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Abstract

Full Text

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STUDY OF THE β^+ DECAY IN Ho^{160}

Using a β-spectrometer with triple beam focusing ([1]), we investigated a holmium fraction that had been isolated from a tantalum target irradiated with protons of energy 660 MeV. The activity was deposited as a thin layer on a cellophane backing 17 μ thick. In measuring the electron spectrum of holmium we found conversion lines belonging to transitions with energies: 197±5; 287±10; 545±20; 652 ± 20; 730 ± 20; 874 ± 25; 974 ± 25 and 1315 ± 30 keV. The half-life for these lines lies within the range from 4.5 to 6 hours.

The study of the holmium and erbium fractions in our laboratory by means of lens spectrometers ([2]) and a $\pi\sqrt{2}$ spectrometer ([3]), and by scintillation methods in the laboratory of the Radium Institute of the Academy of Sciences of the USSR ([4]), as well as in works ([5], [6]), showed that the conversion electrons corresponding to transitions with energies: 196; 298; 539; 648; 730; 876; 967 keV belong to the isotope Ho^{160}, which has a half-life of 5.3 hours.

Thus, it may be considered that the conversion spectrum of our preparation is entirely due to Ho^{160} (with the exception of the line $ch\,\gamma = 1315$ keV, which until now has not been detected by anyone).

Fig. 1. Positron spectrum of Ho^{160}

Up to the present time there have been no indications in the literature concerning positrons in the radiation of Ho^{160}. Meanwhile, study of the positron spectrum of this isotope could provide information on the mass difference of Ho^{160} and Dy^{160}.

We measured the positron spectrum of Ho^{160}. The measurements showed that the spectrum is a complex curve (Fig. 1). Assuming that this spectrum is the result of β^+ decay, we constructed for it the Kurie plot shown in Fig. 2.

The plot clearly shows the presence of four components of the β^+ spectrum. The endpoint energies of the components are: 1900 ± 100; 970 ± 30; 570 ± 20 and 300 ± 50 keV, and the relative intensities are $0.14 : 0.26 : 1 : 0.47$. As for the

Fig. 2. Kurie plot of the β^+-spectrum of Ho^{160}

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last soft component of the spectrum, we cannot assert its independent existence with confidence, since in this energy region the corrections for scattering in the instrument are large.

To determine the half-life of all components of the spectrum, we followed for 30 hours the change in counting rate at the corresponding positron energies and established that the half-life is the same for all components of the spectrum and is 5.6 ± 0.7 hours.

Fig. 2. Kurie plot of the β^+-spectrum of Ho^{160}

In analyzing the results obtained, two questions arise:

1. To which holmium isotope does the positron radiation belong?

2. What is the origin of these positrons—are they in fact a consequence of β^+-decay, or are they positrons of pair conversion of the corresponding transitions?

In considering the first question, it should be noted that the value of the half-life of the positron spectrum speaks in favor of the assumption that this spectrum belongs to Ho^{160}. However, the possibility is not excluded that the positron spectrum owes its origin to some unknown Ho^x having a period close to 5 hours. If this Ho^x is a small impurity in Ho^{160}, then its conversion spectrum may not be visible against the background of the intense conversion spectrum of Ho^{160}. To decide the question of which A the positron spectrum belongs to, we carried out two additional experiments.

It is known from the literature that Ho^{160} is produced by electron capture in Er^{160}, which has a half-life of about 30 hours. We obtained the first control source by separating holmium from the erbium fraction 45 hours after it had been obtained. In measurements of this source, the same results were obtained as before—the same conversion spectrum, the same half-life, the same components of the positron spectrum. Moreover, the ratio of the area of the total positron spectrum to the area of the conversion line with $h\nu = 730$ keV, undoubtedly belonging to Ho^{160}, also proved to be the same. This ratio S_{β^+}/S_{e^-730} is 1.6 ± 0.2 for both sources.

It follows from this:

1. since a β^+-spectrum with a half-life of 5.6 hours was observed in the source separated from Er after 45 hours, the proposed Ho^x is produced, just like Ho^{160}, from Er^x;

2. the fact that the ratio S_{β^+}/S_{e^-730} proved to be the same for both sources indicates an astonishing closeness of the periods not only of Ho^{160} and Ho^x, but also of Er^{160} and Er^x.

In the second additional experiment, the erbium fraction was used after lying for 110 hours following separation. From it we obtained the same results. The ratio S_{β^+}/S_{e^-730} in this case proved equal to 1.7 ± 0.2, which, within the limits of error, is in full agreement with the preceding measurements. Meanwhile, if in the erbium fraction, in addition to Er^{160}, there had also been present Er^x with a period differing from the period of Er^{160} only by ⋯

3 hours, then over 110 hours this difference in periods would have led to the ratio $S_{\beta^+}/S_{e^-_{730}}$ changing by 35%. From the experiments carried out it may be concluded that the positron radiation belongs to holmium with mass number 160.

If it is assumed that the positrons found by us arise as a result of pair conversion, then the corresponding transitions must be sufficiently intense, and we should have observed hard conversion lines. In the region from 1 to 2.5 MeV we observed only one weak line at 1315 keV. The bulk of the positrons ($\sim$ 50%) has an endpoint near 550 keV. Even for multipolarity $E1$ the corresponding conversion line or lines should have a total intensity 100 times greater than that observed for the 1315 line. In an analogous manner it can be shown that the harder positrons also are not a consequence of pair production. Therefore one may assume that the bulk of the positrons belongs to the β^+-decay of Ho^{160}. Assuming that the hard part of the positrons belongs to a continuous β^+-spectrum, we arrive at the conclusion that the mass difference Ho^{160}—Dy^{160} is not less than 2920 ± 100 keV.

To determine the intensities of the positron spectra (the number of positrons per decay) one may use the ratio measured by us, $S_{\beta^+}/S_{e^-_{730}} = 1.6 \pm 0.2$. Using the ratio $e^-_{726}/e^-_{60} = 0.0029$, measured by Grigor' ev et al. ([3]), we find $\beta^+/e^-_{60} = 0.46\%$.

Since the transition with energy 60 keV is isomeric, it is strongly converted, and the number e^-_{60} practically coincides with the number of decays (possible, but unestablished, β-processes from the 5-hour level of Ho^{160} are neglected). Hence follow the intensities and the values of $\log \tau f$ for the components of the β^+-spectrum (Table 1).

Table 1

Endpoint energy	Percentage of decays via the β^+-branch	$\log \tau f$
$E_1 = 300$ keV	0.11	4.9
$E_2 = 570$ »	0.25	5.9
$E_3 = 970$ »	0.06	7.6
$E_4 = 1900$ »	0.04	9.2

Endpoint energy	Percentage of decays via the β^+-branch	$\log \tau f$
Sum···	0.46	

Thus, the transitions to the upper levels are allowed. It may seem surprising why, then, so few positrons occur in the decay. This is explained by the fact that at low decay energy K-capture is dominant. Considering the decay to the two upper levels as allowed, we can, from Zweifel' s tables ([7]), approximately determine K/β^+. The resulting values, $\sim$ 6000 and 450, are very large, and, although their accuracy is not great, it may be asserted that a significant fraction of all transformations of Ho^{160} proceeds by K-capture to these two upper levels. The intensity of K-capture to the lower levels is small. It is difficult to calculate it accurately, but the ratio K/β^+ does not depend strongly on forbiddenness; therefore, for these components as well, the intensity can be calculated according to Zweifel. The corresponding values are 1.7 and 0.12% of decays.

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References

1. B. S. Dzhelepov, O. E. Kraft, *Izv. AN SSSR, ser. fiz.*, **20**, No. 3, 318 (1956).

2. B. S. Dzhelepov, B. K. Preobrazhenskii, I. M. Rogachev, P. A. Tishkin, *Izv. AN SSSR, ser. fiz.*, **21**, No. 7, 962 (1957).

3. E. P. Grigor' ev, B. S. Dzhelepov et al., *DAN*, **117**, No. 1 (1957).

4. G. M. Gorodinskii, A. N. Murin et al., *DAN*, **112**, No. 3, 405 (1957).

5. W. Nervik, G. Seaborg, *Phys. Rev.*, **97**, 1092 (1955).

6. J. Mihelich, B. Hermatz, T. Handley, J. Pinajera, *Bull. Am. Phys. Soc.*, **1**, No. 7, 330 (1956).

7. P. Zweifel, *Phys. Rev.*, **96**, 1572 (1954).

Note: Figure translations are in progress. See original paper for figures.