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Preliminary Shielding Analysis for the Neutron Science Facility in RAON

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1. Introduction

Fast neutron cross sections data are needed for the development of innovative nuclear power plants and the design of an Accelerator-Driven System. The Neutron Science Facility (NSF) in Korea heavy-ion accelerator, which is called RAON, will be constructed to attract the requirements [1]. To generate neutrons, the ^{nat}Li(p,n) and ^{9}Be(d,n) reactions using a proton energy of 70 MeV and deuteron energy of 53 MeV are used, respectively. However, the number of neutrons produced from these reactions is limited. It is necessary to produce the neutron source to perform an efficient and fast calculation for a Monte Carlo simulation.

In view of this, we produced a neutron source in the ^{nat}Li(p,n) reaction using a MCNPX code [2]. The produced neutron sources were evaluated in terms of the angular distribution and shielding thickness of concrete for a target room with various neutron energy groups. In addition, it was compared with neutrons produced from an actual reaction to know whether or not suitable for a shielding design analysis.

2. Methods and Results

2.1 Determination of target

Natural lithium (Li) of a cylindrical form was selected as the target for the productions of neutrons using a 70 MeV proton beam. From the simulation by a MCNPX code, a Li target with a thickness of 10 cm was determined by considering the proton energy deposition and the number of neutrons for the thickness, as shown in Fig. 1. The radius of the Li target was also determined to be 3 cm based on the maximum neutron production for the conservative shielding analysis.

2.2 Calculation

The number of neutrons in the ^{nat}Li(p,n) reaction was produced at about 0.123 for one proton incident on the target. To obtain the reliable results for the shielding, it is required to make the neutron source terms with various energy groups and several angles. The neutron source was considered to have a distribution per 10 solid angles along with the energy groups of 100 and 1000. In addition, the energy groups were divided from 10^{-9} to 100 MeV as linear- and log-scales. The angular distribution for a neutron source was calculated using a cell tally (F4) where the cell having a thickness of 1 cm is located at a 100 cm distance from a target. It is specified in the void space in the cell. The calculated neutron spectra for the energy of 100 groups in a linear and a log scale are shown in Fig. 2. For the 1000 energy groups in each scale, was also found a similar tendency as the 100 energy groups. The obtained neutron spectra are re-determined as the number of neutrons for every solid angle used to make a neutron source.

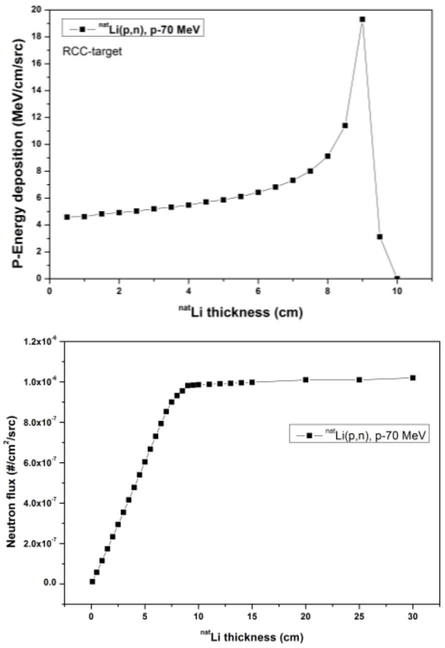

Fig. 1. Proton energy deposition and neutron flux for Li target thickness.

It can be seen from Fig. 3 that the Li target in NSF will be placed on a point area to the x- and y-axes, and is located at 1.5 and 3.5 m from the bottom and the ceiling, respectively. In this study, the shielding material was considered as concrete. In the calculation, the thickness of the concrete wall was set at 10 cm intervals from 10 to 600 cm in all directions, as shown in Fig. 3. By considering the number of track to each cell, the well-known splitting method was used to determine the accurate concrete thickness for the shielding. The importance of each cell was carried out repeatedly until the amount of its change is less than 10%. Based on this method, the shielding calculations using the produced neutron sources and an actual reaction were focused on the dose limits for workers and the public. In addition, concrete thickness by the produced neutron sources was compared with those by the ^{nat}Li(p,n) reaction in order to find the neutron source term similar to the actual reaction.

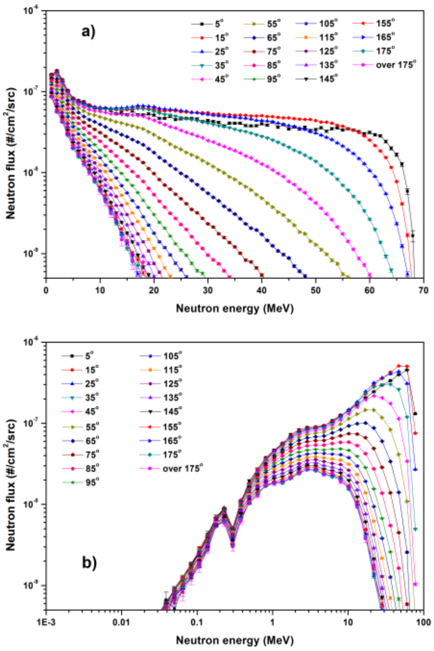

Fig. 2. Neutron spectra for the angle in the energy group of 100: a) linear energy scale, b) log energy scale.

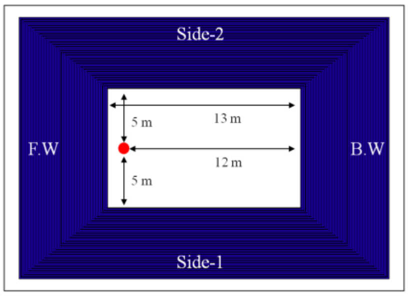

Fig. 3. Schematic of the Li target position and concrete structures.

2.3 Results

The dose rate attenuation according to the thickness of concrete walls at all directions was determined using the MCNPX code. As shown in Fig. 4, the concrete thickness to shield the radiation based on the workers limit (10 μSv/hr) in the ^{nat}Li(p,n) reaction with a proton energy of 70 MeV were needed to 300, 160, 170, 170 and 180 cm for front, back, side-1, side-2 and ceiling, respectively. However, some results show the high uncertainties and an unexpected tendency. This may be due to the low neutron production in a nuclear reaction.

On the other hand, the concrete thickness for the shielding from the produced neutron sources at all directions is listed in Table I. The results show the reliable values in comparison with an actual reaction. The calculated results using the linear energy groups were found to be a good agreement with an actual reaction. However, in case of the produced neutron sources for the log energy groups, the thickness of the concrete for the shielding is thicker than those of the actual reactions.

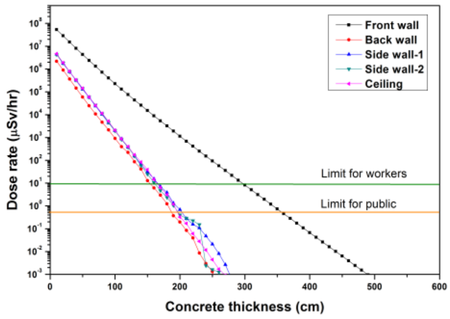

Fig. 4. Dose rate attenuation for the concrete thickness in the ^{nat}Li(p,n) reaction with a proton energy of 70 MeV.

Table I: Concrete thickness (cm) required to shield the radiation in the produced neutron sources. (workers limit: 10 μSv/hr, public limit: 0.5 μSv/hr)

	Linear - 100		Linear -1000	
	Workers	Public	Workers	Public
F.W	300	360	300	360
B.W	160	190	160	190
Side-1	170	210	170	210
Side-2	170	210	170	210
Ceiling	180	220	170	220

	Log-100		Log-1000	
	Workers	Public	Workers	Public
F.W	320	380	320	380
B.W	160	190	160	190
Side-1	170	220	170	220
Side-2	170	220	170	220
Ceiling	180	220	180	220

3. Conclusions

We produced the neutron sources for various energy groups in the ^{nat}Li(p,n) reaction being considered at NSF. The size of the Li target and the neutron sources were determined using a MCNPX code. We found that the produced neutron sources are useful to apply the shielding analysis in comparison with an actual reaction. Of the produced neutron sources, linear energy groups show the best performance in the shielding analysis. For a more detailed analysis of the shielding, it is necessary to perform a calculation for the angular distribution of 5 degrees.

REFERENCES

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[2] J.S. Hendricks *et al.*, MCNPX extensions 2.5.0, LA-UR-05-2675, 2005.