Statistical error analysis of neutron induced activation cross-sections for Bromine

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Introduction

The neutron activation cross-section at 14.77 MeV neutron energy holds significant importance in fusion reactor technology, particularly in the context of nuclear transmutation calculations and addressing challenges related to induced radioactivity [1]. The cross sections of Bromine isotopes induced by 14 MeV neutrons have been measured by many laboratories but there is significant discrepancy. Bromine can be used as a neutron absorber or a neutron poison in nuclear reactors. Its ability to capture neutrons makes it useful in controlling reactor power and preventing excessive neutron flux, contributing to reactor safety [2]. In the present work we have measured the formation cross-section of ^{79}Br(n,2n)^{78}Br nuclear reactions at 14.77 MeV neutron energy using offline gamma spectroscopy.

Experimental details

A 1-gram sample of LiBr, with natural isotopic abundance and a purity level of 99.9%, in powdered form, was employed for the experiments. To monitor the neutron flux, the samples were enveloped in 0.3 grams of aluminum foil. The neutron irradiation was carried out utilizing the 14 MeV neutron generator situated at the Department of Physics, Savitribai Phule Pune University, Pune. The samples were positioned at an angle of 0 degrees, corresponding to the incident deuterium beam, where the neutron energy amounted to 14.77±0.17 MeV. The irradiation process continued for a duration of 3600 seconds. Following the irradiation process, the samples were moved to the gamma spectrometry counting area. The cooling time for the samples was around 360 seconds and the counting time was 3600 seconds for sample. Gamma ray activity in the samples was quantified using a high-purity germanium (HPGe) detector, which was pre-calibrated and shielded with lead. This HPGe detector has good 1.5 keV energy resolution at 1.33 MeV gamma energy. Data acquisition was performed using an Ortec Manufactured Easy MCA 8k, which was coupled with PC-based Maestro software.

Table 1: Nuclear spectroscopic data for reaction products.

Product Nuclei	Half-life	Eγ (keV)	Iγ (%)
^{78}Br	6.45 ± 0.004 min	613.68	13.6
^{27}Mg	9.458 ± 0.012 min	843.76	71.8

Data Analysis

The cross section was determined using the neutron activation equation:

$$\sigma_s = \sigma_m \frac{F_S C_S M_m a_m A_S \epsilon_m I_{\gamma m} f_{\lambda S}}{F_m C_m M_S a_S A_m \epsilon_S I_{\gamma S} f_{\lambda m}} \qquad (1)$$

the parameters of the sample reaction, denoted as subscript 's', and those of the monitor reaction, indicated as subscript 'm'. The parameters are ε for detector efficiency, C for photo peak counts, a for isotopic abundance, A for atomic mass, M for mass, Iγ for the branching ratio of γ-ray as obtained from Ref. [3], and f for the timing

factor. The timing factor 'f' is determined by the following formula:

$$f_\lambda = \frac{\lambda}{(1-e^{-\lambda t_1})e^{-\lambda t_2}(1-e^{-\lambda t_3})} \quad (2)$$

λ representing the decay constant, $t1$ as the irradiation time, $t2$ for the cooling period, and $t3$ denoting the counting duration. The correction factor (F), resulting from factors like coincidence summing effects (fc) and gamma ray self-attenuation (fa), is expressed as $F = fc \times fa$. Detailed information concerning HPGe detector calibration, detection efficiency curve along with its uncertainty, as well as insights into coincidence summing effects and self-attenuation, can be found in our prior research. The cross-section data is adopted from IRDFF-II library [4]

The uncertainty in the measured cross sections was estimated following the procedure described in literature [5,6]. The error $\Delta\sigma$ in the measured cross section σ can be obtained by quadratic summation of attributes of Eq.1.

Parameter	fractional uncertainty (%)
σ_m	1.45761
C_s	2.129278
C_m	1.436614
$I_{\gamma s}$	0.294118
$I_{\gamma m}$	0.0015
M_s	0.345794
M_m	0.345794
a_s	0.17769
$\eta_{m,S}$	1.37826
$f_{\lambda s}$	0.003321
$f_{\lambda m}$	0.106047
Total	**3.315177**

Results and discussion

The measured cross section of ^{79}Br(n,2n)^{78}Br reaction was found to be 754.71 ± 25.02 mb at 14.77 ± 0.17 MeV neutron energy. The present result is in good agreement with TALYS-1.96 calculations. The present study lists the various sources of uncertainty and the total uncertainty in the present measurement is **3.315**%. The details about uncertainty quantification will be presented during the conference.

The figure 1 shows the current measured cross sections compared with the EXFOR data, TALYS 1.96 calculation and other evaluated data for ^{79}Br(n,2n)^{78}Br reaction.

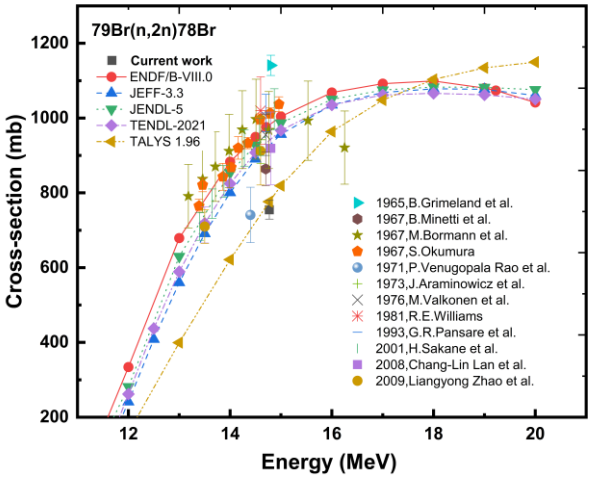

Fig. 1. Comparison of present ^{79}Br(n,2n)^{78}Br reaction cross-section with literature and evaluated data

Conclusion

In this study, we have documented the cross-sections for Bromine activation caused by neutron exposure. Our findings align well with existing literature and theoretical predictions. These results hold significance for enriching the nuclear EXFOR database.

References

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