Measurement of Isomeric Ratio for 198-Pt(g,n)197-Pt with End-point Bremsstrahlung Energies of 55-, 60- and 65- MeV at Pohang Neutron Facility

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1. Introduction

Nuclei with an isomeric state and an unstable ground state are used for study on the structure and properties of the compound nuclei and a mechanism of the nuclear reaction. The relative population of these two states is known as the isomeric yield ratio of nuclei. The isomeric yield ratios are very important because they are useful for studying the angular momentum effects in nuclear reactions and the spin dependence of the nuclear level density[1].

The isomeric yield ratio measured with photon has some essential advantages in studying nuclear structure and reaction mechanism. V. A. Zheltonozhsky already measured isomeric ratio of ^{198}Pt(γ,n)^{197}Pt at the bremsstrahlung ranging from 9.5 MeV to 17.0 MeV[2]. We measured the isomeric yield ratios for the photonuclear reactions of ^{198}Pt(γ,n)^{197}Pt by the activation method and the off-line γ-ray spectrometric technique with the end-point bremsstrahlung energies of 55-, 60-, and 65-MeV using the electron linac at Pohang Neutron Facility.

2. Experimental setup of electron beam and theory

2.1 Electron Linac of Pohang Neutron Facility

The experiment was done at the electron linac of the Pohang Neutron Facility operated from 50- to 65-MeV beam energy, 1.6 μs beam pulse, and 15-30 Hz repetition rate.

Figure. 1: Electron Linac of Pohang Neutron Facility

The accelerator parameters of the linac including the RF and beam optics systems are listed in Table 1.

Table. 1: The parameters of the PNF electron linac components at the experiment

Beam	
Energy (MeV)	55-, 60-, 65-
Pulse Beam Current (mA)	60
Pulse length (μs)	1.6
Pulse Repetition Rate (Hz)	15
Accelerating Structure (2 sets)	
Mode (π)	2/3
Frequency (MHz)	2,856
Type	*Constant grad*
Length (m)	3

2.2 Activation Sample and Experimental Setup

High-purity (>99.99 %) activation foils in rectangular shape with a size of 1.25 cm x 1.25 cm and a thickness of 100 μm were exposed to uncollimated bremsstrahlung beam from the electron linac. The bremsstrahlung beam was produced when a pulsed electron hits a thin W target with a size of 10 cm x 10 cm and a thickness of 100 μm. The Pt sample was placed in air at 12 cm from the W target and it was positioned at zero degree with the direction of the electron beam as shown in Fig. 2.

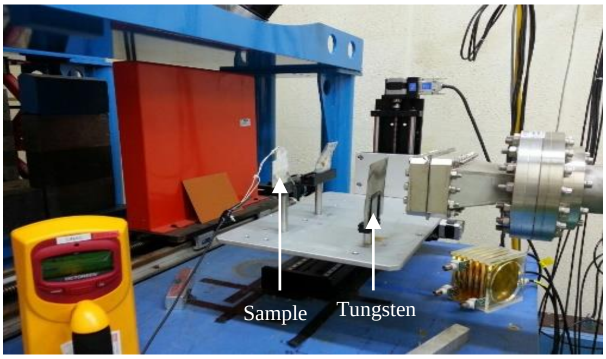

Figure. 2: The experimental setup for the platinum irradiation

2.3 Computation of isomeric yield ratios

The isomeric yield ratio represents the ratio of cross sections between metastable state and ground state as follows:

$$\boldsymbol{IR} = \frac{\sigma_m}{\sigma_g} = \left[\frac{\lambda_g F_m}{\lambda_m F_g} \times \left(C_F \frac{S_g}{S_m} \times \frac{I_{\gamma m}}{I_{\gamma g}} - \frac{P\lambda_g}{\lambda_g - \lambda_m}\right) + \frac{P\lambda_m}{\lambda_g - \lambda_m}\right]^{-1}, \quad (1)$$

where $\boldsymbol{\lambda_i}$ is decay constant of nuclei, $\boldsymbol{C_F}$ is correction factor during detection dead time, $\boldsymbol{S_i}$ is photo-peak area of gamma spectrum, $\boldsymbol{I_{\gamma i}}$ is branching ration of gamma-ray, $\boldsymbol{P}$ is isomeric transition ratio and $\boldsymbol{F_i}$ is followings :

$$\boldsymbol{F_i} = \frac{(1-e^{-\lambda_i \tau}) \times (1-e^{-\lambda_i t_r}) \times e^{-\lambda_i t_w} \times (1-e^{-\lambda_i t_c})}{1-e^{-\lambda_i T}} e^{-\lambda_i (T-\tau)}, \quad (2)$$

where characters 'i' represent the nuclear level as ground and metastable state. $\boldsymbol{\tau}$ is beam pulse width, $\boldsymbol{t_r}$ is irradiation time, $\boldsymbol{t_w}$ is waiting time from finishing the irradiation to counting, $\boldsymbol{t_c}$ is detector counting time and T is cycle period.

The natural platinum was transferred to a metastable state ^{197m}Pt and ground state ^{197g}Pt by the bremsstrahlung irradiation. The ground state ^{197g}Pt emits the 191.4keV, 268.8 keV, and 77.4 keV by a β-decay. In this experiment, we measured γ-ray of 191.4 keV and 346.5 keV with the HPGe-detector.

3. Simulations for the experiments

The electron beam emit the bremsstrahlung photon passing through the tungsten target. So, the bremsstrahlung photon yield depends on electron beam energy and the thickness of tungsten target. Figure.4 shows the yield results of bremsstrahlung photon as electron beam energy.

The electron beam energy distribution was Gaussian-distribution ±1 MeV from peak energy which was measured by the energy analyzing bending magnet.

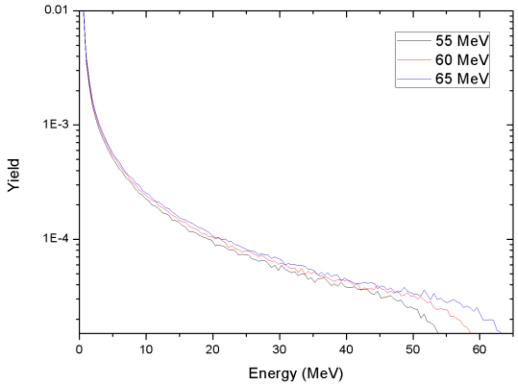

Figure. 4: The bremsstrahlung yield distribution by MCNPX

4. Experimental results

In this experiment, the isomeric ratio was calculated using Eq. (1), where the result of measurement. Figure.5 represents the isomeric ratio values of present work. For the comparison, V. A. Zheltonozhsky's measurement of the isomeric ratio for ^{198}Pt(γ,n)^{197}Pt reaction at low energies bremsstrahlung from 9.5 MeV to 17.0 MeV[2] are plotted together.

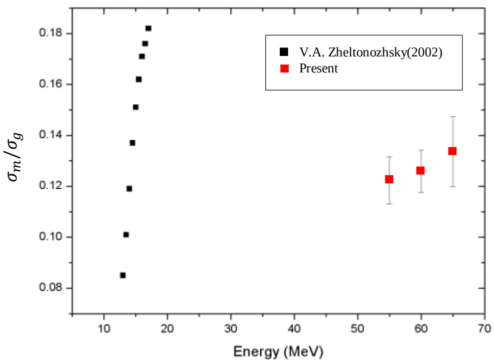

Figure. 5: The flux distribution of bremsstrahlung photon

The numerical values of isomeric ratios measured in this experiments are 0.12241±0.009202, 0.12579±0.00824 and 0.13363±0.013751 at 55, 60 and 65 MeV, respectably. The error bars includes uncertainties from beam energy spread, photo peak counting, absolute efficiency, sample weight, half-life, and branching ratio of each photo peak.

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