THE INTERNAL MAGNETIC FIELD IN ATOMS OF W *AND* Ru *DISSOLVED IN IRON*

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The internal magnetic field H_{eff} acting at the nuclei of isotopes of W and Ru dissolved in iron was measured. The field H_{eff} was determined from the anisotropy of the γ radiation from the radioactive nuclei W^{187} and Ru^{103}, oriented at very low temperatures. The value $H_{eff} = 1.1 \times 10^6$ Oe was found for W^{187}. For Ru^{103} the sign of the γ ray asymmetry was found and the decay scheme was improved.

A large internal magnetic field H_{eff} acts at the nuclei of elements dissolved in ferromagnets. One method for determining this field is to measure the anisotropy of γ radiation from radioactive nuclei of elements dissolved in the ferromagnet and polarized at very low temperatures.

The present paper gives the results of measurements of anisotropy of γ radiation from nuclei of W^{187} and Ru^{103} embedded in iron. The alloys contained 2-3 wt % of the elements to be studied. The experimental setup was described earlier.[1]

W^{187} Nucleus

The part of the decay scheme of W^{187} which is of interest to us is shown in Fig. 1.[2] The polarization of the nuclei was determined from the anisotropy of the γ rays with energies 482 and 686 keV. The probability for emission of a 686-keV γ quantum at an angle ϑ to the axis of polarization of the nuclei is given by the expression [3,4]

$$w(\vartheta) = 2[1 - {}^{18}/_{25} f_2 P_2(\cos\vartheta)]. \qquad (1)$$

The corresponding expression for the 484-keV γ ray is

$$w(\vartheta) = 2[1 - {}^{9}/_{28} f_2 P_2(\cos\vartheta) - {}^{27}/_{448} f_4 P_4(\cos\vartheta)]. \qquad (2)$$

Here f_2 and f_4 are nuclear orientation coefficients while P_2 and P_4 are Legendre polynomials.

The expressions (1) and (2) take account of the partial disorientation of the nuclei in the β transitions which precede the γ rays. The coefficients f_2 and f_4 are functions of the quantity $\beta = \mu H_{eff}/I_0 kT$ (μ is the magnetic moment of the nucleus, k is the Boltzmann constant and T is the absolute temperature). When $\beta \ll 1$ the coefficient f_4 is negligibly small. From the experimentally measured anisotropy of the γ radiation

$$\varepsilon = [w(\pi/2) - w(0)]/w(\pi/2) \qquad (3)$$

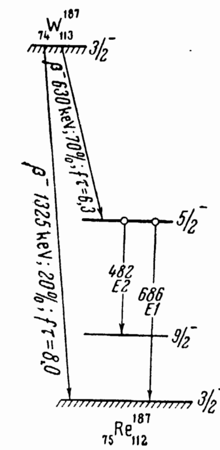

FIG. 1. Main part of decay scheme of W^{187}.

one determines the quantity β and then the product μH_{eff}. Figure 2 gives the dependence of ϵ on $1/T$ for both lines of W^{187}. From a computation using the anisotropy of the 482-keV radiation we get $\mu H_{eff} = (0.37 \pm 0.14) \times 10^{-17}$ erg; from the 686-keV line, $\mu H_{eff} = (0.38 \pm 0.07) \times 10^{-17}$ erg. These values agree well within the experimental error. The averaged value is $\mu H_{eff} = (0.38 \pm 0.06) \times 10^{-17}$ erg.

The magnetic moment of W^{187} has not been measured, but one can make an estimate of it.

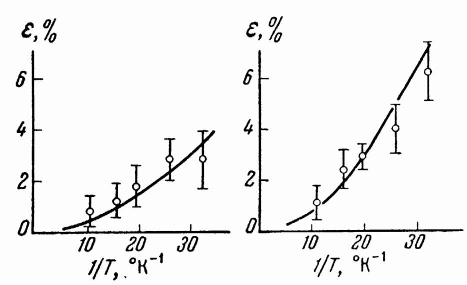

FIG. 2. Dependence of ϵ (formula (3)) on temperature for the two main lines in W^{187}: a – 482 keV; b – 686 keV. Curves are computed for $\mu H = 0.38 \times 10^{-17}$ erg.

Level scheme j_0	j_i	j_f	Transition type and multipolarity	Sign of ϵ	Level scheme j_0	j_i	j_f	Transition type and multipolarity	Sign of ϵ
$^5/_2$	$^7/_2$	$^7/_2$	$E2$	—	$^5/_2$	$^7/_2$	$^7/_2$	$M1$	+
$^5/_2$	$^5/_2$	$^7/_2$	$E2$	—	$^5/_2$	$^5/_2$	$^7/_2$	$M1$	—
$^5/_2$	$^3/_2$	$^7/_2$	$E2$	+	$^5/_2$	$^3/_2$	$^7/_2$	$M1$*	
$^7/_2$	$^7/_2$	$^7/_2$	$E2$	—	$^7/_2$	$^7/_2$	$^7/_2$	$M1$	+
$^7/_2$	$^5/_2$	$^7/_2$	$E2$	—	$^7/_2$	$^5/_2$	$^7/_2$	$M1$	—
$^7/_2$	$^3/_2$	$^7/_2$	$E2$	+	$^7/_2$	$^3/_2$	$^7/_2$	$M1$*	

*M1 transition impossible.

The stable nucleus Os^{189} (μ = 0.7 nuclear magnetons) has a $^3/_2{}^-$ ground state, like W^{187}, and differs from it in having an extra pair of protons. The magnetic moments of these two nuclei should be the same. Taking μ for W^{187} equal to 0.7, we get

$$H_{\text{eff}} = (1.1 \pm 0.15) \cdot 10^6 \text{ Oe}.$$

From the results of a comparison of experimental moments for similar pairs of nuclei, we can estimate the precision of the W^{187} moment to be 0.1 magneton. The error given for H_{eff} includes only the error in the determination of μH_{eff}.

Ru^{103} Nucleus

The decay scheme of Ru^{103} has not yet been definitely established. In principle, the measurement of the asymmetry of the γ radiation from Ru^{103} permits improvement of the decay scheme and measurement of μH_{eff}. One can estimate the magnetic moment for Ru^{103} in just the same way as for W^{187}, and then determine H_{eff}. But the value of ϵ found experimentally for the 495-keV line was (1 ± 0.5)% at T = 0.04°K. The sign of the asymmetry may be regarded as definitely established, but the error in the determination of μH_{eff} is so large that it makes no sense to evaluate the internal field.

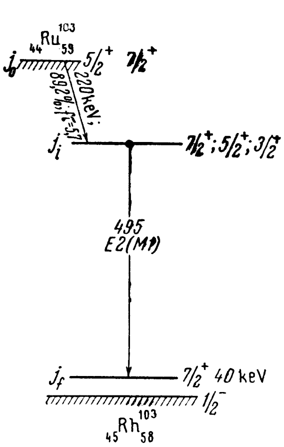

FIG. 3. Main part of the decay scheme of Ru^{103}. Spins and parities are given for the levels involved in the measured transitions.

Figure 3 shows the main part of the decay scheme of Ru^{103} and gives all the possible values of spins and parities of the levels.[5]

The Table gives the sign of the asymmetry of the γ radiation from oriented Ru^{103} nuclei, computed for different decay schemes, for M1 and E2 transitions. To agree with the experimentally observed sign of the asymmetry ($\epsilon > 0$), only the transitions

$$^5/_2 \xrightarrow[\beta]{} {}^3/_2 \xrightarrow[E2]{} {}^7/_2, \quad ^5/_2 \xrightarrow[\beta]{} {}^7/_2 \xrightarrow[M1]{} {}^7/_2, \quad ^7/_2 \xrightarrow[\beta]{} {}^7/_2 \xrightarrow[M1]{} {}^7/_2$$

are possible.

The variant $j_0 = j_f = {}^7/_2$, $j_i = {}^3/_2$, is not possible, since then the β transition $^7/_2 \to {}^3/_2$ should be forbidden, in disagreement with the $f\tau$ value for the β spectrum with end point 220 keV. If, as found in most experiments, the 495-keV transition is electric quadrupole, the only possible variant is the transition

$$^5/_2 \xrightarrow[\beta]{} {}^3/_2 \xrightarrow[E_2]{} {}^7/_2.$$

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