GAMMA-RAYS FOLLOWING THE DECAY OF ^{65}Ga

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In a study of the decay of 15^{min} ^{65}Ga, about eight new gamma rays were found, and in all twenty-five gamma transitions were observed. A level scheme has been constructed. Levels not reported earlier in the decay studies of ^{65}Ga are found at 910 keV and 2419 keV. Gamma-ray energy- and intensity values are given, and branching ratios for the β^+ — decay and EC-processes are deduced. Corresponding log ft values have also been calculated.

1. Introduction

Low-lying energy states in ^{65}Zn are known at 54, 115 and 208 keV. Recently, the properties of these levels have been extensively studied by investigation of the gamma radiation which follows the decay of 15^{min} ^{65}Ga [1–3]. From these experiments, spin values are obtained for the following levels: g.s. $5/2^-$, 54 keV $1/2^-$ and 115 keV $3/2^-$. Studies made a short time ago by Bałanda *et al.* [3] of internal conversion electron spectra have established the spin and parity of the 208 keV level as $3/2^+$.

August and Friichtenicht [1] have studied a complete gamma-ray spectrum obtained in the decay of ^{65}Ga. They list 23 gamma rays in the energy region 54–2330 keV, and propose a level scheme with ten levels from 54 keV to 2330 keV. By the application of a Ge(Li)-detector technique, Li-Scholz and Bakhru [2] have investigated the gamma-ray spectrum up to 1414 keV, but a study of the high energy end of the spectrum was not made because of radioactive impurities in the source material.

Earlier, ^{65}Ga sources were prepared from copper targets, which were bombarded with alpha-particles [2, 3], or were produced from the ^{64}Zn$(p, \gamma)^{65}$Ga reaction [1]. In the first of these reactions other gallium isotopes were produced, what interfered with the measurements.

Positions and branching ratios for levels in ^{65}Zn have also been arrived at from the ^{65}Cu$(p, n)^{65}$Zn reaction [4, 5].

About twenty-two excited states below 3 MeV are known in ^{65}Zn from (d, p) — [6, 7], (p, d) — [8] and (p, n) — reactions [9]. These levels have been compiled in Fig. 2. Only about ten of these levels have been reported as fed in the decay of ^{65}Ga.

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Altogether, the results indicate an experimental complexity in the high energy level structure of ^{65}Zn, which has not yet been satisfactorily investigated. As it has proved possible to use a 2.5 MV Van de Graaff accelerator for activation purposes, it seems worthwhile to re-investigate the decay of ^{65}Ga, now produced by proton bombardment of Zn. By this means the difficulties encountered by alpha bombardment of copper [2] will be avoided. The Ge(Li)-technique will be employed, and special emphasis will be laid on the analysis of gamma-ray spectra above ~ 200 keV.

2. *Source preparation and experimental technique*

The 2.5 MV Van de Graaff-accelerator of the University of Helsinki permits of the activation of material by proton bombardment. Sufficiently strong sources are obtained in the study of light or medium weight nuclei ($Z \lesssim 45$). In the present experiment thick, natural Zn targets (supplied by Outokumpu Oy, purity 99.999%) were bombarded with 2.0–2.4 MeV protons. The beam strengths were kept at 15–35 μA, and the targets were cooled by running water. Each irradiation lasted about 15 minutes, after which the zinc targets were removed from the target chamber.

As several irradiations were performed in order to arrive at sufficient statistics in the gamma-ray spectra, new targets were used on each occasion, to avoid too strong a build up of the ^{68}Ga-activity. Accordingly only a small amount of the ^{68}Ga-activity was traceable in the spectra.

For spectra recording use was made of a 38 cm^3 Ge(Li)-detector with an energy resolution of 3.5 keV FWHM for the 1332 keV gamma ray in ^{60}Ni; spectra were recorded with a 4096 channel Nuclear Data ND 160 analyser. This type of analyser permits of the recording and storage of four 1024 channel spectra. The time of measurement of each spectrum was 15 minutes. This made it practicable to follow the decay of 15^{min} ^{65}Ga and to take the possible effects of other activities into account. The favourable abundance of ^{64}Zn in natural zinc, and suitable half-lives, enabled the recording of only weak activities of ^{67}Ga and ^{68}Ga. IAEA standard sources were used for the energy and efficiency calibration of the spectrometer.

3. *Results and discussion*

Fig. 1 illustrates a singles gamma-ray spectrum following the decay of ^{65}Ga. Spectra taken at different time-intervals after irradiation have been added, and several zinc-targets were used. The gamma-ray energies given in the figure are mean values calculated from several spectra obtained at different runs; they are accurate to within ± 1 keV. Intensity values are included in Fig. 2 which indicates the level scheme of ^{65}Zn arrived at in the present work. The stronger gamma-ray intensities are within $\pm 10\%$ error limits, whereas the errors rise to $\pm 50\%$ for the weaker gamma rays.

A comparison with the results reported by Li-Scholz and Bahkru [2] reveals close agreement between their findings and those presented here as regards the stronger gamma rays. However, new gamma rays can be reported at the following energies: 714, 795, 856,

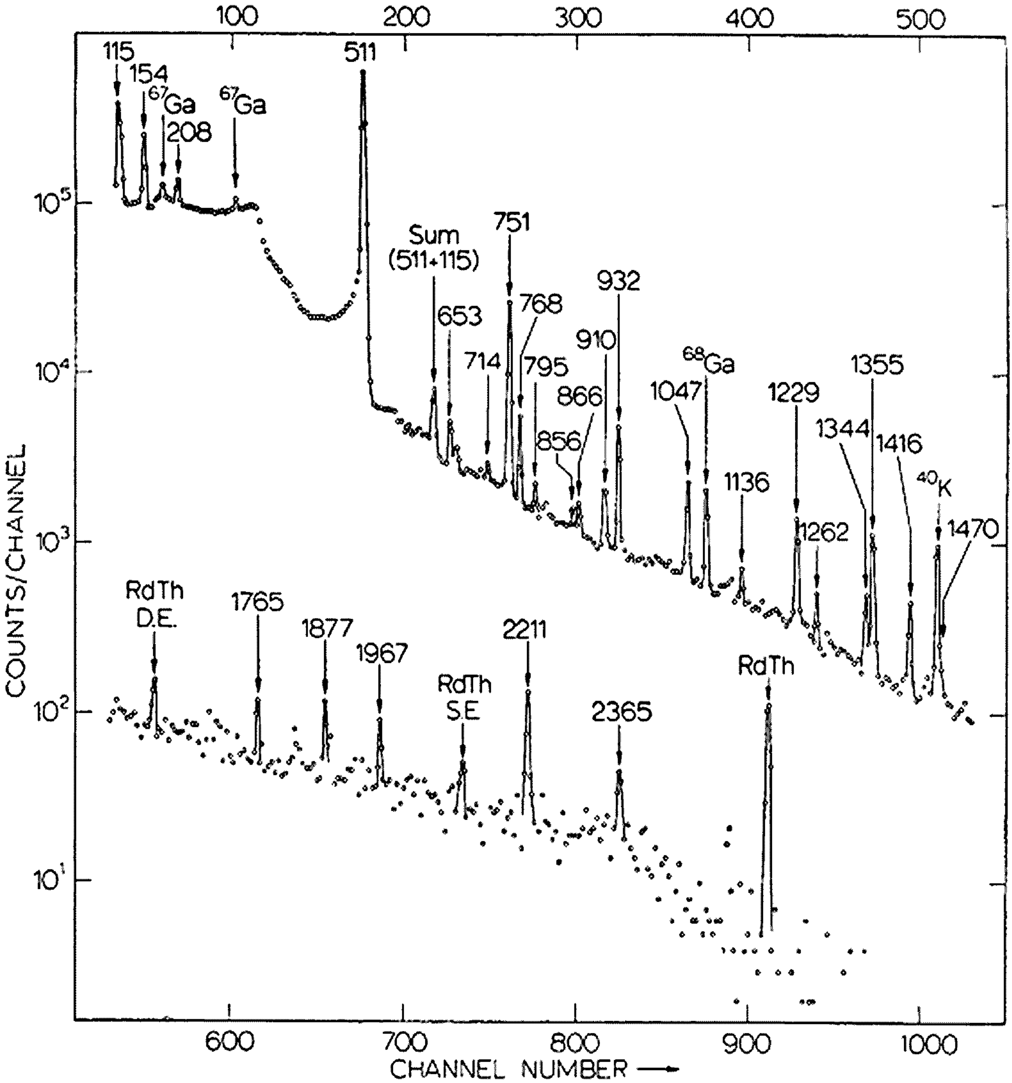

Fig. 1. Gamma-ray spectrum following the decay of ^{65}Ga. The peaks at 1765 keV and 1877 keV are uncertain assignments and are not included into the decay scheme

866, 910, 1136, 1262, 1470, 1967, 2211, and 2365 keV. Most of these gamma rays are transitions between levels known to be populated in the decay of ^{65}Ga [1, 2], but for an explanation of all transitions new levels reached in the decay are suggested at 910 keV and 2419 keV. These results also agree with the preliminary report by Sawa *et al.* [10] on gamma transitions in ^{65}Zn observed in the (α, n)-process.

Fig. 2 presents a compilation of the results arrived at here. This figure also includes the results obtained from different reaction studies [6–9]. The low lying levels at 54, 115 and 208 keV are well known, and their decay properties have been accurately investigated

[3]. The level at 768 keV is probably the same level as that at 776 keV reported in a (p, n) -reaction [9]. At about 870 keV, all reactions report a level which coincides with the present level at 866 keV.

The reports on both (d,p)- [6] and (p, n)- reactions [9] indicate a level in the same energy region as the level at 910 keV given here. Li-Scholz and Bahkru [2] have also reported a gamma ray at 910 keV, which can be interpreted as the ground state transition from this level. Weak transitions from this level to the levels at 54 keV and 115 keV have also been remarked. The levels at 1047 keV, 1344 keV and 1470 keV are firmly established and are observable in both decay and reaction studies.

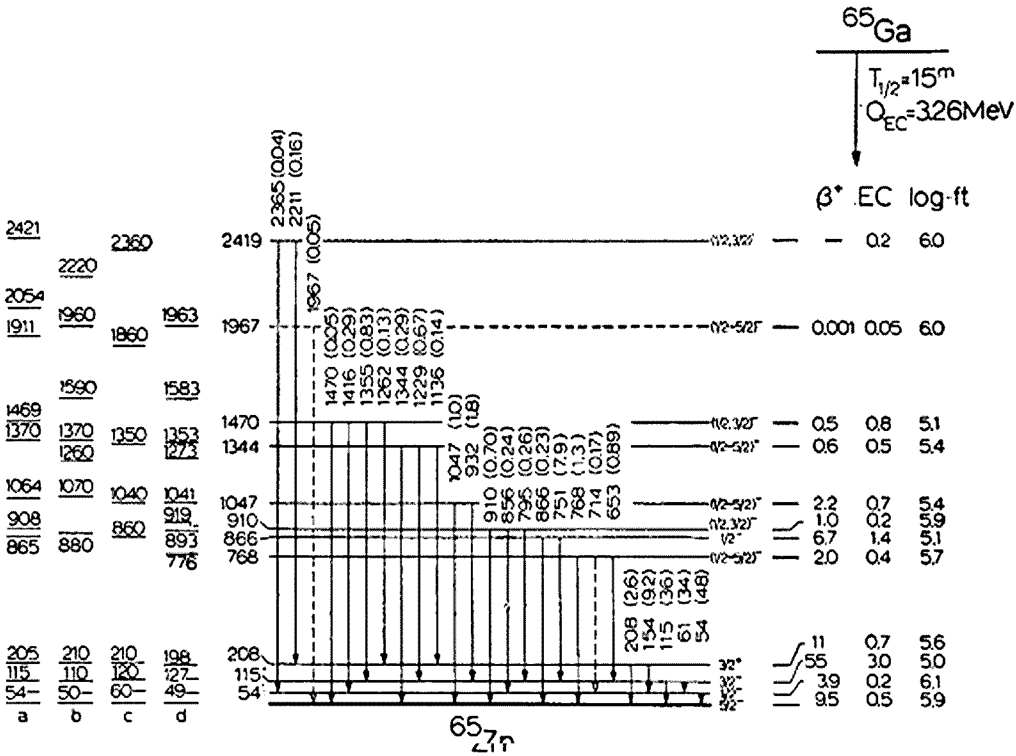

Fig. 2. Decay scheme of ^{65}Ga. The level positions are taken from *a*) Ref. [6], *b*) Ref. [8] *c*) Ref. [7], *d*) Ref. [9]

In our spectra a weak gamma ray is observed at 1967 keV. Its position in the level scheme is uncertain, but it might be a transition de-exciting the level at 1967 keV [1, 8, 9]. A level at 2419 keV, also reported earlier [6], is found to decay to the states at 54 keV and 208 keV.

In calculation of branching ratios for the decay of ^{65}Ga, the assumption was made that 10% of the decay proceeds to the ground state [2, 11]. Furthermore, from the known level positions in ^{65}Zn, and the use of $Q = 3.26$ MeV for the decay, it is possible to deduce $\log ft$ values for the β^+-branches. The results have been included in Fig. 2. The calculated $\log ft$ values display allowed character demanding a spin change of 0 or ± 1 and no parity change, but the transitions to the levels at 910 keV, 1967 keV and 2419 keV can also be considered as first forbidden non-unique transitions demanding a spin change of 0 or ± 1 and parity change.

As the ground state of ^{65}Ga is a $(3/2^-)$ state [2], levels in ^{65}Zn are concluded with spins and parities $1/2^-, 3/2^-$ and $5/2^-$, but the abovementioned levels may also have positive parity. However, reaction data favour negative parity [6–8]. Nonetheless, the level at 208 keV is assigned $3/2^+$ [3]. The log *ft* value deduced is in contradiction to this finding.

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