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DETERMINATION OF THE TOTAL ENERGY Q_{EC} FOR ^{156}Ho ($T_{1/2} \sim 56\,\mathrm{min}$) β^+/EC DECAY USING THE TOTAL ABSORPTION γ-RAY SPECTROMETER

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The total energy Q_{EC} for ^{156}Ho β^+/EC decay has been determined using the χ^2 criterion. The optimal energy interval in the total absorption γ spectra for Q_{EC} determination was selected. The value $Q_{\mathrm{EC}} = 5.05 \pm 0.09$ MeV for ^{156}Ho β^+/EC decay was obtained.

С использованием χ^2-критерия определена полная энергия Q_{EC} β^+/EC-распада ^{156}Ho. Для определения Q_{EC} был выбран оптимальный интервал в γ-спектре полного поглощения. Получено значение $Q_{\mathrm{EC}} = 5{,}05 \pm 0{,}09$ МэВ.

The total β-decay energy from the end point of the total absorption spectrum of γ rays accompanying β decay may be determined for a wide range of nuclei with the uncertainties 20–100 keV [1]. For ^{156}Ho ($T_{1/2} \sim 56$ min) there are data about the total electron-capture energy Q_{EC} extracted from some estimations or systematics [2] and it is important to have the direct experimental data about Q_{EC} for ^{156}Ho and compare it with the systematics data. The ^{156}Ho ($T_{1/2} \sim 56$ min) source was produced in the spallation reaction with tantalum exposed to the internal 660-MeV proton beam of the JINR LNP Phasotron. After the exposure the tantalum target was dissolved and the Ho fraction was separated by chromatographic techniques [3]. The ^{156}Ho nuclides were isolated by mass separation of the Ho fraction at the YASNAPP-2 mass separator [4]. The ^{156}Ho ions were collected on an Al foil and investigated with a total absorption gamma-ray spectrometer (Fig. 1). The total absorption spectrometer [5] of gamma rays consists of the 200×110 mm and 200×140 mm NaI(Tl) crystals. The larger crystal has a 70 by 80 mm well into which the nuclei under investigation are supplied and where a Si(Au) detector is installed. Its sensitive layer is 2 mm thick, and it allows detecting beta particles. Operation of the total absorption spectrometer (TAS) is based on summation of cascade gamma quantum energies in the 4π geometry. Isolating total absorption peaks in the TAS spectrum, one can find the occupancy of the levels $I(E)$, and the beta-decay strength function $S_\beta(E)$ [1]. The end-point energy of the TAS spectrum is related to the total electron-capture energy Q_{EC}.

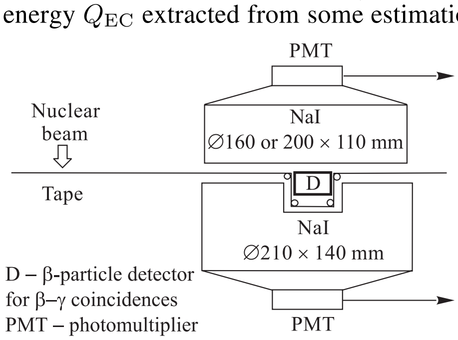
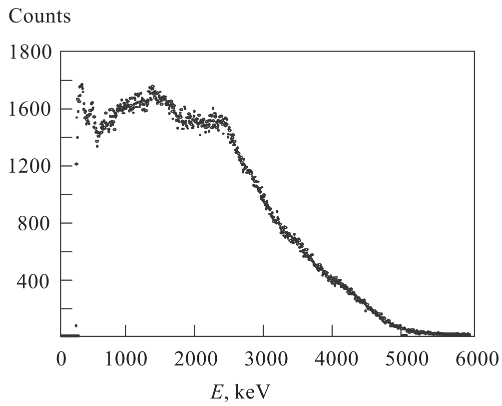


Fig. 1. Scheme of the total absorption spectrometer

The most informative region for the TAS spectrum end-point determination has, as a rule, low counting per channel and it may be very difficult to determine the end-point directly. The parts of the TAS spectrum with sufficiently high statistics are not so informative for end-point determination. So there is some optimal TAS spectrum interval for end-point determination



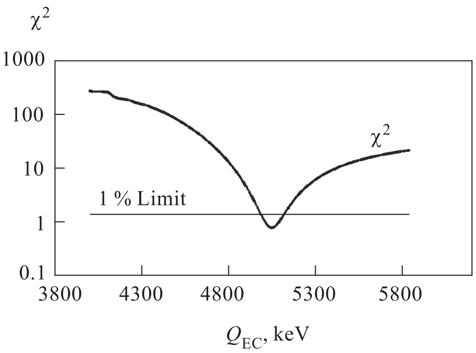


Fig. 2. Experimental TAS γ spectrum for ^{156}Ho β^+/EC decay

Fig. 3. Dependence (logarithmic scale) of χ^2 on the ^{156}Ho total EC energy. The analyzed energy interval was $4.27 \div 5.02$ MeV. The heavy line is the $1\,\%$ limit

and it is very important to have a method for determination of this interval. In the present work we use the parts of the spectra with sufficiently high counting per channel and develop methods for selection of the optimal TAS spectrum interval for end-point determination. The total β-decay energy as a parameter is determined by using the χ^2 criterion. The theoretical spectrum is constructed as

$$N(E) = \int_0^{Q_{\rm EC}} S_\beta(e) f(e, Q_{\rm EC}) \epsilon(e) \phi(e, E) de,$$

where $S_\beta(E)$ is the β-decay strength function; $f(e, Q_{\rm EC})$ is the Fermi function for the β decay; $\epsilon(e)$ is the spectrometer efficiency; $\phi(e, E)$ is the response function of the spectrometer, calculated with the MCNP code.

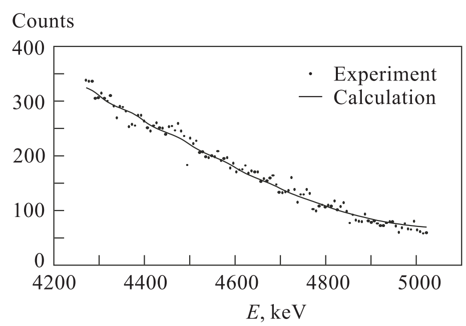


Fig. 4. Experimental and calculated TAS γ spectra for ^{156}Ho β^+/EC decay in the analyzed interval

The TAS spectrum for ^{156}Ho β^+/EC decay is shown in Fig. 2. $Q_{\rm EC}$ is determined from the χ^2 minimum (Fig. 3). After linearization the error $\Delta Q_{\rm EC}$ was established. This procedure was used for different energy ranges. In all cases we obtained approximately identical $Q_{\rm EC}$ but different $\Delta Q_{\rm EC}$. The optimal energy range was selected from the $\Delta Q_{\rm EC}$ minimum (Fig. 4).

The total electron-capture energy $Q_{\rm EC}$ for ^{156}Ho was found to be 5.05 ± 0.09 MeV. This experimental value is in good agreement with $Q_{\rm EC} = 5.06$ MeV from the systematics [2]. The total absorption γ spectroscopy may be used to determine both β^- and β^+/EC-decay total energies with a sufficiently high accuracy. The optimal energy interval selection for such kind analysis of TAS spectra is very important for obtaining a good accuracy of Q-value determination. For the TAS spectroscopy methods, this accuracy cannot be better than the spacing between the levels populated by the beta decay that face within the analyzed interval. Of course, for medium and heavy nuclei far from stability such a level density is high enough at the excitation energy near $Q_{\rm EC}$ or Q_β. But at the energies near Q value the statistics in the TAS spectra is not so high and there is some optimal energy interval for Q-value determination. In this work we selected the optimal energy interval by using the χ^2 criterion.

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