KERNFORSCHUNGSZENTRUM

KARLSRUHE

August 1969

KFK 1026

Institut für Experimentelle Kernphysik

Multipole Mixtures of Some Gamma-Transitions in Fe^{57}

G. Bueche, G. Sigurdsson

GESELLSCHAFT FÜR KERNFORSCHUNG M. B. H.

KARLSRUHE

KERNFORSCHUNGSZENTRUM KARLSRUHE

August 1969 KFK 1026

Institut für Experimentelle Kernphysik

Multipole mixtures of some gamma-transitions in Fe^{57} *)

G. Bueche and G. Sigurdsson

Gesellschaft für Kernforschung m.b.H. Karlsruhe

*) Submitted to Nuclear Physics

Abstract:

The anisotropy of gamma-rays emitted from the $3/2^-$-state in Fe^{57} with an excitation energy of 367 keV was measured after populating this level by inelastic proton scattering. The proton energy was E = 2,5 MeV. The metallic target of 2 mg/cm^2 had been enriched to 91% in Fe^{57}. By using a Ge(Li)-detector it was possible to measure the transitions to the ground state and first excited state separately and to extract the following E2/M1-mixing ratios:

$3/2^-$ (230 keV) $5/2^-$ δ = -0,06±0,06 or -3,7±1,0

$3/2^-$ (352 keV) $3/2^-$ δ = -0,02±0,02 or +4,3±0,5

$3/2^-$ (367 keV) $1/2^-$ δ = 0,09±0,06 or -2,2±0,4

1. Introduction

The properties of the low lying levels in Fe^{57}, which are preferentially populated by electron capture of Co^{57}, are well known [1,2]. For states with an excitation energy higher than 136 keV, only a few parameters have been measured so far. Experiments are under consideration, however, where the characteristic properties of these higher excited states in Fe^{57} have to be known. There is particular interest in the knowledge of the reduced transition probabilities for Coulomb excitation and the multipole mixing ratios for the corresponding gamma-transitions. Apart from more specific applications these parameters could be helpful in getting a more detailed description of the nuclear structure in Fe^{57}, using e.g. the rotational model [3].

In the following we report on measurements where emphasis has been laid on the multipole mixing ratios of the three possible gamma-transitions from the $3/2^-$ (367 keV) state of Fe^{57}. The results of previous measurements [4,5,6] cannot be used for a detailed analysis because the transitions to the ground state and first excited state have not been observed separately.

2. The experiment

2.1. Principle of the measurement

The decay scheme of the excited state under consideration is shown in fig. 1 (ref[1]). The lifetime of this state is fairly well known but the magnetic moment only by order of magnitude. Using a Ge(Li)-detector, the transitions of 352 keV and 367 keV quantum energy have been separated. The population of the initial state was achieved by inelastic proton scattering from Fe^{57}. The protons have been supplied by the van de Graaff-accelerator of the Institut für Angewandte Kernphysik of the Kernforschungszentrum Karlsruhe.

The energy was E_p = 2,5 MeV. The current, measured on the target, did not exceed 1,6μA. The scattered protons were not detected. The metallic target of 2 mg/cm^2 was enriched in Fe^{57} to 91%.

The angles of detection for the emitted quanta were $\theta_1 = 30^o$ and $\theta_2 = 120^o$, measured from the direction of the incoming protons (see fig. 2). The angles were changed frequently during one measurement. The obtained pulse height spectra of the Ge(Li)-detector were counted in separate groups of a multichannel analyzer. The plane of the iron target was orthogonal to the detection plane. The angle with the forward direction of the proton beam was $\theta = 75^o$. Also vertically to the detection plane a magnetic field of 950 Oersted was applied in order to orient the internal magnetic field in the target. During one measurement under the same angle θ the direction of this field was reversed several times.

The applied magnetic field causes a rotation of the distribution pattern between incoming protons and outgoing gammas

$$W(\theta) = 1+a_2A_2(\delta)P_2(\cos\theta)$$

by less than $0,3^o$ ($\omega_{larmor}\cdot\tau < 0,006$ (ref.[7])).

Its influence on the results is beyond the precision of our measurement. The magnetic polarization of the source, however, has the following essential advantage: Besides the transitions starting from the state $3/2^-$(363 keV) one observes a strong population of the level $5/2^-$(136 keV) also by Coulomb excitation. Because of the large precession of the intermediate state ($\omega_{Larmor}\cdot\tau = 4,5$) the correlation pattern of the 122 keV-transition becomes nearly isotropic. The intensity within its photopeak therefore gives a counting rate which is very suitable for normalization purposes. This fact was used to eliminate influences on the results which could arise from fluctuations of the beam current or a possible change in detection geometry when the massive counter is rotated.

2.2. Evaluation of data

Fig. 3 shows a typical distribution of the counting rate as a function of quantum energy. The energies E_i = 367 keV; 352 keV and 230 keV are marked together with the normalization peak at 122 keV. Within a certain range of energies around E_i the counting rate N(E) can be written by the sum of the counting rate within the photopeak I(E) and a background rate U(E):

$$N(E) = I(E) + U(E).$$

We separate the part U(E) from N(E) by interpolating the measured spectra within some energy range lower and higher than the photo peaks. U(È) has been considered as a polynomial in the energy:

$$U(E) = A + B\cdot E + C\cdot E^2.$$

The constants A, B, C have been taken from a least squares fit. From the counting rate I(E) we deduced the anisotropy for the energies E_i:

$$A_i = \frac{W(E_i,\theta_1)-W(E_i,\theta_2)}{W(E_i,\theta_1)+W(E_i,\theta_2)} = \frac{I(E_i,\theta_1)/I(122,\theta_1) - I(E_i,\theta_2)/I(122,\theta_2)}{I(E_i,\theta_1)/I(122,\theta_1) + I(E_i,\theta_2)/I(122,\theta_2)}$$

Taking into consideration the finite angular resolution of the counter we got the angular correlation coefficient $a_2\cdot A_2(\delta)$ from the anisotropy. For the particle parameter a_2 we assumed that Coulomb excitation goes via E2 (ref.[8]).The error in a_2 resulting from the energy loss of the protons in the target was 0,5%.

III. Results and Discussion

The results of our measurement are given in the upper part of table 1, where the quoted errors are of statistical origin. For all transitions one of the two possible multipole orders seems to be highly enhanced. For the transitions to the ground state and first excited state a different sign in the mixing ratio is favoured to some extent. The results of earlier experiments are given in the lower part of table 1. For columns 3 and 4 the other results and ours cannot be compared immediately, since the 352 keV and the 367 keV transitions have not been energetically separated in the previous measurements. Rather one has to mix our values of A_2 with respect to the branching ratios of the relevant ransitions. Then one may evaluate δ from the average value of A_2 including the assumption, that the transition is mainly $3/2^-$ to $3/2^-$. This procedure provides in fact a value of the quantity δ which is in agreement with the earlier results [4,5,6] within their respective errors.

In ref.[7] Sprouse and Hanna mention the measurement of some mixing ratios in context with the determination of the lifetimes of excited states of Fe^{57}. But the data are not given explicitly and one cannot derive the mixing ratios without detailed knowledge of the particle parameters a_2.

The mixing ratios given in this paper are due to gamma-transitions starting from the same excited state of the nucleus. If one prefers the values favoured by the single particle model the transitions seem to be of the M1 type. Then, using the branching ratios, one can calculate the reduced transition probabilities from the lifetime measured in [7] and extend the calculations of the rotational model [3] to the $3/2^-$(367 keV) state. In particular, this calculation should allow an estimate for the magnetic moment of this state.

The authors wish to thank Professor H. Schopper for his interest in this work and Professor K.H. Beckurts for offering the use of the van de Graaff generator for our investigations. In particular we are grateful for discussions with Dr. H. Appel and the help of Dr. W. Renz. Last not least thanks are to the accelerator crew for excellent cooperation.

	$3/2^-$(230 keV) $3/2^-$	$3/2^-$(352 keV) $3/2^-$	$3/2^-$(367 keV) $1/2^-$
This paper	A_2= -0,009 ±0,020	A_2= 0,102 ±0,011	A_2= -0,092 ±0,029
	δ= -0,06 ±0,06	δ= -0,02 ±0,02	δ= 0,09 ±0,06
	or -3,7 ±1,0	or 4,3 ±0,5	or -2,2 ±0,4
Pieper and Heydenburg ref.[4,6]	δ= -0,3 or -1,5	δ= -0,12 or 9	
Ritter et al. ref.[5]	——	A_2 = 0,125 ± 0,030	
Bartholomev and Vervier ref.[6]	——	δ = -0,05 ± 0,03 or 5,0 ± 0,5	

Table 1. Results of our measurements and multipole mixing ratios $\delta = \langle I_f|E2|3/2\rangle / \langle I_f|M1|3/2\rangle$ for some gamma-transitions in Fe^{57}. The results of earlier measurements are also quoted.

References.

1) O. Kistner, A. Sunyar, Phys.Rev. 139 (1965) B 295

2) Nuclear Data Sheets, NRC 61-2-13 and 6-2, 3-85

3) P.C. Sood, D.A. Hutcheon, Nucl.Phys. A 96 (1967) 159

4) G. Pieper, N. Heydenburg, Phys.Rev. 107 (1957) 1300

5) R.C. Ritter, P.H. Stelson, F.K. McGowan und R.L. Robinson, Phys.Rev. 128 (1962) 2320

6) G.A. Bartholomev, J.F. Vervier, Nucl.Phys. 50 (1964) 209

7) G.D. Sprouse, S.S. Hanna in: E. Matthias and D.A. Shirley (ed.), Hyperfine Structure and Nuclear Radiations (North-Holland Publishing Company, Amsterdam, 1968) p. 761

8) K. Alder, A. Bohr, T. Huus, B. Mottelson, A. Winther, Rev.Mod.Phys. 28 (1956) 432

Figure captions

Fig. 1 Gamma-ray energies of Fe^{57} observed in this experiment (see ref[1]).

Fig. 2 The geometry used in the experiment

Fig. 3 Pulse height spectrum of gamma-rays observed with a Ge(Li)-detector.

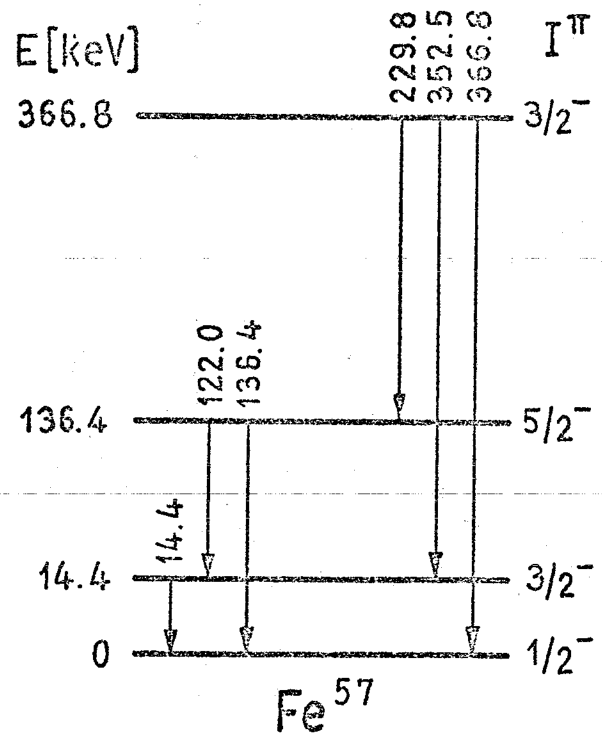
E [keV]
Iπ
366.8
136.4
14.4
0
229.8
352.5
366.8
122.0
136.4
14.4
3/2⁻
5/2⁻
3/2⁻
1/2⁻
Fe 57

Fig. 1

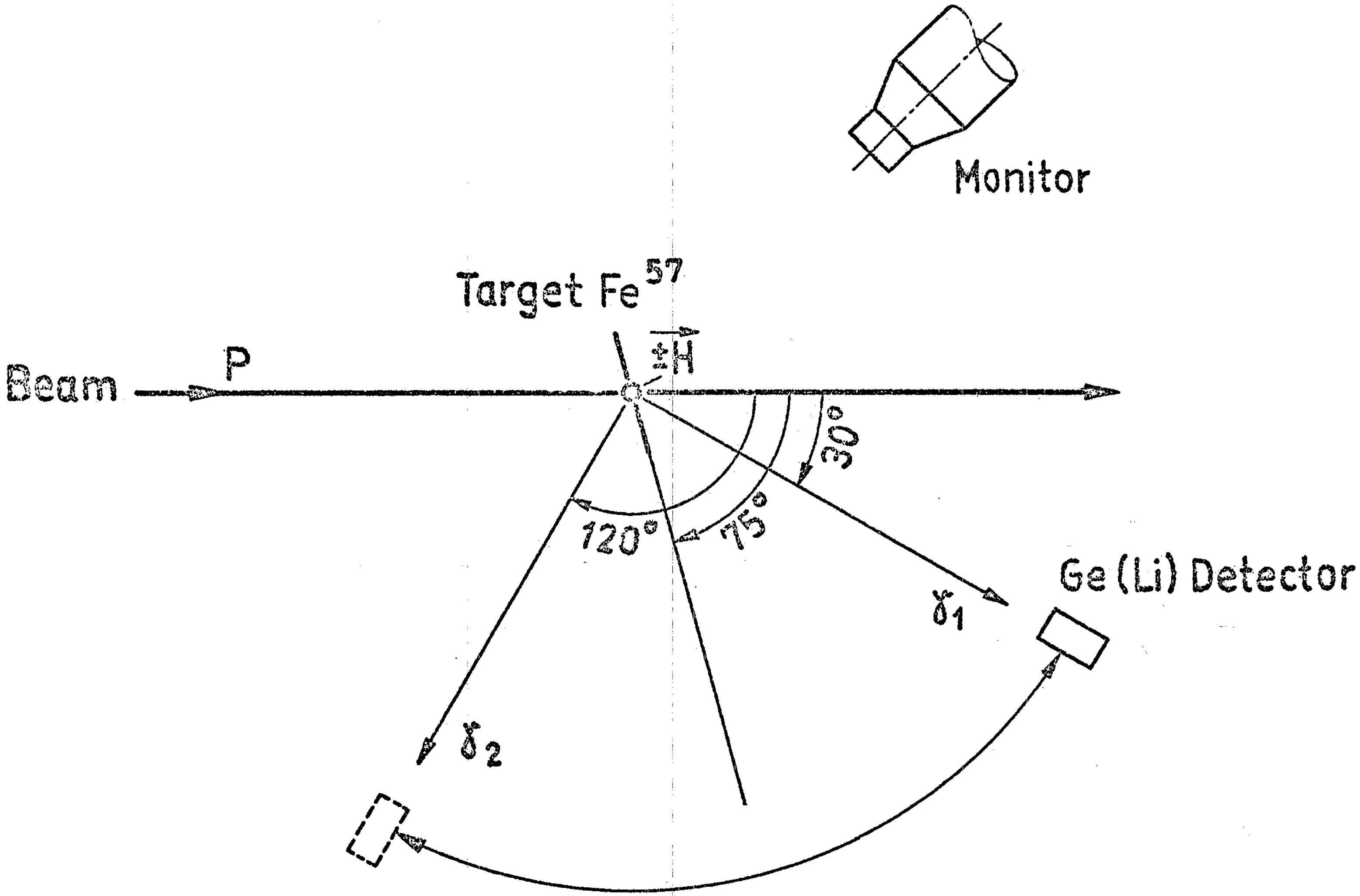

Fig. 2

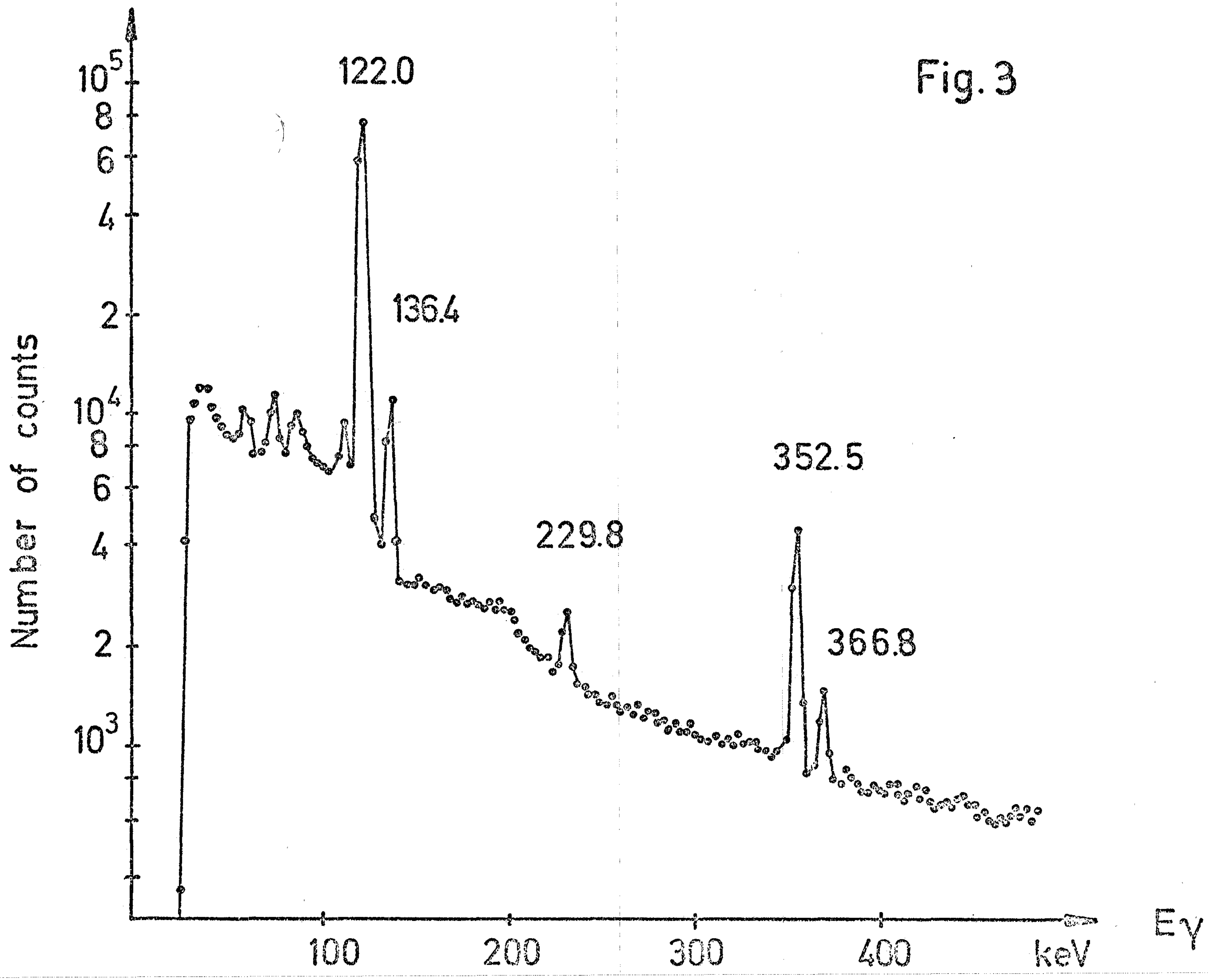

Fig. 3
Number of counts
10^5
8
6
4
2
10^4
8
6
4
2
10^3
122.0
136.4
229.8
352.5
366.8
100
200
300
400
keV
Eγ