INTERNAL MAGNETIC FIELDS AT Hg AND Tl IN FERROMAGNETS*

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With the perturbed angular correlation method the hyperfine magnetic fields acting at ^{198}Hg nuclei embedded in Fe, Co and Ni lattices are found to be -440 ± 105 kG, -370 ± 78 kG and -86 ± 22 kG, respectively. The measured fields at ^{203}Tl nuclei in Fe and Co lattices are -185 ± 70 kG and -90 ± 35 kG, respectively.

The hyperfine magnetic fields at dilute impurity sites in ferromagnetic host lattices have been of considerable interest recently. The internal hyperfine magnetic fields acting at Hg nuclei in Fe, H_{int}(Hg Fe), have been explored by Keszthelyi et al. [1] and by Murray et al. [2]. The results of these authors, H_{int} = -980 kG and -490 kG, respectilvely, are in striking disagreement with each other. A reexamination of H_{int}(Hg Fe) seems important. At the same time a study of H_{int}(Hg Co, Ni) appears worthwhile. The present note describes the results of such a study. We also present results of internal field measurements at Tl nuclei in Fe and in Co ferromagnets, H_{int}(Tl Fe, Co).

The experiments are performed with the integral-reverse-field technique of the perturbed angular correlation method. The apparatus have been previously described [3]. The fields at Hg nuclei have been measured with dilute solid solutions of Au as an impurity in the ferromagnets. High specific activity of ^{198}Au in metallic form was deposited in pots made of 1 g of pure (99.99)Fe, Co and Ni. Tapered pins were driven in the pots under vacuum and the sealed pots were melted in an induction coil in argon gas. All samples had a Au concentration less than 0.1 atomic %.

The 675-412 keV γ-γ cascade used in the Hg experiments and yielded A_2 = -0.253 ± 0.005 and A_4 = +0.107 ± 0.007 for the angular correlation coefficients. The Fe and Ni ferromagnetic samples were aligned with an external field of 5 kG and the Co sample with a field of 18 kG. The experimental values of $\omega\tau$ presented in table 1 were obtained from the ratio $R(\theta)$ = $= [W(\theta, +H) - W(\theta, -H)]/[W(\theta, +H) + W(\theta, -H)]$ = $= (1/W)(dW/d\theta)\omega\tau$ measured at 120° and 240°. The internal magnetic fields are shown in column three of table 1; they were derived with a mean life of τ = 31.5 ± 1.5 ps and a g factor of +0.55 ± 0.11 for the 412 keV level [4]. The quoted hyperfine fields have been calculated by subtracting the external field from the observed field.

Our determination of H_{int}(Hg Fe) = = -440 ± 105 kG agrees with a recent measurement [2] of -490 ± 125 kG. In addition, the hyperfine fields at the Hg nuclei in the three ferromagnets show the expected proportionality between the induced fields on diamagnetic impurities and the magnetic moments of the host metals.

The measurements of the internal magnetic fields for Tl in Fe and in Co were performed

Table 1
Summary of results. Values of $\omega\tau$ obtained from the ratio $R(\theta)$. Internal magnetic fields are deduced from the known lifetime and g-factor of the first excited state in ^{198}Hg and ^{203}Tl.

	$\omega\tau$ ($\times 10^2$ radians)	H_{int} (kG)
Hg Fe	-3.65 ± 0.32	-440 ± 105
Hg Co	-3.00 ± 0.23	-370 ± 78
Hg Ni	-0.68 ± 0.21	- 86 ± 22
Tl Fe	-4.0 ± 1.0	-185 ± 70
Tl Co	-1.5 ± 0.4	- 90 ± 35

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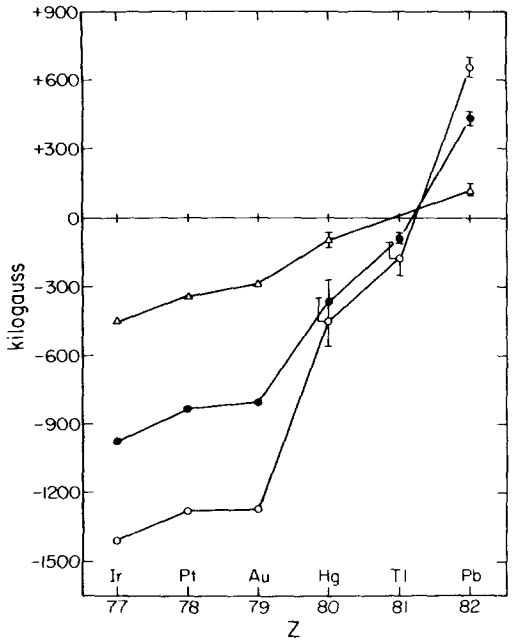

Fig. 1. Hyperfine fields, in kilogauss, at nuclei with Z = 77 to 82 in Fe(○), Co(●) and Ni(△).

with a source of ^{203}Pb. The ^{203}Pb activity was obtained by the reaction ^{203}Tl(d, 2n)^{203}Pb on a Tl metal target. The activity was separated from Tl in the form of $PbSO_4$ (about 1 mg of Pb was used as carrier). The dry sulfate was deposited in a Fe or Co pot and transformed into PbO by heating at 800°C in vacuum. The oxide was converted to metal by reducing it in H_2 at about 250°C. The pot was sealed in vacuum and melted in an induction coil. Due to the larger solid solubility of Pb in Co than in Fe, the source in Co was stronger. Both alloys had less than 0.02 atomic % of Pb.

The 401-279 keV γ-γ cascade in ^{203}Tl was used. The angular correlation coefficients for for this cascade were measured to be A_2 = -0.120 ± 0.008 and A_4 = -0.015 ± 0.012. The results are presented in table 1, where $\omega\tau$ was obtained from the ratio $R(\theta)$ measured at 135° and 225°. The magnetic fields, H_{int}(Tl Fe, Co) shown in table 1, were calculated with τ = 405 + 6 ps and g = +0.110 ± 0.033 for the 279 keV level [4].

A sample of Tl in Fe was also prepared by using a different technique of source preparation [5]. The PbO was dissolved in NHO_3 and mixed with fine iron powder. This mixture was dried, reduced in H_2, coined into the form of a small cylinder and annealed at 800°C for 12 h. This sample gave a field of -30 ± 30 kG. This is a smaller field than that obtained with the melted alloy and it appears that the sample has to pass through the molten phase in order to get the binary alloy.

The obtained field of -185 ± 70 kG for Tl in Fe is between that of Hg and Pb, as expected from systematics. Recently Balabanov and Delyagin [6] in analyzing regularities of magnetic fields at nuclei in ferromagnetic matrices found a semi-empirical law which describes well the experimental data. From their formula the predicted value for the internal field at Tl nuclei in Fe should be of the order of -300 kG, in reasonable agreement with our experimental value.

In fig. 1 are plotted the values of the hyperfine fields in Fe, Co and Ni for nuclei with Z = 77 to 82. The fields on Pb are from ref. [5] and those on Ir, Pt and Au are from the compilation in ref. [4].

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