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GAMMA RADIATION PRODUCED IN THE INTERACTION BETWEEN ACCELERATED C^{12} IONS AND TIN NUCLEI

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COMPOUND nuclei with large excitation energy and angular momentum are produced in nuclear reactions caused by accelerated heavy ions. Strutinskiĭ[1] assumes that during the decay of such a compound nucleus the main part of the angular momentum is carried off by gamma radiation, i.e., the emission of nucleons is accompanied by a gamma-ray cascade.

The present paper is devoted to the study of the gamma-ray energy spectrum appearing during the irradiation of Sn with C^{12} ions, accelerated to about 78 Mev. According to estimates, the maximum excitation energy of the compound nucleus in this case amounts to ~ 66 Mev, and the maximum angular momentum amounts to $\sim 45\ \hbar$. The experiments were carried out with the extracted beam of the 150-cm cyclotron of the Atomic Energy Institute of the U.S.S.R. Academy of Sciences. The intensity of the beam was $\sim 5 \times 10^6$ particles/sec. The 24 mg/cm^2 tin target was set at 45° to the incident beam. The gamma rays in the 0.4- to 4-Mev energy range were registered with a scintillation gamma spectrometer, consisting of a CsI crystal (3 cm diameter, 3 cm height), an S-993 photomultiplier and an ÉLA-2 multichannel analyzer.[2] The channel width was 0.075 Mev. The energy resolution of the Cs^{137} photopeak (0.661 Mev) was $\sim 11\%$. A miniature proportional counter, mounted on the entrance diaphragm, was used to monitor the beam. To absorb the soft x rays appearing when the carbon ions pass through the target, a lead foil $\sim 150\,\mu$ thick was placed in front of the crystal. The distance between the target and the spectrometer crystal could be varied from 0.2 to 5 cm. In the experiments for determining the background, the ion energy was decreased below the Coulomb barrier of tin nuclei for C^{12} ions by inserting a $60\,\mu$ aluminum foil at a distance of 15 cm from the crystal. In processing the spectra, the spectral sensitivity of the instrument and the line shape, obtained during the registration of monochromatic gamma rays,[3] were taken into account.

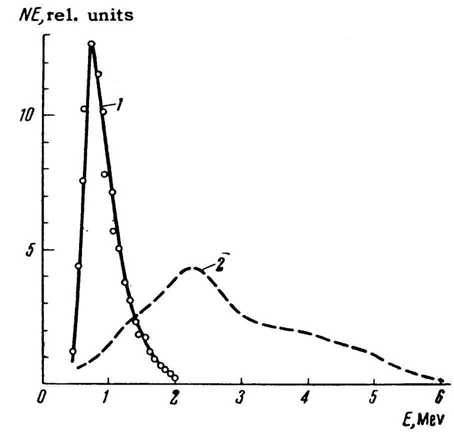

FIG. 1

Figure 1 (curve 1) shows the corrected gamma spectrum in the form NE = f(E) [N is the number of gamma quanta in the channel with an energy E]. The distance R between the crystal and the target was 5 cm. The spectrum has the form of a continuous distribution with a maximum at E = 0.8 Mev. Figure 1 (curve 2) also shows the gamma-ray spectrum from the reaction $Sm^{150}(n, \gamma)$ with thermal neutrons (unresolved portion[4]), which is typical of the case of a compound nucleus with an angular momentum practically the same as in the ground state. This spectrum has a peak energy of about 2 Mev.

Comparison of these two spectra indicates that in our case the transition of the nucleus to the ground state takes place overwhelmingly with emission of softer gamma quanta than emitted in radiative neutron capture.

An attempt was also made to estimate experimentally the mean number of gamma quanta emitted during the disintegration of the compound nucleus. For this purpose the distance between the crystal and the target was decreased to its minimum; this increased the probability of simultaneous registration of successively emitted gamma quanta.

Figure 2 shows corrected gamma-ray spectra obtained for R = 5 cm (a) and R = 0.2 cm (b) normalized to make the areas under the respective curves, plotted in NE and E coordinates, equal.

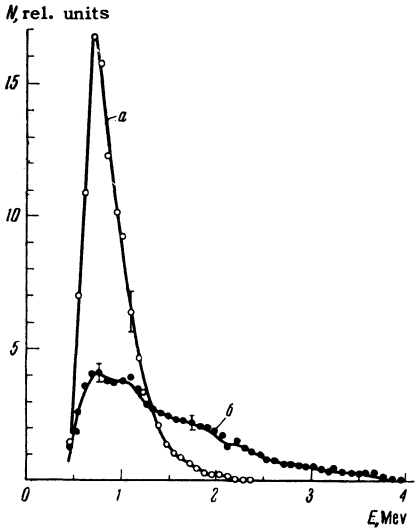

FIG. 2

This normalization takes account of the change in the registration efficiency of the radiation with a change in the distance between the target and the crystal. From a comparison of the spectra it can be seen that with the decreasing target-to-crystal distance the relative number of pulses corresponding to 1.5- to 4-Mev gamma quanta increases. It must be assumed that this is caused by the presence of cascades consisting of relatively soft gamma rays which, being simultaneously registered, simulate gamma quanta of higher energy. The mean number of simultaneously registered gamma quanta for $R = 0.2$ cm, found from the ratio of the areas under curves (a) and (b) (Fig. 2), is ~ 1.8.

To determine the mean number of gamma quanta in a cascade, it is essential to know not only the counting efficiency of the spectrometer, but also the angular distribution of the gamma quanta. At present, there are no data on the angular distribution of gamma quanta emitted by a compound nucleus with a large angular momentum, and therefore a sufficiently precise determination of this quantity is difficult. According to our rough estimates this number is apparently not less than 10.

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BETA DECAY OF P^{32}

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THE β transition in P^{32} appears to be an allowed $1^+ \rightarrow 0^+$ transition. Therefore the β spectrum of P^{32} must have a Fermi shape and a polarization equal to v/c. However experimental results[1-3] have indicated a small deviation from the Fermi shape for the spectrum and from the designated polarization value. The aim of the present paper is to offer a possible explanation of these experimental results.

Since $\log ft = 7.9$ for P^{32}, while for Gamow-Teller transitions $\log ft \sim 4$, this means that the matrix element $\int \boldsymbol{\sigma}$ in this case must be about $30-40$ times smaller than its normal value. Therefore we must examine second-forbidden terms. The transition in question may have contributions from terms of the form $\int \boldsymbol{\sigma} \mathbf{r}^2$, $\int (\boldsymbol{\sigma}\mathbf{r})\mathbf{r}$, $\int [\boldsymbol{\alpha}\mathbf{r}]$ and $\int \gamma_5 \mathbf{r}$. The first two matrix elements are small in comparison to the last two. The matrix element $\int [\boldsymbol{\alpha}\mathbf{r}]$ introduces into the spectrum a term which is proportional to the β-electron energy, but since there is no such term experimentally observed in the P^{32} spectrum, we set this matrix element equal to zero. Therefore we shall consider further only the matrix element $\int \gamma_5 \mathbf{r}$.

Let us introduce the relation $x = \int \gamma_5 \mathbf{r} / \int \boldsymbol{\sigma}$. In β transitions having a normal value of $\log ft$ we have $x \sim (v/c)_{\mathrm{nucl}} \rho_{\mathrm{nucl}} / \lambda\!\!\!^{-}_{\mathrm{Compton}} \sim 0.002$. (We use a system of units in which $\hbar = c = m_e = 1$.) Because of the smallness of $\int \boldsymbol{\sigma}$, the value of x for P^{32} must be about $30-40$ times larger, i.e., $x \sim 0.06-0.08$. For these values of x it is necessary to take into account not only the terms proportional to x, but also terms of the order of x^2.