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Production yields of ^{Nat}Zn(p,x)^{67}Ga reaction in the energy range of 1.6 to 2.5 MeV

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Abstract. Production yield of the ^{67}Ga ($t_{\frac{1}{2}}$=78.3hr.)radionuclide was measured by the ^{Nat}Zn(p,x)^{67}Ga reaction in the energy range from 1.6 to 2.5 MeV. These results are the first reported at energies under 3 MeV. The overall uncertainty of these measurements are around 7%.

1. Introduction

Radionuclide production yield data are important for application of ^{67}Ga in medicine and ion beam analysis [1, 2, 3]. In this paper we present the measurements of yield in the production of ^{67}Ga by the reaction ^{Nat}Zn(p,x)^{67}Ga. In this experiment a thin target of natural zinc was irradiated by protons provided by the Van de Graaff accelerator of the University of Chile. Since ^{67}Ga decays by electron capture in 100%, the subsequent characteristic x-ray emission was detected. The geometrical and efficiency of spectroscopic system were determined in a separate PIXE (Particle Induced X-ray Emission) [4] experiment, following the method of Ref. [5, 6]. In the energy range covered in this experiment no other measurements of yield have been reported according to current literature. However the IAEA has devoloped a set of recommended values [7] for the production of ^{67}Ga and other gamma emitters. This work is aimed to generate new data that may improve the IAEA recommended values.

2. Theory

The activity reached by a sample after an irradiation time τ can be calculated by,

$$A_{\text{EOB}} = n_z \sigma \phi \left(1 - e^{-\lambda\tau}\right), \tag{1}$$

where, σ is the production cross section, ϕ (#part/s) represents the flux of the beam, n_z is the atomic surface density in #atm/cm^2 units, λ decay constant and τ is the irradiation time. If the A_{EOB} is known then the saturation activity expressed in μCi is obtained through,

$$A_{\text{SAT}} = A_{\text{EOB}} \left[3.7 \times 10^4 \left(1 - e^{-\lambda\tau}\right)\right]^{-1}. \tag{2}$$

Thus, the production yield can be obtained from:

$$Y(E) = \frac{A_{\text{SAT}}}{\langle I \rangle}, \tag{3}$$

where $\langle I \rangle$ is the average current.

3. Experimental

The measurement reported in this paper were performed at the KN3750 Van de Graff of the University of Chile. The irradiations covered an energy range from 1.6 to 2.5 MeV with beam intensities in the range of 0.2 to 1.3 μA. Target was irradiate in tipical times of four hours. The energy of the accelerator was calibrated prior to these measurements by means of the 872, 934 and 1370 keV resonances of the ^{19}F(p,$\alpha\gamma$)^{16}O reaction, plus the 1733 keV resonance of ^{12}C(p,p)^{12}C reaction and the 2085 keV resonance of ^{28}Si(p,p)^{28}Si reaction. The corresponding energy relative error found was about 3%.

3.1. Target preparation

The targets were preparated by physical vapour deposition [8, 9] at high vacuum conditions using zinc wires provided by GoodFellow with a 99.95% of purity. Using an evaporation facility implemented recently in the laboratory, the zinc wires were evaporated over microscope glass coated with layer of $BaCl_2$. Subsequently, the whole material was submerged in distilled water and the targets of zinc were removed and fixed to suitable holder. Given the mechanical properties of thin zinc samples a thick aluminium holder was used to remove the heat produced by the proton beam impact. In order to keep the target at low temperature, its holder was connected to a cooling system using liquid nitrogen. Equilibrium temperatures of less than 0 °C were achieved during irradiation tests using a proton beam of 2.33 MeV and a current density of 0.157 μA/mm^2. It is pointed out that the abovementioned temperature is lower than the zinc melting point (420 °C) [10]. Targets were characterized by PIXE and RBS [11] techniques. The experimental setup can be found elsewhere [13]. For RBS analysis the theoretical fitted spectra was calculated using the SIMNRA code [12], The RBS method allowed determination of zinc targets thickness which were 2.5±0.2 μm, approximately. The energy loss corresponding to this thickness is about 5%.

3.2. Data adquisition at EOB

Twenty minutes after EOB the irradiated natural zinc targets were installed inside the PIXE chamber to detect the zinc characteristic x ray spectra using a Canberra Si(Li) criogenic detector having 220 eV FWHM resolution at 5.9 keV. Pulses were analysed with proper electronic circuitry and colected by an ORTEC PC MCA model Trump-8K in long collecting times up to 170 hours.

Table 1. Production yields of ^{67}Ga

E_p [keV]	$\langle I \rangle [\mu A]$	A_{EOB}[Bq]	$A_{SAT}[\mu Ci]$	Y $\left[\frac{\mu Ci}{\mu Ah}\right]$
1678	0.23	3.33×10^{1}	2.83×10^{-2}	$(3.34\pm0.24)\times10^{-2}$
2212	1.31	6.96×10^{2}	7.18×10^{-1}	$(1.83\pm0.09)\times10^{-1}$
2328	0.78	1.86×10^{3}	1.65	$(6.03\pm0.43)\times10^{-1}$
2444	0.54	5.51×10^{3}	3.02	$(9.81\pm0.69)\times10^{-1}$

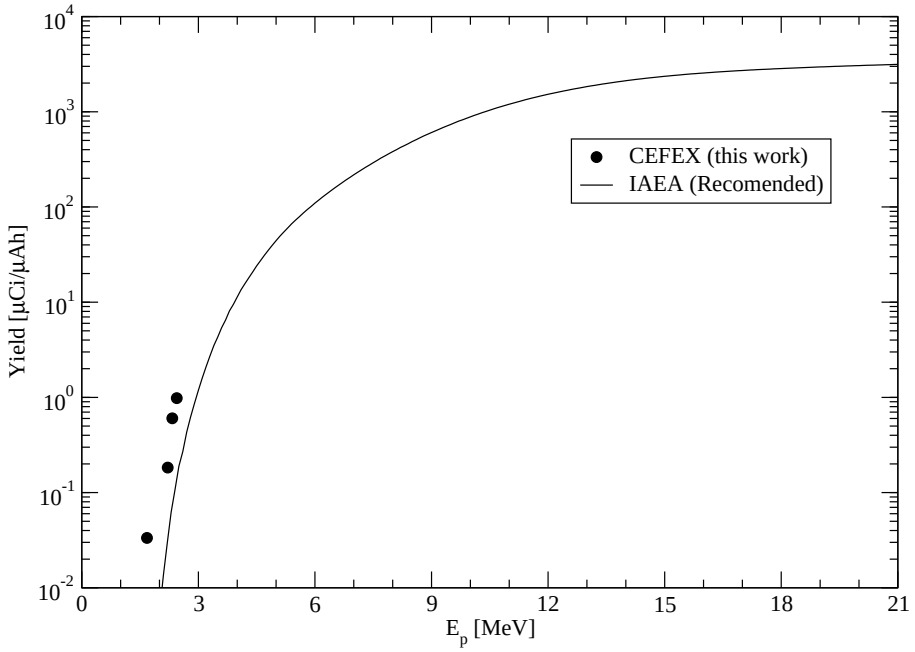

Figure 1. Experimental production yields obtained and comparation with recomendations give by IAEA.

4. Results and Conclusions

With the experimental cross section, areal density of target and particle flux, we obtained the saturation activation and production yield by means of equations (Referencessaturacion) and (Referencesprod). The main results are given in table Referencesresult. The results of the present study are compared in the figure Referencescomparacion with the recommended values of Ref.[7]. As can be seen there is a fair agreement between them, considering that the recommended values by IAEA were calculated for the ^{67}Zn(p,n) reaction using enriched targets of ^{67}Zn. While in this experiment the contribution of the reaction ^{66}Zn(p,γ) is included because a natural zinc targets was used. This may explain the observed difference in both cases.

The method used in these determination has proved to be convenient since required rather short irradiations times, in the order of 4 hours for a half life of 78.3 hours, and low average uncertainties about 7%.

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