I. 6. Monochromatic p-Li Neutron Field Estimation for The Measurement of Activation Cross Sections

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Introduction

Activation cross sections for high energy neutrons are requested by neutron dosimetry, radiation safety and material damage studies, and those in the energy region from 10 to 50 MeV are especially demanded by the construction project of the Energy Selective Neutron Irradiation Test Facility (ESNIT). We have measured many activation cross sections by using a p-Be semi-monoenergetic neutron field\(^1\) at the SF cyclotron of the Institute for Nuclear Study, University of Tokyo. The excitation functions obtained in this field cannot avoid an ambiguity coming from the unfolding method. To avoid this ambiguity, we made a p-\(^7\)Li target system also at the SF cyclotron facility. The peak neutrons from the p-\(^7\)Li reaction are much clearly monoenergetic compared with the p-Be neutrons, and the unfolding method will not be necessary in obtaining cross sections.

The peak neutrons produced by the \(^7\)Li(p,n)\(^7\)Be reactions correspond to the ground state and the 1st excited state (0.43 MeV) of \(^7\)Be. Since the energy loss in the used \(^7\)Li target (99.98% enriched, 2-mm thick) is 1.2 MeV for 40 MeV protons, the energy difference of 0.43 MeV cannot be distinguished. The 2nd (4.6 MeV) and higher excited states of \(^7\)Be decay with the proton and alpha emission, and they do not remain as \(^7\)Be. From this reason, the neutron emission of the peak energy at 0 degree, \(\Phi_0\), can be estimated by the following formula.\(^2\)

\[
\Phi_0 = \frac{N_{Be} d\sigma(\theta=0)}{d\Omega} \int \frac{d\sigma}{d\Omega} d\Omega
\]

\[\int_{4\pi}
\]

\[(1)\]
where $N_{\text{Be}}$ is the number of $^7\text{Be}$ produced in the target, which can be easily measured by a gamma-ray spectrometry, and $ds/d\Omega$ is the angular distribution of the peak neutrons, that is, the double differential cross section in relative value.

Low energy neutrons are also produced by the $p-^7\text{Li}$ reactions. If the neutron spectrum of wide energy region at 0 degree and the angular distribution of the peak neutron emission are measured, the $p-^7\text{Li}$ neutron field for activation experiment can be absolutely determined from an amount of produced $^7\text{Be}$.

**Experiment**

The measurement of $p-^7\text{Li}$ neutron characteristics was performed at CYRIC. A 127-mm-diam. by 127-mm-long NE-213 scintillation counter was placed at about 10 m away from the target. Two targets were used, that is, one consisted of a 2-mm-thick $^7\text{Li}$ target and a small carbon beam stopper, and the other consisted of just a carbon beam stopper.

Measurements at 0 degree were performed twice for two targets with and without the $^7\text{Li}$ disk for the proton beam energies of 20, 25, 30, 35 and 40 MeV. The angular distribution of the peak neutrons was measured with moving a beam swinger from 0 to 125 degree at 20, 30 and 40 MeV energies.

The list data taken by a CAMAC data taking system were analyzed with a two-dimensional n-$\gamma$ discrimination and a calculated response function set. Response functions to several tens MeV neutrons include many ambiguities at a low pulse height region coming from reaction models and light output data of heavy ions. Several pulse height discrimination levels were set during analysis, and the effect of these ambiguities were minimized.

**Results**

Measured neutron spectra at 0 degree are shown in Fig. 1 for the proton energy of 40 MeV. A strong peak corresponding to the ground and 1st excited states of $^7\text{Be}$ is seen at 38 MeV in the spectrum measured with the $^7\text{Li}$ target, and a small peak at 33 MeV is also seen, which corresponds to the 2nd excited state. The Q value of the $^{12}\text{C}(p,n)$ reaction is -18.1 MeV, and the spectrum measured without the $^7\text{Li}$ target sharply decreases at 22 MeV. The neutrons above 22 MeV come from the $^{13}\text{C}(p,n)$ reaction and the room scattered component which almost uniformly distributes in a time spectrum.

The measured angular distributions of the peak neutrons are shown in Fig. 2. The differential cross sections were normalized to unity at 0 degree. We measured at proton energies of 20, 30 and 40 MeV, and the data of Schery and Orihara are also shown. Our data have a depression at 5 degree, and this attributes a shielding effect of a vacuum duct placed after the target box. The forwardness of the distribution becomes stronger with the increase of the beam energy. The thickness of our used $^7\text{Li}$ target is much thicker than that of
Schery and Orihara, and our curves of 30 and 40 MeV proton energies lie closer to 24.8 and 35 MeV proton energy ones.

References


Fig. 1 Neutron spectra at 0 degree from two targets with and without 2-mm thick $^7$Li disk bombarded by 40 MeV protons.
Fig. 2 Angular distribution of peak neutrons from $p^7\text{Li}$ reaction.