Exploring Nucleosynthesis of Zinc Isotopes Through Neutron Activation Technique

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Nucleosynthesis of elements heavier than iron is of major concern in nuclear astrophysics which can be produced through s-process and r-process neutron capture reactions [1]. There are different experimental techniques in literature to extract neutron capture cross-sections. Neutron activation technique is one of them, which shows an extremely high sensitivity and selectivity [2].

In the present work, the interests were to explore neutron activation techniques using the existing neutron source available at the department of physics and astrophysics, University of Delhi and estimate the fast and thermal neutron flux from the source. And also, estimate the neutron capture cross-section of astrophysical capture reactions ^{68}Zn(n,γ)^{69}Zn as a test case which is one of the key nuclei in the s-process nucleosynthesis [3]. An experimental setup for neutron activation techniques has been developed with the existing neutron source (Radium-Beryllium) and paraffin block as a moderator. GM gas detector and HpGe detector was used to record the data with conventional electronic setup.

The experiment was initially performed with the high purity metallic sample of natural Indium (In) of dimensions 2.13 × 1.90 cm^2 with thickness of 0.263 mm were irradiated by the neutrons in the energy range 3-5 MeV [4] from the existing neutron source. After irradiation, the In sample was moved to a set-up consists of HpGe detector for measurement of γ-ray yield from $^{115}In(n,\gamma)$ reaction. The irradiated Indium foil was placed in front of the detector at a distance of 2 cm and 12

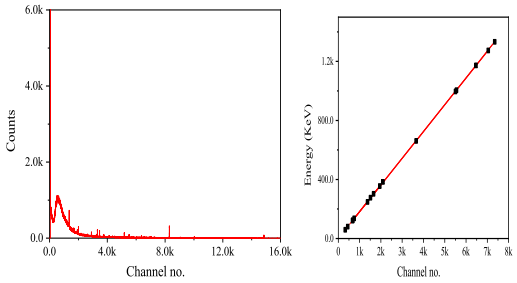

FIG. 1: (a) background spectra and (b) Energy calibration for HpGe detector.

consecutive γ-ray spectra were recorded each of 15 minutes time interval.

The HpGe detector has been calibrated using the known sources Am^{241}, Ba^{133}, Co^{57}, Co^{60} and Cs^{157} first and then the efficiency was calculated. A background (fig.1(a)) was also recorded for several times during the experiment and proper understanding of γ-rays emerging from the neighbouring area was also investigated. The peaks of Europium source were identified and its efficiency values were also normalized with respect to other sources. Finally, the γ-rays emerging from the irradiated In foil was recorded (fig.2(a)) and identified using the RadWare software and the peaks were analysed after proper background subtraction. The intensity of the γ-rays was used to extract the information about the neutron flux of the source [5]. Using the value of first neutron capture cross-section for ^{115}In from NNDC website [4], neutron flux of In was determined, 57×10^4 neutrons cm^{-2}sec^{-1}.

The same experiment for indium foil was also performed with the GM detector. Data was recorded for different activation time (30, 50, 120, 180, 240 and 1440 minutes) to extract the appropriate time of activation to reach an

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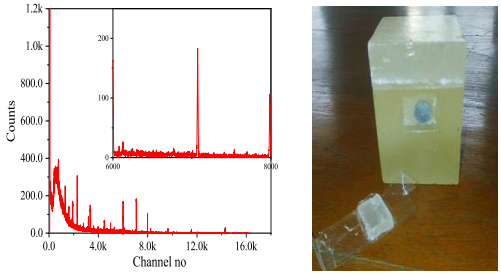

FIG. 2: (a) spectrum of gamma-rays and peak identification and (b) Block of wax with foil placed in it.

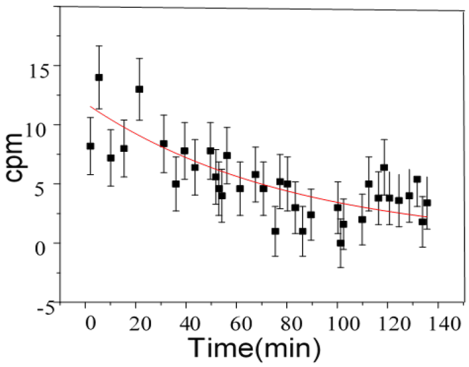

FIG. 3: Curve for the determination of the half-life of natural zinc sample

equilibrium state with parent and daughter nuclei.

The experimental set-up has been modified to slow down the first neutron emits at its thermal energy as the probability of neutron capture is large with thermal neutrons [6]. Thus, a moderator (block of paraffin wax) was designed (fig.2(b)) in such a way that the neutrons get thermalized in energy loss from 6 MeV to thermal energy (0.025 eV). These thermalized neutrons then allowed to be impinged on the high purity metallic sample of Indium (2.13 $\times$ 1.90 cm^2). The counts were measured with respect to the time for neutron flux calculation. Computer program "Origin lab" [6] was used to analyse the data. The half life of In was determined, $T_{1/2} = 54.44 \pm 2.09$ minutes.

A test experiment was performed with the high purity metallic sample of natural Zinc having 18.45% abundance of ^{68}Zn with dimensions 1.02 $\times$ 1.30 cm^2 and thickness of 0.026 cm. The Zn source was activated for 5 days 18 hours 54 minutes 53.94 seconds and the data were recorded for 3 hrs using GM detector. The value of neutron flux calculated for the case of thermal neutrons of Indium was used for estimating the neutron capture cross-section of the zinc foil because half life of ^{116}In is comparable to half life of ^{69}Zn. The thermal activity of the zinc isotopes after thermal neutron capture has been measured using GM counter and the cross-section has been extracted.

The Half-life determined after correction due to branching ratio $T_{1/2} = 38.38 \pm 0.002$ minutes. The preliminary value of thermal neutron cross-section found to be 2.14 $\pm$ 1.72 barns.

As the natural zinc sample contains several isotopes of Zn and hence there were several γ-rays possible from the different isotopes of Zn after neutron induced reaction. Therefore, large error was expected in the experiment. Further analysis is in progress to estimate the errors and also planning to perform the same experiment with the HpGe detector.

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