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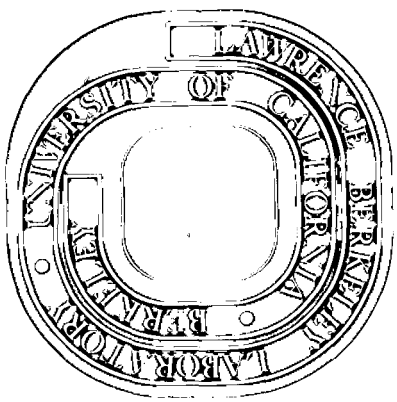

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MAGNETIC HYPERFINE FIELDS AT BISMUTH IN IRON AND NICKEL†

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December 1971

The magnetic hyperfine interaction of ^{204}Bi in iron and nickel has been studied by thermal equilibrium nuclear orientation technique. For temperatures < 0.1 K the following magnetic hyperfine fields were derived: H_{hf}(Fe) = 1180 ± 130 kOe and H_{hf}(Ni) = 325 ± 35 kOe.

- - -

Magnetic hyperfine fields on impurities in ferromagnetic host metals have been studied in the past for a large number of elements, but so far only very few experimental data are available for the heavy elements with Z > 80. Recently the discrepancy in the measured fields for lead in Fe (Co and Ni) has been clarified by means of the time-differential perturbed angular correlation technique (DPAC) [1] and by channelling experiments [2]. In this context the fields at bismuth became of increased interest. We report here on measurements of the magnetic fields at bismuth in Fe and Ni by thermal equilibrium nuclear orientation of ^{204}Bi.

The ^{204}Bi activity ($T_{1/2}$ = 11.3 h) was produced by the ^{206}Pb(p,3n)^{204}Bi reaction with 30 MeV protons on a 99.8% enriched $^{206}PbSO_4$-target. The carrier free ^{204}Bi activity, obtained by anion exchange separation, was precipitated with 50 mg $Fe(OH)_3$ carrier, heated to form the mixed oxides, and reduced in hydrogen at 800°C. The samples were quickly melted in a hydrogen stream without excessive loss of activity and quenched to room temperature in less than 10 seconds.

The ^{204}Bi(Ni) sample was prepared in a similar way.

Together with a ^{60}Co(Fe) thermometer the Bi samples were attached with Bi-Cd solder to the copper fin of an adiabatic demagnetization apparatus. Using CMN as a cooling salt, the lowest temperatures reached were 0.005 K. A superconducting Helmholtz pair, operated in persistent mode, was employed to magnetize the samples in a field of 4 kOe. Gamma ray spectra parallel and perpendicular to the polarizing field were taken during the warm-up of the samples over a typical period of 8 hours with high resolution Ge(Li) detectors. After background and decay corrections, the anisotropies were obtained for the 899 keV, 912 keV, and 984 keV γ lines of ^{204}Pb as well as for the ^{60}Co γ lines. Fig. 1 shows the temperature dependence of the anisotropy of the 984 keV γ transition in ^{204}Pb measured with the ^{204}Bi(Fe) sample. The data were least-squares fitted for a nuclear spin I = 6, using the hyperfine interaction $|\mu H|$ and an amplitude factor as free parameters. All the measured samples were also investigated at room temperature by DPAC of the 1274 keV state of ^{204}Pb ($T_{1/2}$ = 290 ns), using the 912 - 375 keV γ cascade, in order to check the samples. In all cases the same fields as previously observed for sources of ^{204m}Pb in Fe and Ni were obtained. The insert in fig. 1 shows as an example the spin rotation of the 1274 keV state as observed with one of our ^{204}Bi(Fe) samples. The modulation frequency obtained from a least-squares fit corresponds to an internal field at the Pb nucleus of +262 ± 5 kOe, in very good agreement with the result quoted in ref. 1 and 3.

Due to the intermediate 9^- state in ^{204}Pb ($T_{1/2}$ = 66.9 min.) the anisotropies of the 899 keV and 912 keV γ lines do not necessarily have to show the same temperature dependence as the one of the 984 keV γ transition. This transition is not fed by the 9^- state of ^{204}Pb, while about 60% of the 912 keV

γ transition and less than 15% of the 899 keV γ transition occur via the 9^- state. However, the effects of a reorientation of the 9^- state on the temperature dependence of the γ-ray anisotropies can be neglected, because of the much smaller hyperfine interaction expected for this state as compared to the ^{204}Bi groundstate. Within statistical accuracy the least-squares fits of the anisotropy curves for the three γ lines yield the same values for the magnetic splitting. As a final result the mean values for ^{204}Bi(Fe) and ^{204}Bi(Ni) are given in table 1.

The results of recent channelling experiments on Tl, Pb and Bi impurities in an iron lattice [2] provide evidence, that the hyperfine field of 262 kOe measured for Pb(Fe) is associated with the substitutional site for lead. We therefore may conclude from our DPAC results for ^{204}Pb(Fe), measured on the same sample as used for our orientation work, that our field value for ^{204}Bi(Fe) is also associated with the substitutional site. The same argument applies for Bi(Ni).

Our value for the hyperfine field for ^{204}Bi(Ni) can be compared with the result of a previous IPAC measurement on ^{211}Bi(Ni), using an ^{227}Ac(Ni) source: H_{hf} = +160 ± 30 kOe [5]. This value is by a factor of two smaller than our result. The ratio of the hyperfine fields found in the present experiment for Fe and Ni hosts agrees very well with the ratio of the magnetic moments per atom of the ferromagnetic host lattices. If we assume the positive sign for our field values, they agree also rather well with the predictions of the phenomenological theory of Balabanov and Delyagin [6], namely +935 kOe for Bi(Fe) and +255 kOe for Bi(Ni), respectively.

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FOOTNOTES AND REFERENCES

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TABLE 1. Magnetic hyperfine fields on Bi in iron and nickel at temperatures T < 0.1 K.

Host	$\lvert\mu H\rvert$ [10^{-18}erg]	H_{hf} [kOe]
Fe	25.4 ± 2.9	1180 ± 130
Ni	7.0 ± 0.8	325 ± 35

FIGURE CAPTION

Fig. 1. Temperature dependence of W(0) - 1 for the 984 keV γ-rays, emitted from the polarized ^{204}Bi(Fe) source. The insert shows the spin rotation of the 1274 keV state of ^{204}Pb, measured with the same sample at room temperature. The solid curves are the results of least-squares fits.

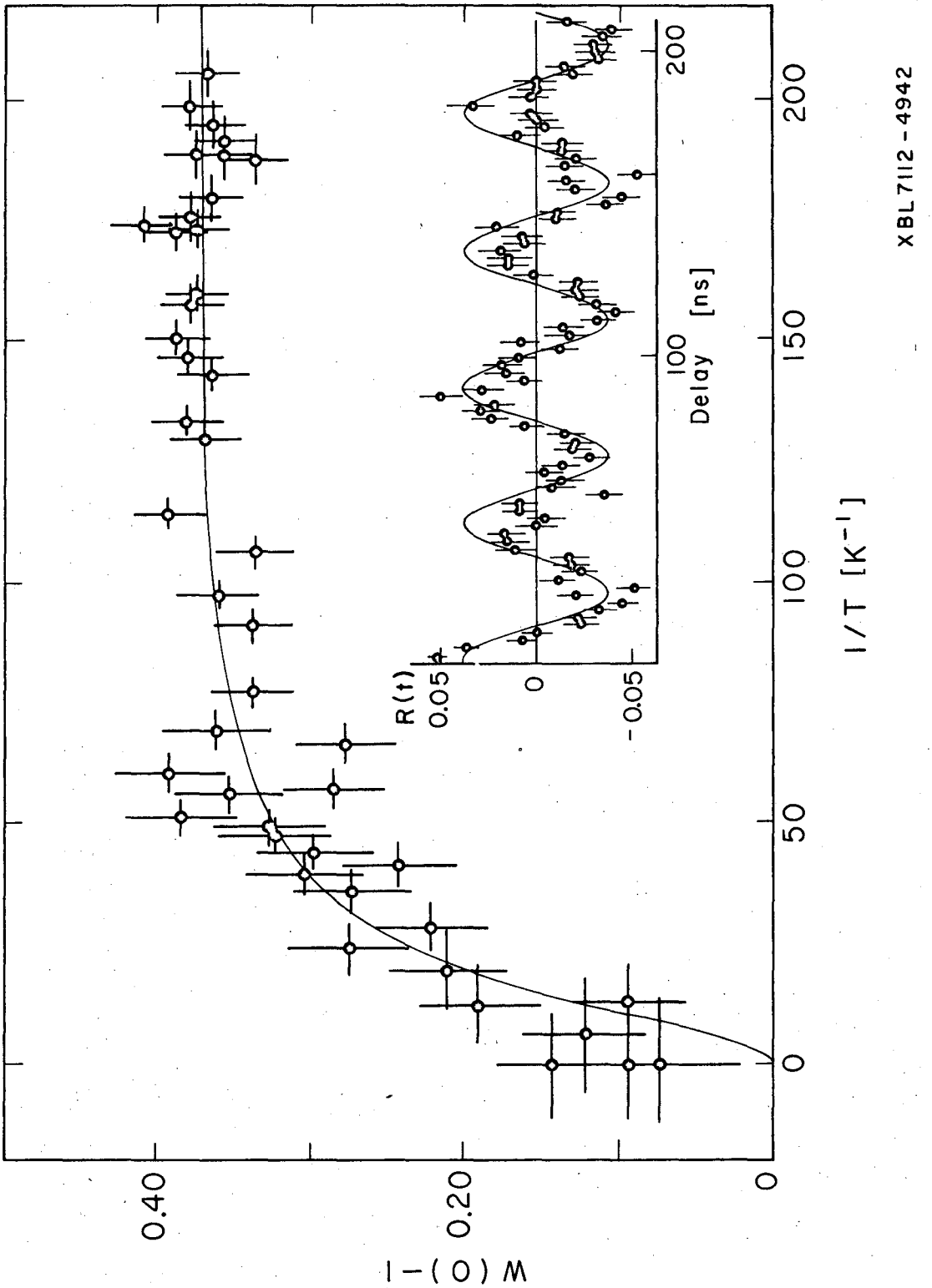
W(0)-1
0.40
0.20
0
0
50
100
150
200
1/T [K⁻¹]
R(t)
0.05
0
-0.05
100
200
Delay [ns]
XBL7112-4942

Fig. 1

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