Measurement of $^{107}$Ag(n, 2n)$^{106}$Ag$^g$ reaction cross-section at 14.8 MeV neutron energy

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Introduction

Cross-section data for the nuclear reactions induced by neutrons of energy 14-15 MeV are needed for fission and fusion reactor technology, experiments in dosimetry, radio-analytical work, activation analysis, accelerator-driven sub critical system (ADSs) and neutron yield monitors [1]. Usually (n, 2n) reaction cross-sections for 14 MeV neutrons are very high and increase with atomic weights of the elements. The (n, γ), (n, n′) and (n, 2n) reaction cross-sections are essential components in the neutron transport calculations [2]. New nuclear energy system requires significant amount of new nuclear data in the extended energy region and improvement of the presently available nuclear data. A literature survey indicates that, neutron-induced reaction cross-sections for $^{107}$Ag(n, 2n)$^{106}$Ag$^g$ reaction are widely studied and reported, and have a lot of discrepancies, particularly around 14 MeV neutrons [3]. As a result, re-measurement of a (n, 2n) reaction cross-sections around 14 MeV region are required.

In the present work, we have measured the cross-section for the formation of $^{106}$Ag$^g$ from the $^{106}$Ag(n, 2n) reaction at $E_n$ = 14.8 MeV using activation and off-line γ-ray spectrometric technique. The theoretical values of cross-sections for this reaction were estimated from reaction threshold to 20 MeV by using the TALYS-1.4 computer code [4]. The cross-section measured in the present work has been compared with the literature values from EXFOR database [3], and with the theoretical values from TALYS-1.4 code [4].

Experimental

The neutron irradiation was carried out at the 14 MeV Neutron Generator facility at the Department of Physics, University of Pune [1]. The 14 MeV neutrons were generated via the $^3$He(d, n)$^4$He reaction ($Q = 17.59$ MeV), in which an 8 Curie activity tritium target was bombarded by deuteron ions energy of ~175 keV at a beam current of ~100 μA. The sample sandwiched between monitor foils was irradiated for 5 min at a 0° angle in forward direction with respect to the incident deuteron beam. The distance between the sample and the tritium target was ~ 50 mm during the irradiation.

The sample was prepared by packing a known weight of the Ag powder along with a piece of an aluminium foil (~99.99% pure) of known weight in a polyethylene vial. The size of sample was ~10 mm × 10 mm and ~2 mm thick. However, the sample for neutron irradiation was mounted under atmospheric conditions. Table 1 gives the details of the nuclear reactions and their related nuclear decay data [5] used in the present work.

Table 1: Measured reactions and decay data.

<table>
<thead>
<tr>
<th>Nuclear reaction</th>
<th>Half life (min)</th>
<th>$E_γ$ (MeV)</th>
<th>Gamma ray Intensity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$^{107}$Ag(n,2n)</td>
<td>23.96</td>
<td>0.511</td>
<td>118</td>
</tr>
<tr>
<td>$^{27}$Al(n,p) $^{27}$Mg</td>
<td>9.46</td>
<td>0.844</td>
<td>71.8</td>
</tr>
</tbody>
</table>

The sample was irradiated with 14.8 MeV neutrons. The induced γ-ray activity of product radio nuclides in both target and reference foil was measured with a coaxial HPGe detector of 38% relative efficiency. The resolution of the detector system had a FWHM of 1.8 keV at 1.33 MeV γ-energy of
The detector was connected to a personal computer based multi-channel analyzer (MCA). The area under each photo peak was determined with a Canberra Genie-2k system. The photo peak efficiency of the HPGe detector at the position of the activity measurements was determined using standard point γ-ray sources such as $^{22}$Na, $^{54}$Mn, $^{60}$Co, $^{133}$Ba, $^{137}$Cs, etc. The neutron flux rate at the sample position during irradiation was determined via the monitor reaction $^{27}$Al($n$, $p$)$^{27}$Mg. The standard value of the $^{27}$Al($n$, $p$)$^{27}$Mg reaction cross-section is 62.9±1.4 mb at neutron energy of 14.81 MeV [3].

The cross-section for each nuclear reaction was obtained using the following relation [6]:

$$
\sigma = \frac{A_{obs} (CL/LT) \lambda}{N \alpha \phi (1-e^{-2\lambda t}) e^{-2\lambda T} (1-e^{-2\lambda CL})}
$$

where $\phi$ is the neutron flux, $N$ is the number of target atoms, $A_{obs}$ is the observed photo peak activity of the respective γ-ray peak, $\lambda$ is the decay constant of the product nucleus, $\epsilon$ is the detection efficiency for the γ-line of interest and ‘a’ is the γ-ray intensity taken from Ref. [5]. ‘t’ is the irradiation time and T is the cooling time, whereas CL and LT are clock time and live time of counting, respectively. In the above equation, the CL/LT term has been used for dead time correction.

**Results and discussion**

![Excitation function of $^{107}$Ag(n, 2n)$^{106}$Ag$^{6+}$ reaction](image)

**Fig. 1**: Excitation function of $^{107}$Ag(n, 2n)$^{106}$Ag$^{6+}$ reaction.

Fig.1 shows the excitation function for the $^{107}$Ag(n, 2n)$^{106}$Ag$^{6+}$ reaction. In the present work, the cross-section for the $^{107}$Ag(n, 2n)$^{106}$Ag$^{6+}$ reaction is reported at 14.8 MeV incident neutron energy, by using the latest nuclear decay data [5]. The present measured and literature cross-sections data are compared with the cross-sections calculated theoretically by using TALYS-1.4 computer code. The threshold value of $^{107}$Ag(n, 2n)$^{106}$Ag$^{6+}$ reaction is 9.6 MeV.

The cross-section reported in the present work at neutron energy of 14.8 MeV is in good agreement with the cross-sections calculated theoretically using TALYS-1.4 code. The measured cross-section data at $E_n = 14.8$ MeV in the present work is also in close agreement with the data of W. Augustyniak et al. [3] and B. Mitra et al. [3] data. The TALYS-1.4 calculation underestimates the measured cross-sections data of D. R. Koehler et al. [3] and L. A. Rayburn et al. [3] in the neutron energy between 12 and 20 MeV.

**Conclusion**

The $^{107}$Ag(n,2n)$^{106}$Ag$^{6+}$ reaction cross-section was measured with the neutron energy of 14.8 MeV by using activation and off-line γ-ray spectrometric technique. The present data is in good agreement with some of the literature data and the theoretical value of TALYS-1.4 calculation.

**Acknowledgements**

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**References**