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Precise absolute $\gamma$-ray and $\beta^-$-decay branching intensities in the decay of $^{67}\text{Cu}$


ABSTRACT

Absolute $\gamma$-ray emission probabilities in the $\beta^-$ decay of $^{67}\text{Cu}$ were measured by means of $\gamma$-ray and $\beta^-$-decay singles and $\beta^-\gamma$ coincidences. The new results, together with the known decay scheme of $^{67}\text{Cu}$, were used to determine absolute $\beta^-$-decay branching intensities. The present data differ significantly from previously published values. In addition, the half-life of the $I_{1n}=12^-$ isomer in $^{67}\text{Zn}$ was measured as $T_{1/2}=9.37(4)$ $\mu$s, in a good agreement with earlier measurements. From the analysis of the Fermi–Kurie plots, $Q_{\beta^-}(\text{g.s.})=560.3(10)$ keV was deduced, which differs from the previously measured value of $577(8)$ keV but is in good agreement with $Q_{\beta^-}(\text{g.s.})=561.3(15)$ keV recommended in the latest Atomic Mass Evaluation.
The neutron-rich $^{67}$Cu (N=38) nucleus decays by emission of $\beta^-$ particles to the ground state and to the first three excited levels of the daughter $^{67}$Zn nucleus, as indicated in the decay scheme of Fig. 1. Early work of Easterday [1] measured the $\beta^-$-decay branching intensities, with $I_{\beta^0}\approx20\%$ reported for the ground state to ground state branch. By using this value, the absolute $\gamma$-ray emission probabilities were determined in the subsequent $\gamma$-ray spectroscopy studies of Raman et al. [2] and
Meyer et al. [3]. The latter were adopted in the most recent nuclear data evaluation [4]. It should be noted, however, that although the absolute γ-ray intensities in Refs. [3,4] are rather precise, this is somewhat misleading since they are deduced by using the less accurate Iβ0 value of Easterday [1].

FIG. 1.

Decay scheme of 67Cu [4]. The γ-ray energies and the half-life of the lπ=12− level shown are from the present work.

There are several motivations for a precise knowledge of the absolute decay properties of 67Cu. For example, the β− decay to the 67Zn ground state involves a π(p3/2)1→ν[(f5/2)5,(p3/2)4] ℓ-forbidden, Gamow–Teller (GT) transition and the precise branching intensity is needed to determine the corresponding B(GT) value that can be used to validate shell-model predictions in this region located near the N=40 subshell closure. The β− branching intensities are also of interest in measurements of the β− asymmetry parameter in the decay of 67Cu, which can provide information on the search for physics beyond the standard model [5]. Lastly, 67Cu is a
promising radionuclide for cancer diagnostics and radio-immunotherapy (see, for example, Ref. [6] and references therein). Although it has favorable decay properties, its wide application is still hampered by difficulties in production and, as a consequence, the lack of reliable supply [7]. Thus, precise knowledge of the absolute $\gamma$-ray-emission probability of the strongest 184 keV $\gamma$ ray is needed in order to accurately determine the resultant activity, and the corresponding production cross sections for this isotope. Other decay properties, such as the absolute $\beta$--decay branching intensities, for example, are important in therapeutic applications and in quantifications of radiation doses.

In this paper, we report on precise measurements of absolute $\gamma$-ray emission probabilities in the $\beta$--decay of $^{67}$Cu. By using the new data and the adopted decay scheme of $^{67}$Cu [4], $\beta$--decay branching intensities were also determined. Our results differ significantly from those reported by the previous measurements [1–4].

II. EXPERIMENTAL DETAILS

III. RESULTS AND DISCUSSIONS

IV. CONCLUSIONS

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REFERENCES