Measurements of Neutron Cross Section of the $^{243}Am(n,\gamma)^{244}Am$ Reaction

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The effective thermal neutron cross section of $^{243}Am(n,\gamma)^{244}Am$ reaction was measured by the activation method. Highly-purified ^{243}Am target was irradiated in an aluminum capsule by using a research reactor JRR-3M. The tentative effective thermal neutron cross sections are 3.92 b, and 84.44 b for the production of ^{244g}Am and ^{244m}Am, respectively.

1. Introduction

Minor actinides are produced by successive neutron capture reactions of nuclear fuel and accumulated in a high burn up reactor. The minor actinides caused severe problems in nuclear waste management. The nuclide ^{243}Am is one of the important minor actinides, because of this alpha emitter has long half-life(7380 year), a large amount of its activity remains in waste a long period. To reduce such radioactivity, nuclear transmutation system by reactor or proton accelerator has been actively investigated(1,2). It is necessary for the system to obtain the accurate neutron cross sections for determining the transmutation rate of the nuclide ^{243}Am. In this study, the effective thermal neutron cross section of $^{243}Am(n,\gamma)^{244}Am$ reaction was measured by the activation method

2. Experiment

For target preparation, 1 μl of highly-purified americium solution containing 3 kBq of ^{243}Am was put into a small quartz tube and evaporated to dryness. The tube was heat-sealed and housed in an aluminum capsule together with a flux-monitor wire of Co/Al-alloy.

The target contained in an alminum capsule shown in **Fig.1** was irradiated during a 10 hour period in the HR-pipe of the JRR-3M reactor at JAERI. The irradiation position is characterized with a thermal neutron flux of 1 x 10^{14} n/cm^2 s.

After the irradiation, the quartz tube was measured by using a HP Ge detector with 1.8

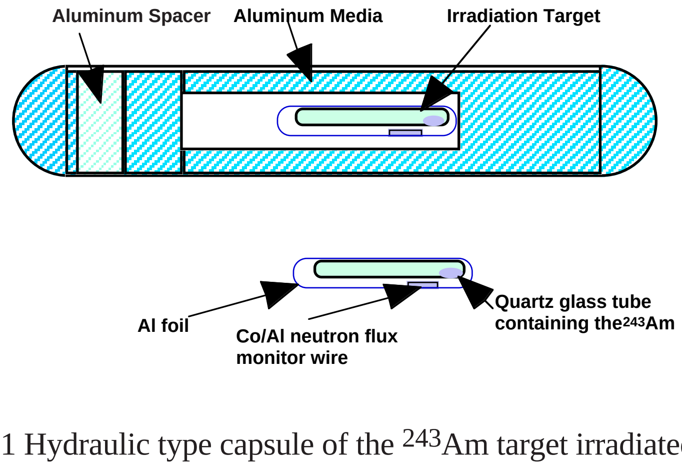


Fig. 1 Hydraulic type capsule of the ^{243}Am target irradiated in JRR-3M.

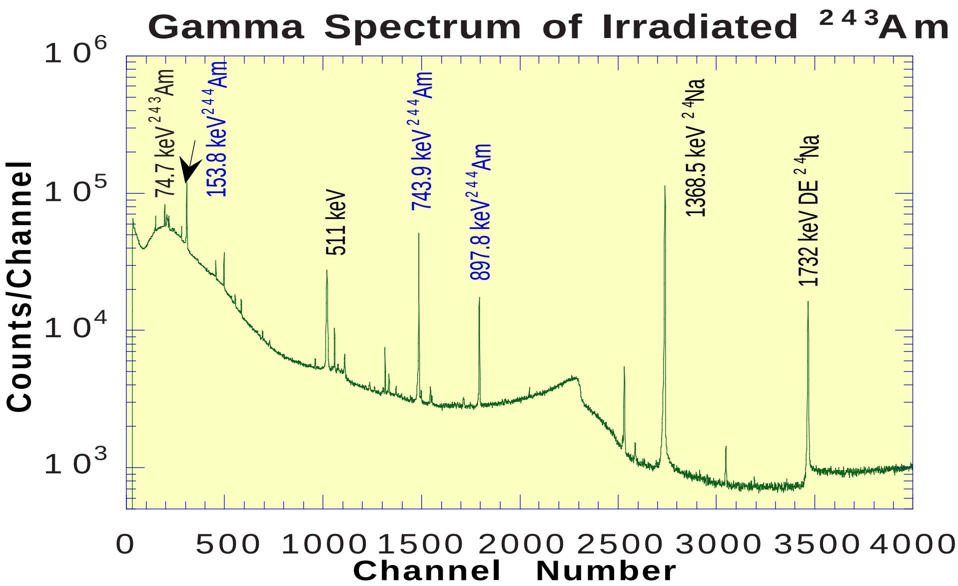


Fig. 2 Gamma spectrum of the irradiated ^{243}Am target.

keV energy resolution at 1.3 MeV. After γ-ray measurements, the target was dissolved in water and a radiometric source for alpha spectroscopy was prepared by dropping the americium solution onto a tantalum disk and evaporating it. The alpha particle spectrum of the source was measured with a silicon surface barrier detector.

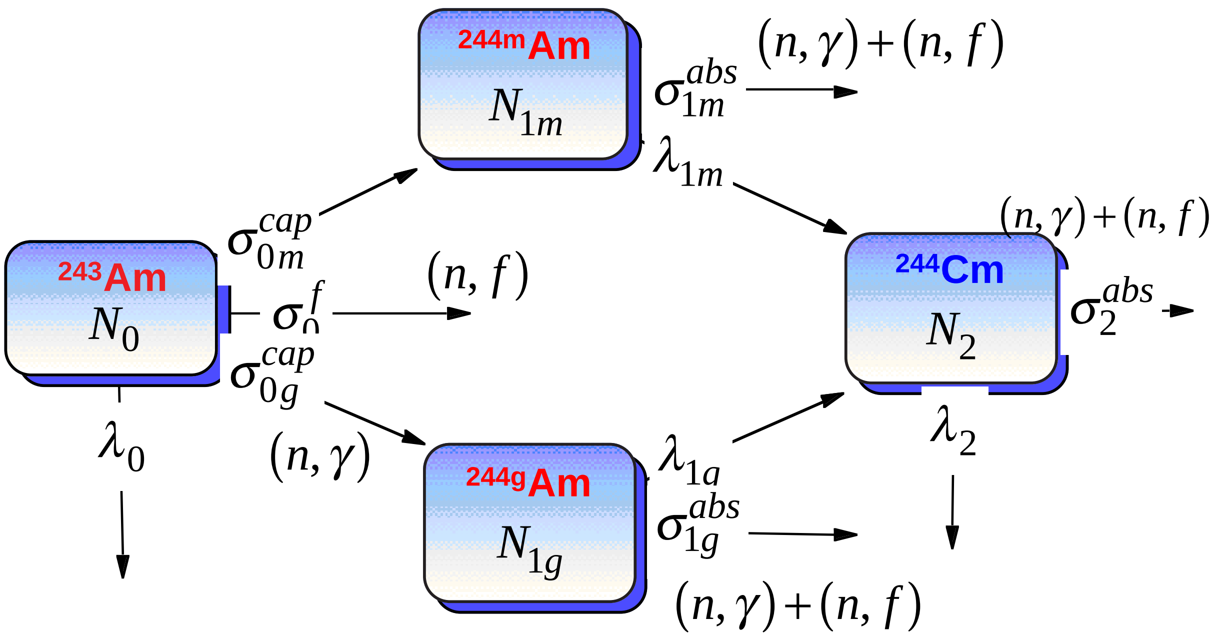


Fig. 3 Decay and growth of Am and Cm isotopes in neutron irradiation of the ^{243}Am target.

3. Results and Discussions

Figure 2 shows a γ-ray spectrum obtained from the irradiated ^{243}Am targets, where the γ-rays of ^{244g}Am can be seen at 154, 744 and 898 keV. The cross section for the ^{243}Am(n,γ)^{244g}Am reaction was deduced from the intensities of ^{244g}Am γ-rays and determined to be 3.92 b.

The ^{244}Cm nuclide is formed by the decays of the nuclides ^{244m}Am and ^{244g}Am that are produced by the neutron capture reaction of ^{243}Am as given in **Fig. 4.** In order to obtain the cross section of the ^{243}Am(n,γ)^{244m}Am, the α-particle spectrum of the irradiated target shown in Fig.4 was analyzed and determined the activity of 5.80 MeV peak of ^{244}Cm. The cross section for the formation of ^{244m}Am was calculated according to the following formulas:

We define that $N_i(t)$, σ_i^{abs} and σ_i^{cap} are the atom number, the absorption cross section and the capture cross section for the nuclide i at irradiation time t, respsctively. The time-derivatives of atom numbers of the actinide nuclides during irradiation are given by

$$\frac{dN_0(t)}{dt} = -N_0(t)\left(\lambda_0 + \phi\sigma_{0t}^{abs}\right) \qquad (1)$$

$$\frac{dN_{1m}(t)}{dt} = N_0(t)\phi\sigma_{0m}^{cap} - N_{1m}(t)\left(\lambda_{1\mathrm{m}} + \phi\sigma_{1m}^{abs}\right) \qquad (2)$$

$$\frac{dN_{1g}(t)}{dt} = N_0(t)\phi\sigma_{0g}^{cap} - N_{1g}(t)\left(\lambda_{1\mathrm{g}} + \phi\sigma_{1g}^{abs}\right) \qquad (3)$$

$$\frac{dN_{2m}(t)}{dt} = \lambda_{1m}N_{1m}(t) - N_{2m}(t)\left(\lambda_2 + \phi\sigma_2^{abs}\right) \qquad (4)$$

$$\frac{dN_{2g}(t)}{dt} = \lambda_{1g}N_{1g}(t) - N_{2g}(t)\left(\lambda_2 + \phi\sigma_2^{abs}\right) \qquad (5)$$

$$N_2(t) = N_{2m}(t) + N_{2g}(t) \qquad (6)$$

where the notation of each nuclide i is given in **Fig.3**. ϕ and λ_i are the netron flux and the decay constant, respectively. The solution of these differential equations are

$$N_0(t) = N_0 e^{-A_0 t} \qquad (7)$$

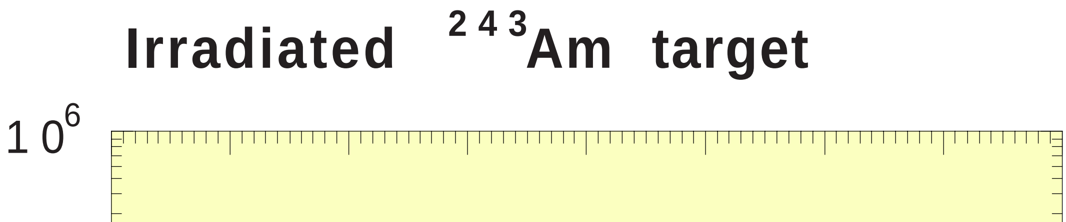
$$N_{1m}(t) = \frac{N_0(0)\phi\sigma_{0m}^{cap}\left(e^{-A_0 t} - e^{-A_{1m} t}\right)}{-A_0 + A_{1m}} \qquad (8)$$

$$N_{2m}(t) = \frac{N_0(0)\phi\lambda_{1m}\sigma_{0m}^{cap}\left[-A_0\left(e^{-A_{1m} t} - e^{-A_2 t}\right) + A_{1m}\left(e^{-A_0 t} - e^{-A_2 t}\right) - A_2\left(e^{-A_0 t} - e^{-A_{1m} t}\right)\right]}{\left(A_0 - A_{1m}\right)\left(-A_0 + A_2\right)\left(-A_{1m} + A_2\right)} \qquad (9)$$

$$N_{2g}(t) = \frac{N_0(0)\phi\lambda_{1g}\sigma_{0g}^{cap}\left[-A_0\left(e^{-A_{1g} t} - e^{-A_2 t}\right) + A_{1g}\left(e^{-A_0 t} - e^{-A_2 t}\right) - A_2\left(e^{-A_0 t} - e^{-A_{1g} t}\right)\right]}{\left(A_0 - A_{1g}\right)\left(-A_0 + A_2\right)\left(-A_{1g} + A_2\right)} \qquad (10)$$

where A_i is

$A_i = r_i + \phi\,\sigma_i^{abs}$.



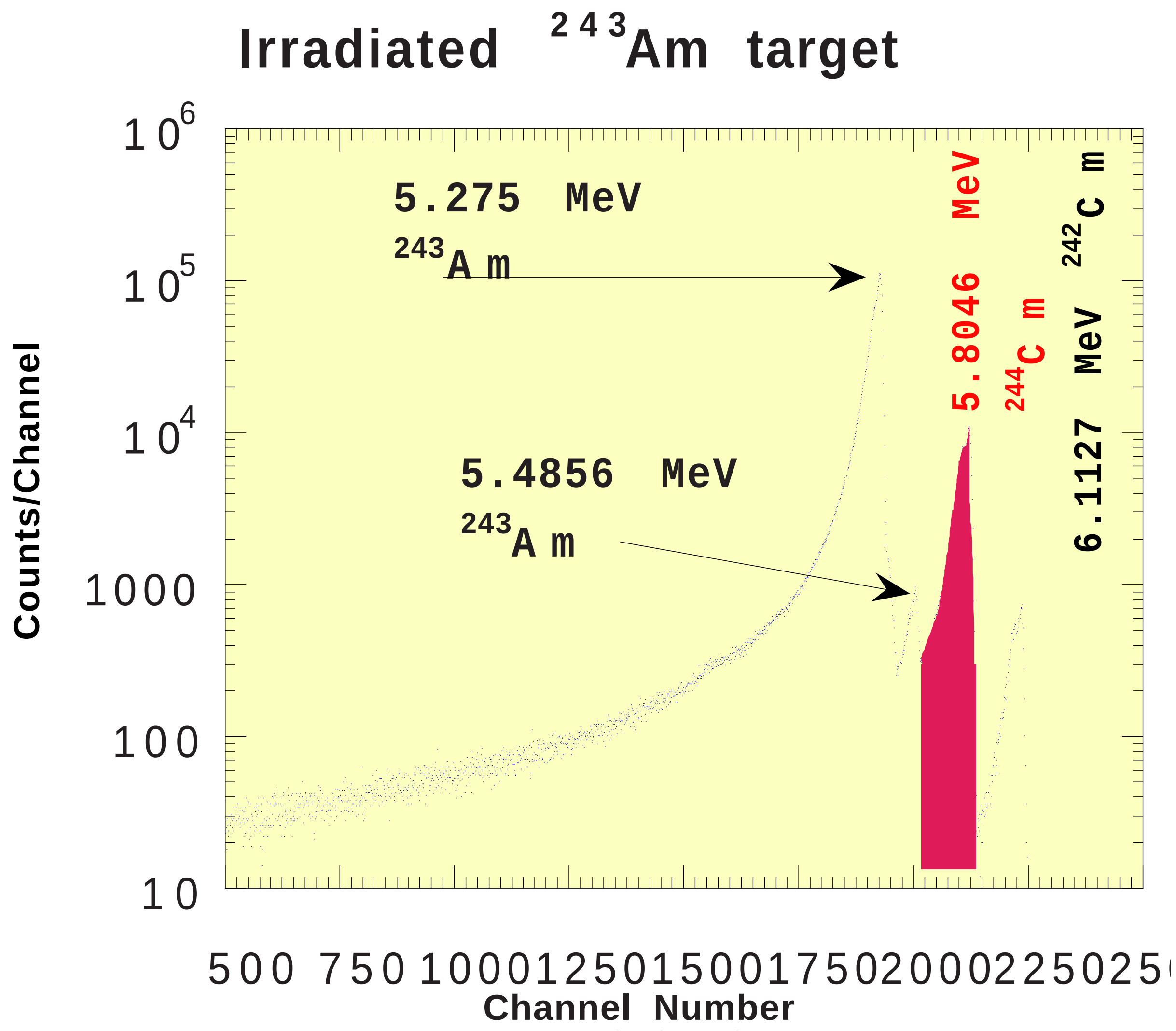


Fig. 4 Alpha spectrum of the irradiated ^{243}Am target

The cross sections of ^{243}Am(n,γ)^{244}Am reaction obtained from the calculated atom number of ^{244m}Am is 84.4 b.

The present value of 3.92 b for ^{243}Am(n,γ)^{244g}Am reaction is good agreement with the previous one of 3.8 ± 0.4 b(4). On the other hand, the cross section of the ^{243}Am(n,γ)^{244m}Am reaction measured in this study (84.4 b) is not consistent with the value of 75.1 ± 1.8 b(4) but agree with that of 83 ± 6 b measured by Garrilov et al.(5) The neutron cross sections for ^{243}Am in JENDEL-3-2 should be evaluated newly on the basis of these results.

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