Pm^{145}: A New Alpha Activity†

M. NURMIA,* P. KAURANEN, AND A. SIIVOLA
Institute of Physics, University of Helsinki, Helsinki, Finland
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Pm^{145} was prepared by means of the chain $Sm^{144}(n,\gamma)Sm^{145} \xrightarrow{E.C.} Pm^{145}$. The alpha activity of Pm^{145} was studied by means of a gridded ionization chamber and a 512-channel pulse-height analyzer. The alpha energy was found to be 2.24 ± 0.04 MeV, and the branching $(2.8\pm0.6)\times10^{-9}$ alphas per disintegration. With a view to proving that the alpha activity was not due to Sm^{147}, a further Sm-Pm separation was carried out with no detectable change in the branching ratio. The thermal neutron capture cross sections of Sm^{144} and Sm^{145} were estimated to be 0.7 and 110 b.

INTRODUCTION

IN view of the effect of the 82-neutron closed shell, the promethium isotope most likely to exhibit measurable alpha activity is Pm^{145}, which has 84 neutrons. This nuclide was discovered by Butement,[1] who established that it decays by electron capture with a half-life of approximately 30 yr. In the thorough investigation of Brosi, Ketelle *et al.*[2] this value was revised and reduced to 18 yr.

On the basis of known reaction energies, Toth and Rasmussen[3] estimated that the alpha energy of Pm^{145} is 2.30 MeV. From a recent compilation of Yamada and Matumoto[4] and the alpha energy of Nd^{144}, 1.84 MeV,[5] a value of 2.23 MeV is obtained. These results suggest that the alpha activity of Pm^{145} might be detectable, but although the matter has been considered by some investigators,[6] we are aware of no experimental studies on the matter.

In this paper, we report the results of an investigation on Pm^{145} carried out at the Institute of Physics, University of Helsinki.

PREPARATION OF Pm^{145}

Pm^{145} was prepared essentially in the manner described by Brosi *et al.*[2] 30 mg of Sm^{144} enriched to 94.6%[7] was irradiated for four weeks in a flux of about 2×10^{14} n/cm^2 sec in the ORR to form Sm^{145}, which has a half-life of 340 days. 21.5 mg of the irradiated Sm^{144} were then chemically fractionated by means of a cation exchange column according to the method described by Choppin *et al.*[8] The resin was Dowex 50×8, -400 mesh, and the elution was carried out with 0.25-*M* α-hydroxy-isobutyrate at *p*H 4.60 at 70°C.

After seven months the Sm-145 obtained was run through a similar separation process to isolate the daughter Pm^{145}. From the elution curves, it was estimated that the decontamination against Sm was better than 99.8% in a single separation. The process was repeated, following which the Pm^{145} was mounted on stainless steel planchets for alpha spectrometry.

MEASUREMENTS

The alpha activity of Pm^{145} was studied by means of a gridded ionization chamber as described by Siivola.[9] Pulses induced into the source plate were separately amplified and utilized for opening the coincidence gate of the analyzer in order to reduce the pile-up of pulses resulting from the x-rays and electrons from the source. The amplifier system was operated with integrating and differentiating time constants both equal to 1 μsec; the alpha-energy resolution (full width at half maximum) of the system was about 40 keV, but in the presence of strong sources in the chamber it was found to deteriorate to 100 keV or more. The background of the chamber was uniform and amounted to about 0.1 count/channel (35 keV)$\times$hours between 1 and 4 MeV. The pulses were analyzed with a Nuclear Data 512-channel pulse-height analyzer.

The alpha energy of Pm^{145} was determined with the help of alpha particles from the $B^{10}(n,\alpha)Li^7$ reaction and natural uranium, and was found to be 2.24 ± 0.04 MeV. The spectrum used is illustrated in Fig. 1.

In order to obtain the alpha branching ratio of Pm^{145}, several sources were measured without energy calibration in the ion chamber. The geometry was taken to be 2π, and no correction for back-scattering or self-absorption was applied. The gamma- and x-ray activity of the sources was determined by means of a scintillation spectrometer equipped with a NaI(Tl) crystal 1 in. in diameter and 1 in. thick. On the basis of the results of Brosi *et al.*[2] and the Wapstra tables,[10] it was estimated that Pm^{145} emits 0.75 *K* x-ray quanta per disintegration; this figure was used for the calculation of the amount of

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* Present address: Department of Physics, Oklahoma State University, Stillwater, Oklahoma.
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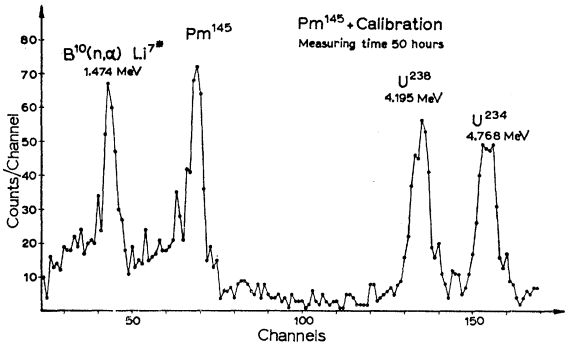

FIG. 1. The alpha spectrum of a source consisting of Pm^{145}, natural uranium, and natural boron under neutron irradiation.

Pm^{145} present in the sources. The results are given in Table I.

The amount of Sm^{145} was determined similarly, but it was calculated that 1.38 K x-ray quanta are emitted by Sm^{145} per disintegration. Fourteen months after irradiation 8.2 mC of Sm^{145} was found to be present in the fractionated sample; this led to an estimate of 0.7 b for the thermal neutron capture cross section of Sm^{144}.

As a check against eventual Sm^{147} contamination, source No. 1 was dissolved and a small amount of Sm^{145} tracer added to it. It was then run once again through the ion exchange process and made into source No. 4, which still exhibited the same alpha branching ratio. The elution curves indicated that at least 99% of any Sm present in the source had been removed; the alpha activity of the Sm fraction was undetectable in the ion chamber.

A larger amount of the Sm^{145} was studied in the ionization chamber and found to contain Sm^{146} formed by neutron capture. The thermal neutron capture cross section of Sm^{145} was estimated to be 110 b under the assumption that the half-life of Sm^{146} is 5×10^7 yr.[11]

TABLE I. Alpha Branching Measurements of Pm^{145}.

Source No.	Amount of Pm^{145} (μC)	Alpha activity (dis/h)	Branching
1	121.0	46.5	2.88×10^{-9}
2	47.0	14.0	2.23×10^{-9}
3	16.5	6.0	2.74×10^{-9}
4	43.0	17.0	2.95×10^{-9}
		Weighted average:	$(2.8\pm0.6)\times10^{-9}$

DISCUSSION

The alpha energy of Pm^{145} is in close agreement with the predictions made above, and it exactly coincides with that of Sm^{147}, found by Macfarlane[5] and Siivola[9] to be 2.23 and 2.24 MeV, respectively. Despite this, it is considered that the evidence presented above excludes the possibility of the alpha activity being due to Sm^{147} contamination. No other alpha emitters close to this energy are known, and the method of preparation eliminates all the known nuclides apart from Pm^{145}.

The systematics of Taagepera and Nurmia[12] predict for a nuclide with $z=61$ an alpha half-life of 1.7×10^{10} yr at an alpha energy of 2.24 MeV. This agrees reasonably well with the experimental value of 6.3×10^9 yr obtained from the alpha branching ratio and the half-life of Pm^{145}.

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