Cross sections of Indium isotopes through (γ, γ') reactions induced by bremsstrahlung with an end point energy of 6 MeV

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Introduction

In worldwide particle accelerator has been used for different applications in the field of basic and applied sciences as well as in medical fields. The advantage of an Electron accelerator is to produce radioactivity and radioisotopes for different applications. When high energy electron interacts with high Z material to generate the bremsstrahlung radiation. The bremsstrahlung radiation of high energy can induce the nuclear reaction with different particles such as neutrons, protons, beta, etc, through the gamma-ray induced nuclear reactions with the elements present in shielding [1].

Photon induced nuclear reactions have become powerful tools in studying the properties and characteristics of nuclei. Most of these can be used for the activation of materials using (γ, γ`) reactions. The threshold of a nuclear reaction depends on the element and reaction products. [16-18] A literature survey shows that the cross-section for the production of isomeric states of a given nuclear reaction increases. The study on bremsstrahlung induced nuclear reactions element present within the shielding materials is important [1, 2]. In present study reports an estimation of flux weighted average cross sections for formation 113In (γ, γ`) 113mIn, and 115In (γ, γ`) 115mIn, reactions induced by the bremsstrahlung radiation produced by 6 MeV electrons. The flux of the bremsstrahlung was generated by the FLUKA code [3]. The theoretical flux weighted average cross sections of 113In (γ, γ`) 113mIn and 115In (γ, γ`) 115mIn, reactions for bremsstrahlung radiation of energies from 0.5 MeV to 6 MeV were calculated by TALYS [4][8]. The cross-sectional data for photon induced reaction is not available in the EXFOR library [5].

Experimental Method

The electron accelerators were used to produce bremsstrahlung radiation and irradiation work was carried out at the 6 MeV Race track microtron Accelerators Laboratory, Department of Physics, Savitribai Phule Pune University, Pune India [6]. The pulsed current of the electron beam is in the range of 1 to 50 mA, with a pulse width of 2.0 ms and a pulse repetition rate of 50 PPS. The average current of the electron beam was in the range of 1 and 5 μA [7]. The electron beam of energy 6 MeV was incident on a lead target, of size 21 mm x 14.5 mm x 0.6 mm thick. The bremsstrahlung radiations emitted in the forward direction were used the inducing nuclear reaction. In the present work, samples of Indium were prepared from the respective foil of natural isotopes.

Table .1: Details of the sample element, weight, isotope, and isotopic abundance [9,10].

Target Material	Weight of the sample (gm)	Isotope of Interest	Isotopic abundance (%)
In	0.6306	In^{115}	95.77
In	0.6306	In^{113}	4.23

The thin metallic foils of known weight of the foil (~99.99% pure) of the element in a polyethylene vial and the details are given in Table 1. The size of each sample was 20 mm x 20 mm and 6 mm thick. In this manner, five samples of same size for each element were prepared.

Theoretical simulated bremsstrahlung spectrum

Bremsstrahlung spectrum for the 6 MeV electrons on the lead sheet sample was simulated using FLUKA code and shown in fig.1[3,11]. It

is observed from fig.1 that the photons of continuous energies over 0.5 to about 6 MeV energies are produced by bombarded 6 MeV electrons on the lead target. The total photon flux estimated by FLUKA code was found to be from range 1.0 × 10^8 photon/cm^2-sec to 1.0 × 10^{10} photon/cm^2-sec.

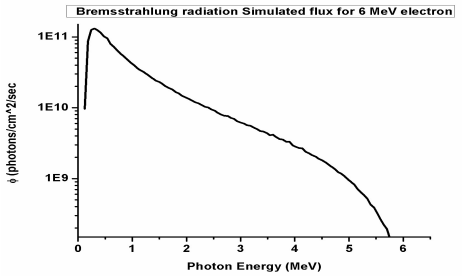

Fig.1: Using FLUKA code, the simulated bremsstrahlung spectrum produced by bombarding 6 MeV electron on thin Lead Target.

Data Analysis

The estimation of the cross section of nuclear reaction, corresponding to the continuous energy spectrum of photon [11].

$$\overline{\sigma} = \frac{A_i \lambda}{\varphi_{integrated} \beta N \varepsilon \left(1 - e^{-\lambda t_1}\right) e^{-\lambda t_2} \left(1 - e^{-\lambda t_3}\right)} \quad (1)$$

The expression (1) was used for the estimation of the experimental average cross section of nuclear reaction at continuous energy spectrum of photons over 0.5 MeV to E_{max} MeV or from threshold to the end point energy of the bremsstrahlung radiations.

Table.2: Give details of the experiment and measurement of radiation

Reaction (γ, γ')	Half life	Gamma energy MeV)	Intensity (%)	Irradiation time (t_1) Sec
^{115}In(γ,γ')^{115m}In	4.05 hr	0.336	46	1815
^{113}In(γ,γ')^{113m}In	99.8 min	0.393	64	1815

Results

Gamma-ray spectrum of ^{113m}In and ^{115m}In from ^{113}In(γ,γ') and ^{115}In(γ, γ') respectively nuclear reaction at bremsstrahlung end point energy 6 MeV shown in fig 2.

The flux weight average cross sections for ^{113}In(γ,γ')^{113m}In and ^{115}In(γ,γ')^{115m}In at 6 MeV is 0.037978±0.002786 mb and 0.02866±0.001307 mb respectively.

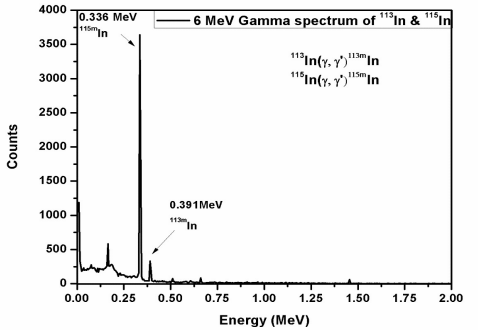

Fig.2: Gamma-ray spectrum of ^{113m}In and ^{115m}In

Conclusion

The experimental flux weighted average cross section data will be the first contributions for EXFOR library in low bremsstrahlung end point energies. The average cross section for formation of metastable reactions with their life time produced in (γ, γ`) reactions was estimated.

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