LOW-ENERGY EXCITED STATES OF ^{65}Zn FROM THE DECAY OF ^{65}Ga

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The internal conversion electron spectrum of the gamma transitions following the 15.2-minute decay of ^{65}Ga has been measured several times. The half-lives for the individual transitions and the relative internal conversion coefficients are determined. A spin value of $3/2^+$ for the third excited state of ^{65}Zn is suggested.

1. *Introduction*

The low-energy excited states of ^{65}Zn have been investigated by many authors using various methods. This problem has been investigated both by measuring the radiation following the decay of ^{65}Ga [1–3] and by nuclear reaction techniques [4–7]. The former is rather inconvenient owing to the short half-life of ^{65}Ga (15.2 min) and requires special adaptation of equipment. Spectroscopic measurements made by the nuclear reaction technique are also tricky because background is usually high.

The diagram of the low-energy excited states of ^{65}Zn is shown in Fig. 1. It is based primarily on the work of Bernstein and Lewis [4], who measured the spectra of the internal conversion electrons of gamma transitions associated with the reaction ^{65}Cu (p, n) ^{65}Zn.

Lin and Cohen [7] in their study on the angular distribution of protons from the reaction ^{64}Zn (d, p) ^{65}Zn assigned a spin of $5/2^-$ to the third excited state. In all earlier work the value suggested for this state was $3/2^-$.

Our intention in this work was to examine the decay of ^{65}Ga by beta spectroscopy, to determine the internal conversion coefficients of the low-energy gamma transitions in ^{65}Zn, and to try to confirm the existence of an 8-minute isomeric state in ^{65}Ga, which had been suggested by Crasemann [1].

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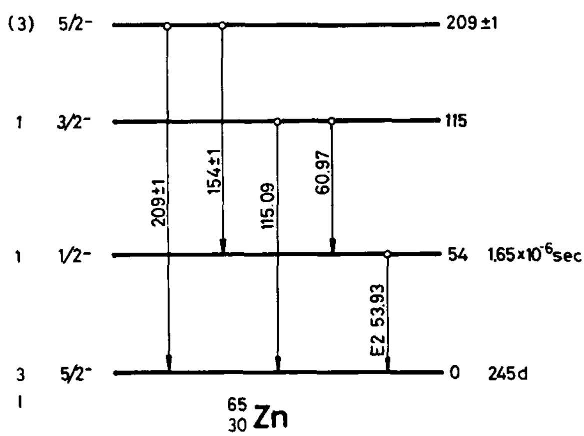

Fig. 1. Diagram of low-energy excited states of ^{65}Zn

2. Source and apparatus

The ^{65}Ga source was produced from copper bombarded with 25-MeV alpha particles in the C-120 cyclotron at the Institute of Nuclear Physics in Cracow. The gallium was separated from the target by evaporation in vacuum onto thin aluminium bases [8]. The sources obtained thus were carrier-free, but besides ^{65}Ga also contained other isotopes of gallium produced in the target. The entire process of producing the source, from the moment the beam in the cyclotron was switched off up to initiation of measurements in the spectrometer, lasted an average of ten-odd minutes.

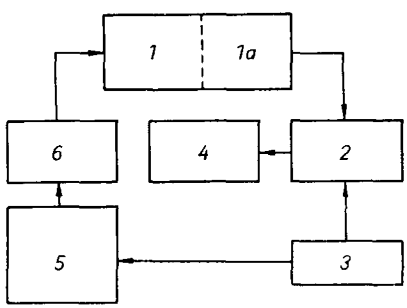

Fig. 2. Block diagram of equipment operating at beta spectrometer. *1* – spectrometer, *1a* – electron detector, *2* – 512 channel multiscaler, *3* – control timer, *4* – printer and coordinatograph, *5* – reference voltage rising synchronously with scalar channels, *6* – spectrometer power supply

The spectrum of internal conversion K electrons of the low-energy gamma transitions in ^{65}Zn following the decay of ^{65}Ga was measured with a toroidal coreless spectrometer [9]. This spectrometer was especially adapted for these measurements [10].

Figure 2 presents a block diagram of the equipment for automatic and rapid measure-

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ment of the electron spectrum. These measurements of the electron spectrum in the range from 700 to 1800 $B\varrho$ lasted about 1000 sec, and thanks to this expediency it was possible to measure the electron spectrum of a single source several times.

3. *Half-life of* ^{65}Ga

A time analysis of the radiation emitted from the source was performed in order to determine whether there is an 8-minute isomeric state of ^{65}Ga or not. The measurement of the internal conversion electron spectrum of the gamma transitions associated with the decay of ^{65}Ga made it possible to assign the half-lives to the corresponding conversion lines accurately. No half-lives other than those known for the decay of ^{65}Ga and ^{67}Ga had been found by this method.

The gallium isotopes in the source underwent electron-capture and β^+ decay accompanied by emission of annihilation quanta. The decay of the 511-keV line was observed automatically with a scintillation gamma counter. The shortest half-life found by this method was that of ^{65}Ga equal to 15.2 minutes. The time decay of the individual sections of the β^+ spectrum from the entire copper target irradiated with alpha particles was measured by means of a scintillation spectrometer with a thin plastic detector. In this case half-lives shorter than 15 minutes were recorded. These results did not confirm the existence of an 8-minute isomeric state of ^{65}Ga, however.

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4. *Analysis of internal conversion electron spectrum of gamma transitions in* ^{65}Zn

Figure 3 depicts an exampl of the obtained electron spectra in the 700 to 1000$B\varrho$ range. The two spectra are from the same source, but one was measured 30 minutes after the other. The repeated measurement of the electron spectrum from the same source made it possible to make an accurate determination of line intensities.

In order to make an estimation of the ratio of internal conversion coefficients, $\alpha_K/(\alpha_L+\alpha_M)$, for the 54-keV and 61-keV transitions, an additional measurement of the intensities of these lines had been made with improved resolving power of the spectrometer. This section of the spectrum is shown in Fig. 4.

A comparison of the measured ratios of internal conversion coefficients, $\alpha_K/(\alpha_L+\alpha_M)$, with theoretical values (Fig. 5) calculated on the basis of tables by Rose [11] suggests a dipole character of the 115-, 154- and 209-keV transitions. The results of Lin and Cohen [7] exclude the possibility of the 209-keV transitions being of dipole character. In order to resolve this problem the absolute values of the internal conversion coefficients α_K were determined as follows. The relative intensities of the conversion lines measured in this work, together with the relative intensities of gamma transitions measured by August and Friichtenicht [3], let us determine the relative conversion coefficients. For the 115-keV transition the value of 3.7×10^{-2} was accepted as the absolute value of the internal conversion coefficient α_K (for a dipole transition the type of radiation has little effect on the value of α_K). The absolute values of α_K confirm the results obtained from the $\alpha_K/(\alpha_L+\alpha_M)$ ratios, suggesting a dipole

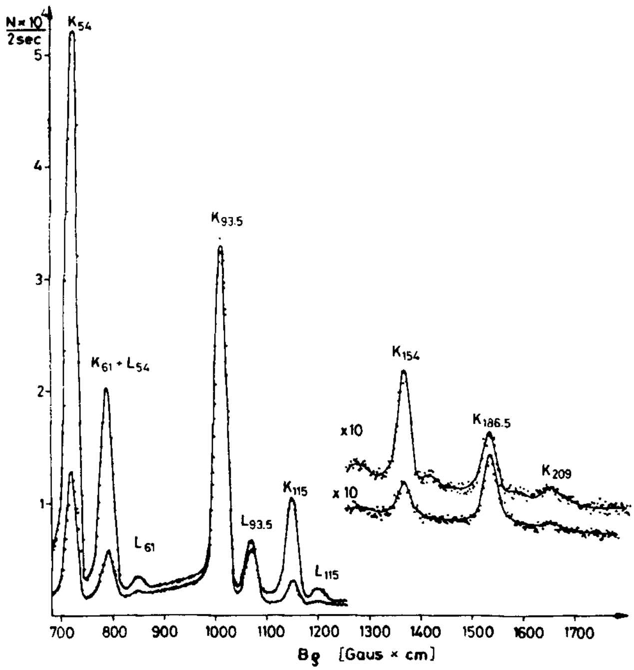

Fig. 3. Internal conversion electron spectra from one source, measured 30 minutes apart

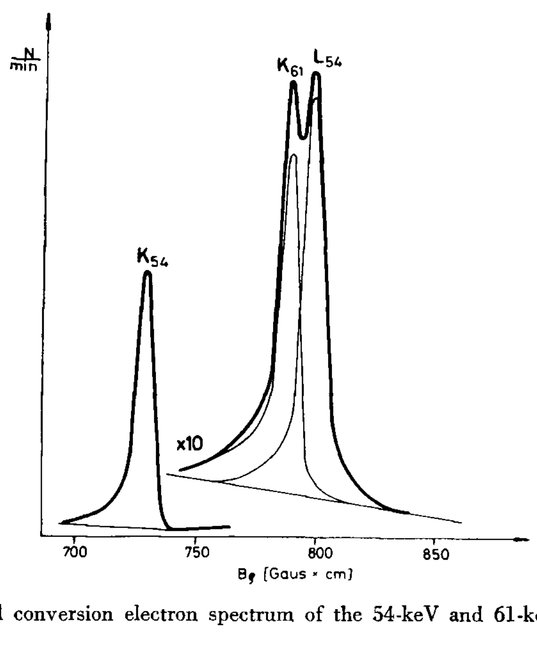

Fig. 4. Internal conversion electron spectrum of the 54-keV and 61-keV transitions

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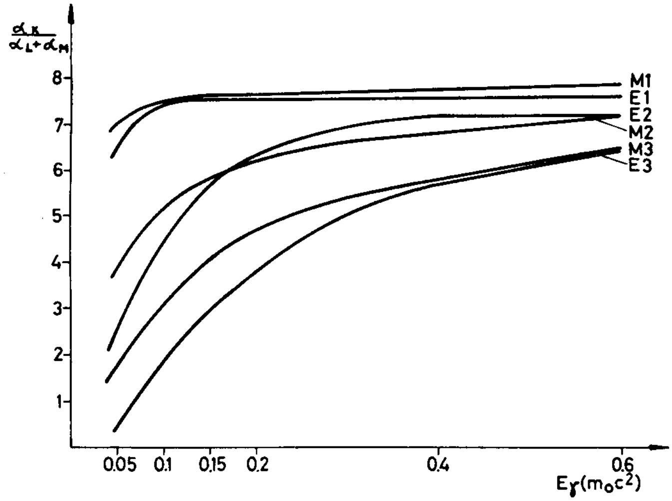

Fig. 5. Ratio of internal conversion coefficients, $\alpha_K/(\alpha_L+\alpha_M)$, for $Z = 30$, calculated according to tables by Rose [11]

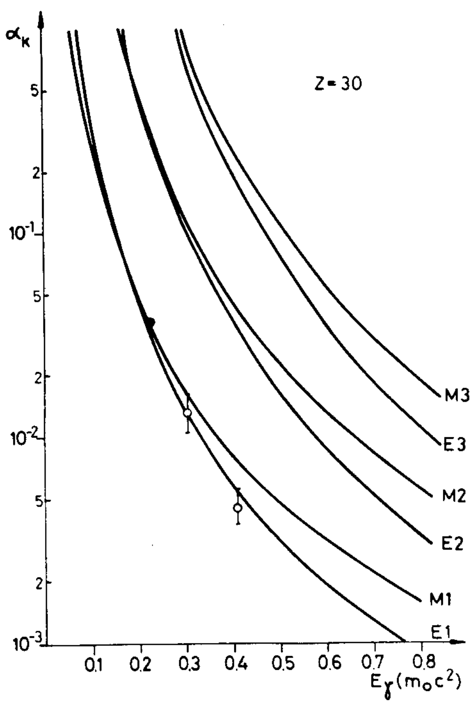

Fig. 6. Comparison of experimental and theoretical values of α_K

character of the 154-keV and 209-keV transitions. In the case of the 209-keV transition, when we compare the measured and theoretical values of α_K (Fig. 6), it is even justifiable to presume that it is of E 1 type. This would mean that the spin of the third excited state is equal to $3/2^+$.

The results of this study are assembled in the table.

TABLE

Results (I_γ –relative intensities of gamma transitions, according to ref. [3], I_e – relative intensities of conversion electrons, α — internal conversion coefficients)

E_γ (keV)	I_γ	I_e	$\alpha_K/\alpha_L+\alpha_M$	α_{exp}	
53.93	35.6±3.5	K 431.3±30 L 77 ±15	5.6±0.6		E 2
60.97		K 79.9±15 L 13.2±2	6.0±1.5		M 1+E 2
115.09	100 ±3	K 100 L 14 ±1.5	7.1±1	3.7 $\times 10^{-2}$ $(5.18\pm0.8)\times 10^{-3}$	M 1
154±1	17.6±3	K 6.4±1.2 L 0.9±0.3	7.1±1	$(1.33\pm0.7)\times 10^{-2}$ $(1.7\pm1)\times 10^{-3}$	E 1 or M 1
209±1	6.6±1.4	K 0.8±0.25		$(4.4\pm2)\times 10^{-3}$	E 1 or M 1

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