The Decay of 8.7 min $^{237}$Pa

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Abstract. The beta and gamma radiations of $^{237}$Pa have been investigated employing semiconductor and scintillation spectrometers and coincidence techniques. Sources of $^{237}$Pa were obtained after bombardments of $^{238}$U with bremsstrahlung and 14-MeV neutrons and subsequent chemical separation. From the total of 18 $\gamma$-rays following the decay of 8.7 ± 0.2 min $^{237}$Pa 17 transitions, representing 99.9% of the $\gamma$-ray intensity, could be placed in a level scheme of $^{237}$U. A $Q_\beta$-value of 2.25 ± 0.1 MeV has been determined.

1. Introduction

Excited levels of $^{237}$U have recently been studied in detail by means of various charged particle reactions [1-3] like $^{236}$U($d$, $p$), $^{238}$U($^3$He, $\alpha$) and $^{239}$U($d$, $t$). Some low energy levels have also been found following the $\alpha$-decay [4-6] of $^{241}$Pu. However, only scanty information has been available from the $\beta^-$-decay of $^{237}$Pa into $^{237}$U. After bombardment of uranium with 190-MeV deuterons Crane and Iddings [7] found in addition to a large excess of $^{235}$Pa, a 10.5 min activity which they assigned to $^{237}$Pa produced via a $^{238}$U($d$, $2p$ $n$) reaction. The mass assignment and the half-life value were determined by repeated milking of the $^{237}$U daughter activity. Takahashi and Morinaga [8], however, reported a value of 39 min for the half-life of $^{237}$Pa. The activity was produced in a ($\gamma$, $p$) reaction irradiating $^{238}$U with 25-MeV bremsstrahlung. A decay scheme was also proposed based on $\beta$ and $\gamma$ singles and $\gamma$-$\gamma$-coincidence measurements. In our own investigations [9, 10] we have found a half-life of 9 min for $^{237}$Pa. Recently, the experiment of Takahashi and Morinaga [8] was repeated by v. Egidy et al. [11] and they came to the conclusion that $^{237}$Pa does not have a half-life of 9 min.

2. Experimental Methods

The activities of $^{237}$Pa have been produced by the ($n$, $p$ $n$) reaction in bombardments of $^{238}$U with 14-MeV neutrons from the Cockcroft-Walton accelerator of this institute; fluxes up to $4 \cdot 10^{10}$ n/cm²/sec were available. As the cross section [12] for the ($n$, $p$ $n$) reaction is only 0.23 mb, we tried to get higher intensities by irradiating $^{238}$U with 100-MeV bremsstrahlung from the Mainz electron linear accelerator. Unfortunately, in this case we always got a mixture of $^{237}$Pa and $^{236}$Pa, due to a ($\gamma$, $p$) and ($\gamma$, $pn$) reaction, respectively. As both nuclides have the same half-life of 9 min [9, 10], we carried out additional irradiations at the Gießen electron linear accelerator with a 21-MeV bremsstrahlung spectrum, in order to get pure $\beta$ and $\gamma$ singles spectra of $^{237}$Pa.

In all cases the protactinium was radiochemically separated from the predominating fission-product activities by partition between diisobutylcarbinol and hydrochloric acid containing complex-forming agents. The chemical separation has been described in more detail elsewhere [12]. Counting samples were prepared by coprecipitation with ferric hydroxide. The first count could be started within 2–3 min after the end of bombardment. Decontamination from short-lived fission products was tested using samples prepared by thermal-neutron irradiations of $^{235}$U in the Mainz research reactor. For the half-life measurements the $\beta$ radiation has been counted with a methane-flow proportional counter. The $\gamma$-ray spectra have been recorded with several Ge(Li) detectors of 30 to 40 cc active volume.
and a resolution of 2.1 to 3 keV FWHM at 1333 keV. A 0.45 cc X-ray detector has been available for measuring the low energy part of the $\gamma$-ray spectrum and especially for checking the purity of the chemically isolated protactinium samples. The $\beta$-ray spectrum has been measured with a 7.5 x 5 cm plastic scintillator. For $\gamma$-$\gamma$-coincidence experiments two 35 cc Ge(Li) detectors have been used together with a constant fraction coincidence circuit. The measurements were performed in the two dimensional mode up to a maximum of 4096 x 4096 channels. The resolving time of the set-up was about 25 nsec. The coincidence data accumulated on magnetic tapes were analyzed on a CDC 3300 computer. The energy and intensity calibration of the detectors has been described elsewhere [13].

3. Experimental Results

a) Decay Curves

Fig. 1 shows the $\beta$-decay curve of the Pa fraction after bombardment of $^{238}$U with 14-MeV neutrons measured with a flow counter. After subtraction of 6.75 h $^{234}$Pa and 24.2 min $^{235}$Pa there remains a 8.7 min component, for which the mass assignment to $^{237}$Pa is confirmed by the growth of the daughter product 6.7 d $^{237}$U, shown as insert in Fig. 1. The main activity of $^{234}$Pa, however, stems from the $\alpha$-decay of $^{238}$U. The strong 2.3 min component [9, 14] belongs to $^{238}$Pa from the $^{238}$U($n, p$) reaction. More accurate values for the half-life of $^{237}$Pa were obtained from the decay of characteristic $\gamma$-rays, for which two examples are shown in Fig. 2. From these measurements, a half-life of $8.7 \pm 0.2$ min results for $^{237}$Pa.