SCI. REP. KYOTO PREF. UNIV. (NAT. SCI. & LIV. SCI.), No. 22, Ser. A, p. 1~6 (NOV. 1971)

The Internal Magnetic Field at Mercury Nucleus in Fe-Au Alloy

By

MITSUHIRO KAWAMURA and TSUYOSHI TOMIYAMA*

(Received July 29, 1971)

The shift of the angular correlation of 675 Kev–412 Kev gamma-gamma cascade in Hg^{198} was measured by utilizing the high internal magnetic field at mercury nucleus in iron host material of alloy magnetized up to saturation. The value of the internal magnetic field at mercury nucleus in 2AT.% Fe-Au alloy was determined to be $|H| = (0.83 \pm 0.35) \times 10^6$ gauss.

Introduction

The decay scheme of Au^{198} is well established. It shows very simple level scheme[1] in Hg^{198} as seen in Fig. 1. Although the beta transition to 1087Kev level of Hg^{198} is so weak as

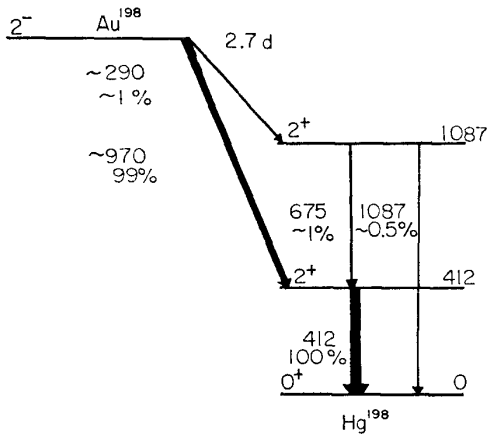

Fig. 1 Decay Scheme of Au^{198}

to be only 1%, the measurement of the angular correlation of 675 Kev-412 Kev gamma-gamma cascade has been performed. The level scheme shows typical vibrational character. From the standpoint of nuclear model, it is very interesting to determine the g-factor of the excited state of vibrational nucleus. In general, however, the determination of the g-factor of the excited 412 Kev level by the measurement of the perturbed angular correlation is not

* Okayama College of Science

so easy because the half life of this level is very short[1-3]. In 1964, L. Keszthelyi et al[4] tried to measure the g-factor of this level by utilizing the internal magnetic field at mercury nucleus in iron host material for the first time, and they reported that $g=+0.38\pm0.11$ assuming the internal magnetic field at gold in iron host material of alloy, ie $|H|=1.42\times10^6$ gauss and the direction of the internal field being negative.

On the other hand, H. J. Körner et al[5] reported fairly large value of g, ie

$$g=+0.55\pm0.11, \tag{1}$$

of this level using metallic source of Au^{198} and the external magnetic field of ±57150 gauss, in Paris Conference on Nuclear Structure held at 1964. The value of g-factor obtained by them seems to be reliable because the uncertainty of the magnetic field applied is very small. As there is no direct evidence in the internal magnetic field at mercury nucleus in iron being same as the one at gold in iron, it is worthwhile to determine the internal magnetic field at mercury nucleus in iron host material by using the vaule of g-factor (1) and the measured value of $\omega\tau$.

Here, the result from the measurement of the shift of the perturbed angular correlation using 2AT.% Fe-Au alloy sample activated by thermal neutron will be introduced.

Experimental Procedure

The preparation of Fe-Au alloy sample containing 2AT.% gold is described in reference 6). The sample was shaped to be 2 mm $\phi\times6$ mm and irradiated for 15 sec in pneumatic tube of KUR Reactor in which neutron flux was 1.93×16^{13} n/cm²/sec.

The gamma spectrum of this source measured by the use of 2 cc Ge(Li) detector is shown in Fig. 2. The peaks at 412 Kev, 675 Kev and 1987 Kev correspond to the decay of Au^{198}, but the peak at 845 Kev is from $Mn^{56}(T_{1/2}=2.58\ h)$ produced by Fe^{56} (n,p) Mn^{56} reaction. The sample sealded in quarz tube in vacuum was annealed for 1 hour at 900°C and the sample

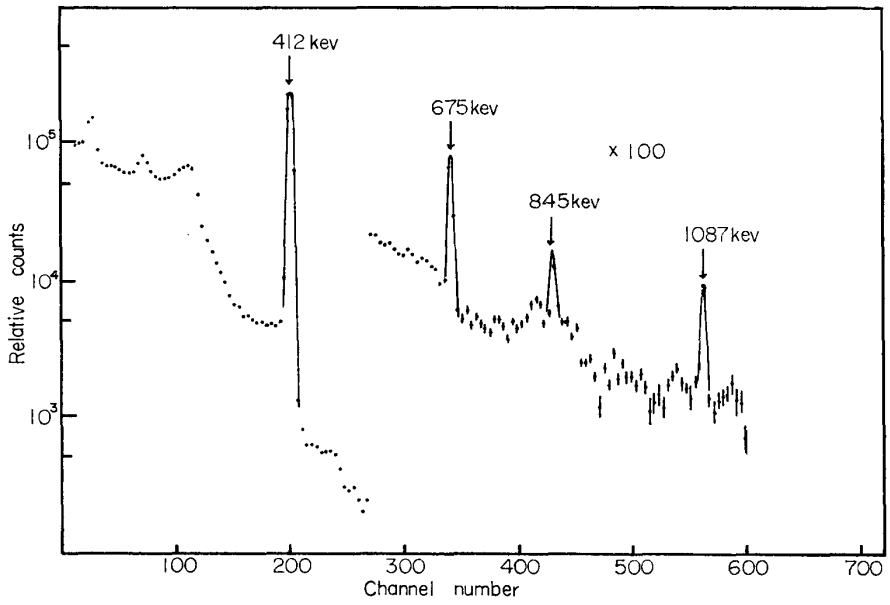

Fig. 2 Gamma-ray spectrum of 2AT.% Fe-Au alloy sample activated by thermal neutron

was used for the angular correlation measurement about 24 hours after annealing in order to ensure the negligible contribution of Mn^{56} activity to Au^{198} ($T_{1/2}=2.7$ days). The source was fixed in the center of the gap of the electromagnet by bridging the gap completely together with the other iron pieces. The goniometer consisted of $3''\times 3''$ NaI(Tl) detectors and automatic driving system.

The detectors were covered by 1 cm acryl resin plate in front of the crystals to stop the beta rays. The distances between source and detector were both 16 cm. This was determined from the neglibible effect due to the stray magnetic field of electromagnet on the movable detector over all angles. The electronic circuit was slow-fast coincidence circuit using double delay line clipping principle having resolving time $2\tau=100$ ns. The windows of the fixed and the movable channel were arranged to accept the photopeak of 675 Kev and 412 Kev gamma ray respectively.

The gain of the movable detector was specially stabilized by the use of spectrostabilizer circuit.

Measurement of the Angular Correlation

In the first place, the measurement of the angular correlation between 675 Kev and 412 Kev gamma ray was performed under the condition of no-applied magnetic field.

When the angular correlation for alloy sample under the condition mentioned above is represented as follows,

$$W'(\theta)=1+A'_2\ P_2\ (\cos\theta)+A'_4\ P_4\ (\cos\theta) \tag{2}$$

the measured value of A'_s was

$$A'_2=-0.271\pm 0.017$$
$$A'_4=+0.144\pm 0.024.$$

The theoretical representation of A'_s shows that it is a product of true correlation coefficient for free nucleus, the correction factor for the finite angular resolution and the attenuation factor due to the polycrystalline structure of bulk of alloy at non-magnetized state.

As the attenuation factor, however, can be considered to be almost completely unity for this case[6], A'_s is simply a product of true correlation coefficient and the correction factor for the finite angular resolution. After the correction of the angular resolution, the value of true correlation coefficient A_s was obtained as

$$A_2=-0.290\pm 0.018$$
$$A_4=+0.183\pm 0.031. \tag{3}$$

The angular correlation function (2) can also be represented as following form

$$W''(\theta)=1+B_2\ \cos\ 2\theta+B_4\ \cos\ 4\theta \tag{4}$$

here,

$$B=(48\ A'_2+20\ A'_4)/(64+16\ A'_2+9\ A'_4)$$
$$B_4=35\ A'_4/(64+16A'_4+9\ A'_4).$$

Using this formura and the value of A'_s, B_s takes the following value

$$B_2 = -0.166 \pm 0.016$$
$$B_4 = +0.083 \pm 0.014.$$

Under the condition of saturation magnetization of bulk of alloy, the correlation function (4) is transformed into[7],

$$W(\theta, H) = 1 + B_2/\sqrt{1+(2\omega\tau)^2} \cdot \cos[2\theta \pm \tan^{-1}(2\omega\tau)] + B_4/\sqrt{1+(4\omega\tau)^2} \cdot \cos[4\theta \pm \tan^{-1}(4\omega\tau)] \quad (5)$$

where τ is the mean life of the intermediate state and

$$\omega = 2\pi g \mu_N H/h$$

here g, μ_N, H and h are g-factor of the intermediate state, nuclear magneton, internal magnetic field at mercury nucleus in dilute Fe-Au alloy and Plank's constant, respectively.

The measurement of the angular correlation under the saturation magnetization was performed. Fig 3 shows the shift of the experimental pattern. The data for the case of

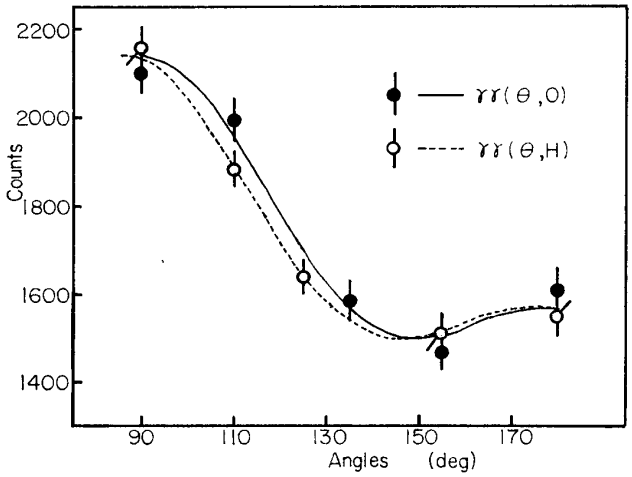

Fig. 3 The shift of the pattern of the angular correlation

applied magnetic field were analyzed following the formura (5).

The value of $\omega\tau$ was determined by the method of least squares fit as

$$\omega\tau = +0.070 \pm 0.030 \quad (6)$$

Result and Discussion

The angular correlation coefficients (3) of 675 Kev-412 Kev gamma-gamma cascade fit well with the theoretical values for the spin sequence 2(D, Q)2(Q)O, where D and Q denote the dipole and quadrupole radiation respectively. The mixing parameter δ for 675 Kev transition (2′→2) was determined as

$$\delta = +1.15 \pm 0.17$$

This value means that the character of 675 Kev transition is the mixing of 57% quadrupole and 43% dipole radiation. The mixing ratio obtained is quite consistent with the one from α_K measurement[8].

In order to determine the internal magnetic field at mercury nucleus in iron host material of 2AT.% Fe-Au alloy, we have to use the life time of 412 Kev level ni Hg^{198}. The life time was calculated from a few measured values cited in Table 1.

Table 1

	τ(sec)	reference
life time	$(3.2\pm0.1)\times10^{-11}$	1)
	$(3.19\pm0.32)\times10^{-11}$	2)
	$(3.6\pm0.7)\times10^{-11}$	3)
weighted mean	$(3.21\pm0.29)\times10^{-11}$	

Combining the life time obtained above, the g-factor (1) and the measured value of $\omega\tau(6)$, the internal magnetic field was determined as

$$|H|=(0.83\pm0.35)\times10^{6} \text{ gauss.} \tag{5}$$

This value of the internal magnetic field is in good agreement with the value $|H|=(0.98\pm0.28)\times10^{6}$ gauss calculated by D. A. Shirley and G. A. Westenbarger[9].

On the other hand, the internal magnetic field at gold nucleus in iron host material of alloy has been measured to be $(1.42\pm0.16)\times10^{6}$ gauss at liquid herium temperature from the Mössbauer experiment by L. D. Roberts and J. O. Thomson[10].

The value of $|H|$ by them, have to be corrected to room temperature in order to compare with our value. Using the correction curve represented in Fig 8 of reference 11), the internal magnetic field at gold nucleus in iron host material of alloy at room temperature was estimated to be

$$|H|=(1.36\pm0.27)\times10^{6} \text{ gauss.}$$

This value is fairly larger than ours. It is very interesting to note this difference considering the so-called conduction electron polarization mechanism of the internal magnetic field.

Acknowledgments

This work was performed as a part of KUR research project in 1970. The authors would like to express their thanks to Prof. T. Hayashi for his encouragement and to Dr. Kawase, Mrs. T. Seo and Y. Hayashi for their help.

References

1) Nuclear Data Sheet.
2) R. Kalish, R. R. Borchers and W. Kugel, Nucl. Phys. **A 147**, 161 (1970).
3) S. Gorodetzky, N. Schulz, E. Bozek et A. C. Knipper, Nucl. Phys. **85**, 529 (1966).
4) L. Keszthelyi, I. Berkes, I. Dézsi, B. Molnár and L. Pócs, Phys. Lett. **8**, 195 (1964).
5) H. J. Körner, K. Auerbach, J. Braunsfurth, U. Ortabasi and J. Heisenberg, Comptes Rendus du Congrès International de Physique Nucléaire préparés par Madame P. Gugenberger Vol. 2 481 (1964).

6) M. Kawamura and T. Tomiyama, Sci. Rep. Kyoto Pref. Univ. No. 21 (1970) A17.
7) R. M. Steffen and H. Frauenfelder, Perturbed Angular Correlation edited by E. Karlson, E. Matthias and K. Siegbahn (North-Holland Publishing Co. Amsterdam, 1964) p16.
8) Nuclear Data Section A Vol. 1 No. 6 (1966).
9) D. A. Shirley and G. A. Westenbarger, Phys. Rev. **138**, A170 (1965).
10) L. D. Roberts and J. O. Thomson, Phys. Rev. **129**, 664 (1963).
11) R. S. Preston, S. S. Hanna and J. Heberle, Phys. Rev. **128**, 2207 (1962).