(α, pxn) REACTIONS ON NATURAL SAMARIUM

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A stack of natural samarium was bombarded with 87 MeV α-particles. Cumulative cross sections for the production of 145Eu, 146Eu, 147Eu, 148Eu, 150Eu, 152Eu and 154Eu have been studied using gamma-ray spectroscopy. The data are compared with the theoretical results provided by equilibrium and pre-equilibrium reaction models, for this purpose we used the code ALICE of Blann.

Introduction

The analysis of excitation functions is an interesting subject, not only for nuclear physics research, but also for practical applications as in radionuclide production and for charged particle activation analysis.

This work, in which the cumulative cross sections for the production of 145Eu, 146Eu, 147Eu, 148Eu, 150Eu, 152Eu and 154Eu induced by α-particles on samarium are reported, is part of a wider and systematic study of nuclear reaction cross section induced by α-particles on different atomic mass nuclei at intermediate energies.1

Excitation functions can generally be regarded as very useful in order to test the reliability of an actual theory of nuclear reaction. Therefore, we have compared the experimental cumulative cross sections with the results of calculations based on the concept of the compound nucleus (CN) in statistical equilibrium as well as on the hybrid model for pre-equilibrium (PE) reactions.

Experimental

Irradiations

Stacks of natural samarium foils were irradiated with α-particles in the internal beam of the Karlsruhe Isochronous Cyclotron.

The projectile energy ranged up to 87 MeV. No absolute beam energy determination was performed in this experiment. However, by reproducing the known excitation func-

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tion of the monitor reactions (see below), we checked the incident beam energy finding excellent agreement.

In each case the target stack was thick enough to stop the 87 MeV internal α-beam. Each stack consisted of several samarium foils (thickness: 18.7 mg/cm², purity: 99.9%, provided by Goodfellows Metals (England)). The uncertainty in the measurement of foil thickness was 2%. This uncertainty affects the energy distribution within the stack. Aluminum and copper foils were interleaved in the samarium stack to degrade the beam energy and to monitor the ion current and maximum incident energy. The ion current was monitored by determination of $^{27}$Al(α, 2n)$^{22}$Na cross sections.2-6

The $^{65}$Cu(α, 2n)$^{67}$Ga and $^{63}$Cu(α, pn)$^{65}$Zn reactions were used to determine the maximum incident energy and to calculate the α-particle flux.7-11

The α-particle flux was $2.47 \times 10^{14} \pm 4.78 \times 10^{12}$ part/s.

For thick stacks, especially in the low energy region, the angular straggling of the beam should be taken into account. Nevertheless, the error due to angular straggling is lower than 1%.

The incident α-particle energy in each foil of the stacks was calculated by means of a computer program based on the range energy relationship given in the literature,12 with an error of about 5%. The uncertainty in the incident particle energy for each foil arises from the energy spread of the incident α-particle beam as well as from the energy loss due to straggling. The error due to energy fluctuations and energy spread, evaluated at 0.3% each,13 is negligible in comparison to the uncertainty in the foil thickness. It is estimated that in the stacks the uncertainty in the energy ranged up to $\pm 1.5$ MeV for the region of 20–70 MeV.

**Counting**

The cumulative cross sections were measured by the activation method. Since the determination of the reaction products was done by non-destructive procedures on target and monitor foils, possible errors introduced by chemical treatment and special source preparation were avoided.

The γ-spectra of each foil were measured off-beam, using a high resolution Ge intrinsic detector connected to a multichannel pulse height analyzer. Gamma-emitter standard sources, provided by Laboratoire de Metrologie des Rayonnements Ionisants (France), with well known values of energy and γ-ray intensities were used for an accurate energy calibration and efficiency detection of the spectrometer. Standard sources were $^{152}$Eu, $^{133}$Ba, $^{22}$Na, $^{60}$Co, $^{57}$Co, $^{54}$Mn and $^{137}$Cs. Most efficiency determinations agreed within an error less than 3%. For other energies, efficiency $\varepsilon(E_γ)$ was calculated by means of a computer program using $\varepsilon(E_γ) = CE^{-n}$, C and n being constants to be determined.