g_T = (M_{T'} + M_{T''})\,(M_{T'}/g_{T'} + M_{T''}/g_{T''})^{-1}\,. \quad (1)$$

For ferromagnetic $Y(Fe_xCo_{1-x})_2$ compounds the g_T values calculated according to (1) using $g_{Fe} = 2.11$ and $g_{Co} = 2.20$ and also the experimental results are plotted in figure 4. A good agreement is observed. In ferrimagnetic $Gd(Fe_xT_{1-x})_2$, where T = Co, Ni, Mn, the g_{ef} values may be considered using the Vangsness' relation [4]

$$g_{ef} = (M_{Gd} - M_T)\,(M_{Gd}/g_{Gd} - M_T/g_T)^{-1}\,. \quad (2)$$

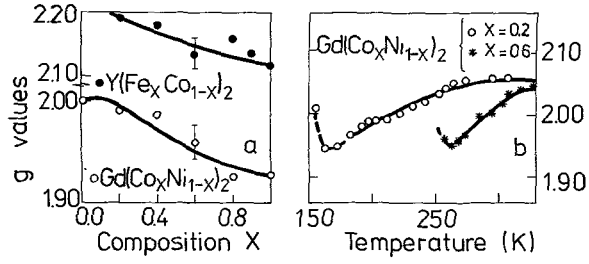

Fig. 4. — (*a*) The composition dependence of g values in $Y(Fe_xCo_{1-x})_2$ and $Gd(Co_xNi_{1-x})_2$ compounds. (*b*) Thermal variation of g values in case some $Gd(Co_xNi_{1-x})_2$ compounds.

The experimental data and those calculated using the relation (2) — plotted by solid line — in case of $Gd(Co_xNi_{1-x})_2$ compounds are also given in figure 4*a*.

(IV) At temperatures $T > T_c$, the g_{ef} values are temperature dependent. This behaviour is illustrated in figure 4*b* for the case of $Gd(Co_xNi_{1-x})_2$ compounds. In order to analyse these data we used the relation (2), written for $T > T_c$, where the susceptibilities χ_{Gd} and χ_T are expressed in the molecular field approximation. By fitting the experimental results we have determined the g_{Gd} and g_T values. In case of $Gd(Co_xNi_{1-x})_2$ compounds, $g_{Co} = 2.20 \pm 0.02$. The g_{Gd} values vary with composition, increasing from 1.980 ($x = 0$) up to 2.07 ($x = 0.6$). This behaviour is due to the breaks of the bottleneck in the relaxation between the conduction electrons and lattice, Co providing a path whereby the conduction electron magnetization can relax to the lattice. On the other hand, by increasing the cobalt content, the magnetic interactions involving Gd atoms increase, this being reflected in greater g_{Gd} values.

Finally, we notice that the spectroscopic splitting factors of transition metals in pseudobinary compounds are nearly the same for a wide range of concentration. The composition dependence of T magnetic moments preserve individual features. Thus, we conclude that 3d electrons of transition metal atoms in pseudobinary cubic compounds do not share a common 3d band.

References

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