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MÖSSBAUER EFFECT IN RHODIUM IRON ALLOYS

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Résumé. — On a mesuré les spectres Mössbauer du ^{57}Fe dans des alliages RhFe à teneur en fer de jusqu'à 25 at. %. On a déterminé la valeur du champ hyperfin de saturation pour le fer dilué en rhodium à 176 ± 3 kOe, en extrapolant à partir des valeurs pour les alliages concentrés magnétiquement ordonnés. Les températures limites de l'ordre magnétique, et les spectres des échantillons dilués dans un champ magnétique appliqué au-dessus de ces températures, montrent des effets qu'on peut attribuer à la compensation Kondo.

Abstract. — Mössbauer spectra of ^{57}Fe in RhFe alloys containing up to 25 at. % of iron have been measured. The saturation hyperfine field for dilute iron in rhodium has the value 176 ± 3 kOe as determined by extrapolation from the values in concentrated magnetically ordered alloys. Both the magnetic ordering temperatures and the spectra for dilute samples in an applied magnetic field above the ordering temperatures, show effects attributable to Kondo compensation.

I. Introduction. — Theoretical investigations of the Kondo effect [1] suggest that below the compensation temperature, the effective moment associated with the impurity is reduced due to the formation of a cloud of polarised conduction electrons. Experimental investigations of iron in copper alloys have confirmed in principle many of the theoretical predictions, and the Mössbauer studies of Frankel et al. [2] have provided the most direct evidence for the reduction of the moment. The major difficulty in such a Mössbauer study is in the determination of the saturation hyperfine field (H_{sat}). There has been an analysis of Mössbauer data by Golibersuch et al. [3] for Fe in Cu, in which it is suggested that there are separable contributions to the susceptibility due to the localised moment and due to the spin cloud. We have studied the rhodium iron system (Window et al. [4]), which is more favourable metallurgically, and have determined the ordering temperatures and the behaviour of H_{sat} for alloys containing 2 – 25 at. % iron. The value of H_{sat} at infinite dilution, obtained by extrapolation, has been used to show that the behaviour in applied magnetic fields of more dilute samples is consistent with all the susceptibility being associated with the iron localised moment.

II. Experimental Results. — Alloys were made in an argon arc furnace and cold rolled with intermediate annealing to 12 μm foils. (The ^{57}Fe concentration was maintained at ≈ 1 at. %.) The source ≈ 100 mCi ^{57}Co in palladium, gave a linewidth of 0.21 mm.s^{-1} . (FWHM) against a thin iron absorber.

The magnetic spectra for the samples containing 2 – 25 at. % iron obtained at low temperatures are shown in figure 1, and are characteristic of narrow distributions of hyperfine magnetic fields around ≈ 170 kOe, with very little broadening due to differing atomic neighbour configurations. The value of H_{sat} obtained by extrapolation to zero iron concentration and zero temperature is 176 ± 3 kOe. The 300 °K spectra also show very little broadening with increasing iron concentration. The ordering temperatures obtained by observing the onset of magnetic splitting in the spectra with decreasing temperature are plotted against iron concentration in figure 2. The points lie on a straight line which does not pass through the origin.

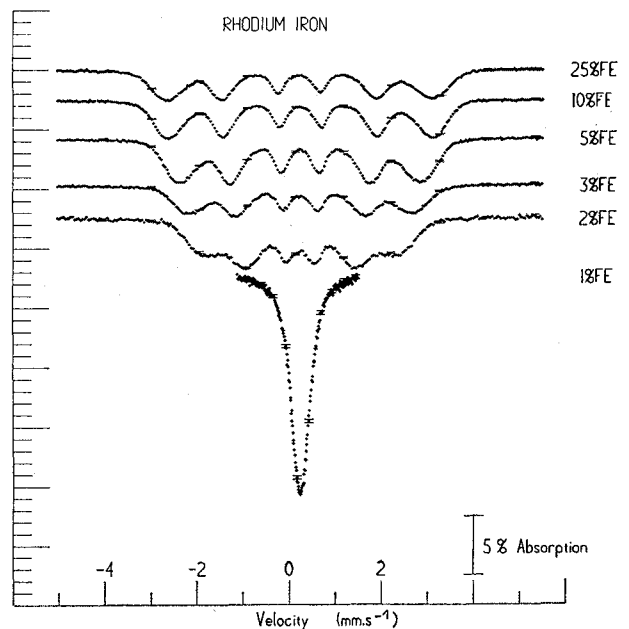


FIG. 1. — Mössbauer spectra of RhFe alloys at 4.2 °K (25 %, 10 %, 5 % Fe) or 1.4 °K (3 %, 2 %, 1 % Fe).

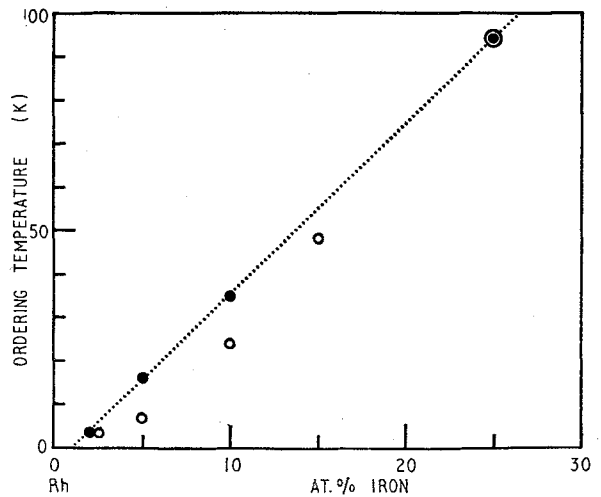


FIG. 2. — Ordering temperature (●) of RhFe alloys as a function of iron concentration. The temperatures of the susceptibility maxima (○) are also shown (Murani et al. [6]).

Using the value of $H_{\text{sat}} = 176$ kOe and assuming that the magnetisation (M) varies as

$$M/M_{\text{sat}} = H/H_{\text{sat}} = B_{3/2}(\mu H_{\text{app}}/kT)$$

the distributions of hyperfine fields obtained above the ordering temperatures in an applied field of 29 kOe, have been analysed to give the distributions of the localised moment (μ) at these temperatures (Fig. 3) [4].

III. Discussion. — The behaviour of the ordering temperatures shown in figure 2 suggests that alloys containing less than 1 at. % iron will not order magnetically owing to the rapid compensation of the localised moment. The compensation also shows up in figure 3 in the 1 at. % iron alloy, where the peaks in the distributions occur at $\mu(29 \text{ kOe}, 4.2 \text{ K}) = 0.92 \mu_B$ and $\mu(29 \text{ kOe}, 2^\circ\text{K}) = 0.53 \mu_B$. Using $\mu = g\mu_B S$ to determine $g(S = 1.5)$, one obtains values for the effective moment $\mu_{\text{eff}}(29 \text{ kOe}, 4.2^\circ\text{K}) = 1.3 \mu_B$ and $\mu_{\text{eff}}(29 \text{ kOe}, 2^\circ\text{K}) = 0.8 \mu_B$. These values agree well with those obtained at these temperatures from the susceptibility results of Knapp [5] ($1.3 \mu_B$ and $0.9 \mu_B$ respectively).

The increase in moments shown in figure 3 for the 2 % Fe sample at 4.2 °K (ordering temperature 3.5 °K) is produced by ferromagnetic interactions between the localised moments. These interactions also show up in the susceptibility results of Murani et al. [6] as a remanent magnetization below the ordering temperatures.

These results show that all the susceptibility is

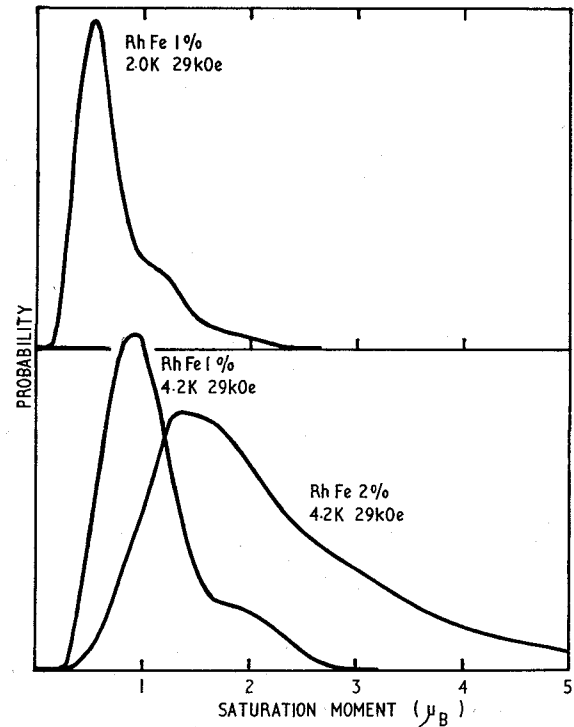


FIG. 3. — Probability distribution of moments ($g\mu_B S$) in RhFe alloys as obtained from the hyperfine field distributions at the indicated temperatures.

localised on the iron impurity in rhodium, and that any contribution due to a compensating cloud [3] is small.

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