# Measurement of $^{27}Al(\gamma,2pn)^{24}Na$ Reaction Cross-sections with 55 -, 60 -, 65 - MeV Bremsstrahlung Employing MCNPX Simulation

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## 1. Introduction

Aluminum is used for monitoring the photon flux. The photon flux during the activation can be measured by substituting the $^{27}Al(\gamma,2pn)^{24}Na$ reaction cross-section induced by bremsstrahlung to reactivity equation. Therefore, if this cross-section is more accurate, gamma-ray flux can be measure more accurately.

In this work, the $^{27}Al(\gamma,2pn)^{24}Na$ reaction cross-sections induced by 55 – 65 MeV bremsstrahlung were measured by activation technique at the Pohang Neutron Facility (PNF) which has produced the nuclear data using Time-Of-Flight method and activation technique. In order to get the photon flux, MCNPX was used. These measurement values were compared with the data of Meyer et al (1968) [1].


Figure.1: A photo of PLS-PNF electron Linac tunnel.

## 2. Experimental method

The experiments were carried out using PNF electron linac which can produce the electron beam in the energy range of 50 - 70 MeV [2]. Electron beam parameters for this experiment are listed on Table 1. The electron Energies and current were measured by bending magnet and beam current monitor (BCM), respectively.

Table 1: The electron beam parameters for activation experiment.

| | |
|---|---|
| Energy (MeV) | 55-, 60-, 65- |
| Pulse Beam Current (mA) | 40 |
| Pulse length (μs) | 1.6 |
| Beam radius (mm) | 5 |
| Pulse Repetition Rate (Hz) | 15 |

The samples were irradiated for 30 minutes with bremsstrahlung. It is generated when the electron beam interacts with tungsten target with a size of 10 cm x 10 cm and a thickness of 100 μm. The aluminum samples with a size of 1 cm x 1 cm, a thickness of 100 μm, and purity more than 99.99% were placed at the 12 cm from tungsten target and in the center of beam line. The experimental setup is shown in Figure 2.

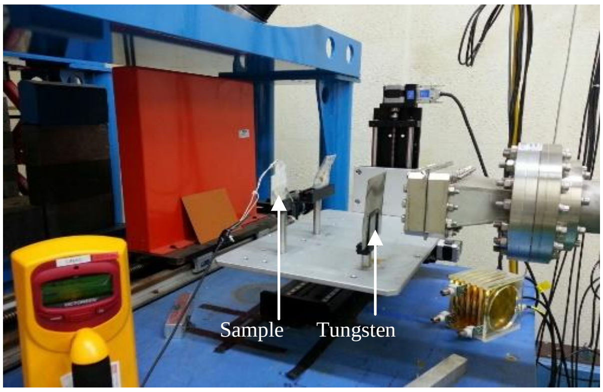


Figure.2: The experimental setup for activation experiment.

After the irradiation, those were cooled for 30 -50 minutes. In order to count the γ-rays from activated samples, HPGe detector with the efficiency of 20% and FWHM of 1.8 keV at 1332.5 keV was used. The dead time was kept less than 5% during the measurements.

## 3. Data analysis and results

The reaction cross-sections ($\sigma_r$) are calculated by using the activation equation as follows [3]:

$$N_{obs}\lambda(CL/LT) = n\sigma_r\varphi I_\gamma\varepsilon(1-e^{-\lambda t})e^{-\lambda T}(1-e^{-\lambda CL}), \quad (1)$$

Where $N_{obs}$ is the numbers of observed photons which are acquired by subtracting the Compton background from their total net areas and n is the number of sample atoms. φ is the integrated photon flux from the reaction threshold to the end-point energy for the photon flux at the photon energy. The t and T are the irradiation and the cooling time, and CL and LT are the real and the live times of counting, respectively. λ is the decay constant of the isotope of interest and ε is the detection efficiency of the γ-rays in the detector system. $I_\gamma$ is the abundance or the branching intensity of the chosen γ-rays of the reaction products. $N_{obs}$ is observed by measuring the 1368.6 keV γ-rays of a $^{24}$Na from the $^{27}$Al(γ,2pn)$^{24}$Na reaction. The half-life and branching intensity of $^{24}$Na is taken from [4, 5] and listed on Table2.

Table 2: The Characteristics of $^{24}$Al from $^{27}$Al(γ,2pn) reaction.

| Nuclei | $^{24}$Na |
|---|---|
| Half-life | 14.997 h |
| Decay mode[%] | β- [100] |
| Eγ(keV) | 1368.626 |
| Iγ(%) | 99.9936 |
| Production route | $^{27}$Al(γ,2pn) |
| Q-value(MeV) | -31.428 |
| Threshold energy(MeV) | 31.447 |

In order to get φ, the conversion factor, which coverts electron current measured by BCM on tungsten target into photon flux incident on the sample, is calculated by MCNPX as shown in Figure 3.

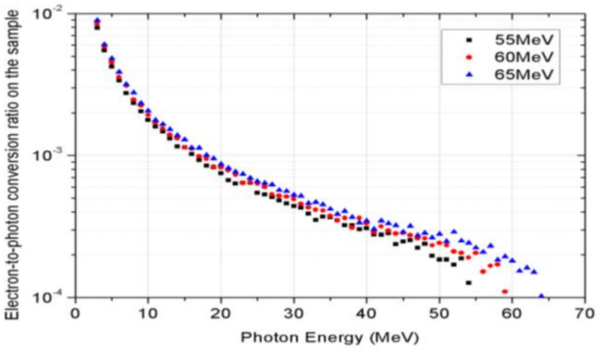


Figure 3: Electron-to-photon conversion ratio calculated by MCNPX as function of photon Energy.

The cross-sections of $^{27}$Al(γ,2pn)$^{24}$Na reaction with 55 -, 60 -, 65 MeV bremsstrahlung are 0.022 ± 0.00226 -, 0.0977 ± 0.01 -, and 0.162 ± 0.0168 mb, respectively. The present data is compared with data of Meyer et al. the uncertainties are determined by considering both random and systematic errors [3]. The random error is due to $N_{obs}$ and is estimated 0.8-2.2%. On the other hand, the uncertainties of the electron current (~10%), detection efficiency (~4%), MCNPX simulation (~1%), half-life of aluminum sample (~2%), and γ-ray abundance (~2%) are factors of systematic errors.

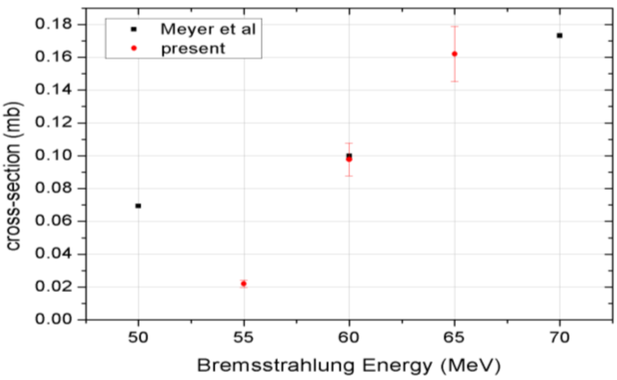


Figure 4: The .cross-section of $^{27}$Al(γ,2pn)$^{24}$Na reaction induced by bremsstrahlung comparing with data of Meyer et al.

## 4. Conclusion and future plan

The cross-sections of $^{27}$Al(γ,2pn)$^{24}$Na reaction with 55 -, 60 -, 65 - MeV bremsstrahlung were measured. In case of 60 -, 65 MeV, the results are in good agreement with the data published by Meyer et al (1968) [1]. However, it is necessary to confirm the measurement result at 55 MeV case which shows significant decrease compared with neighbor values.

In this paper, we confirmed it is possible to measure the reaction cross-sections by combining the MCNPX simulation result together with gamma radiation from the activation of the sample. In order to improve the uncertainty of the results, Flash ADC will be employed to record the beam current during the activation. The electron flux incident on the tungsten can be estimated accurately by this beam-current-recording system. The collimator will be installed at the end-point of the beam port to reduce the electron beam size and to make the circular electron beam. The CCD camera and frame grabber will be used to accurately measure the electron beam energy distribution.

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