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 $^3H(d, n)^4He$ 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 0^0 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. Table1 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.

Nuclear reaction	Half life (min)	Eγ (MeV)	Gamma ray Intensity (%)
$^{107}Ag(n,2n)^{106}Ag^g$	23.96	0.511	118
$^{27}Al(n, p)^{27}Mg$	9.46	0.844	71.8

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

^{60}Co source. 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, ^{57}Co, ^{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];

$$\sigma = \frac{A_{obs}\left(CL/LT\right)\lambda}{Na\varepsilon\phi\left(1-e^{-\lambda t}\right)\ e^{-\lambda T}\left(1-e^{-\lambda CL}\right)}$$

where ϕ 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, λ is the decay constant of the product nucleus, ε 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

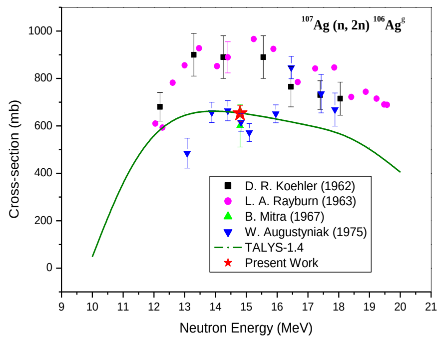

Fig. 1: Excitation function of ^{107}Ag(n, 2n)^{106}Ag^{g} reaction.

Fig.1 shows the excitation function for the ^{107}Ag(n, 2n)^{106}Ag^{g} reaction. In the present work, the cross-section for the ^{107}Ag(n, 2n)^{106}Ag^{g} 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^{g} 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^{g} 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.

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References

[1] V. K. Mulik, B. Lalremruata, H. Naik *et al.*, Proceedings of the DAE Symp. on Nucl. Phys. 55, 360 (2010).

[2] V. K. Mulik, Ph. D thesis, Submitted to University of Pune (May 2014).

[3] EXFOR Nuclear Reaction Data. http://www-nds.iaea.org/exfor

[5] A. J. Koning *et al.*, “TALYS-1.0, A nuclear reaction program,” NRG-1755 ZG Petten, The Netherlands (2008) [http://www.talys.eu].

[5] Nudat-2.6, NNDC BNL database, [http://www.nndc.bn1.gov].

[6] H. Naik *et al.* J. Radioanal Nucl Chem 293, 469-478 (2012).