NUCLEAR DATA FOR BASIC AND APPLIED SCIENCE

Volume 1

Proceedings of the International Conference
Santa Fe, New Mexico 13-17 May 1985

Editors
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A Special Issue of Radiation Effects

GORDON AND BREACH SCIENCE PUBLISHERS

ANALYSIS OF A 14-MeV NEUTRON SCATTERING EXPERIMENT WITH Li_2O

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Abstract Analysis was performed for neutron leakage spectrum measurements with Li_2O assemblies to test the adequacy of ENDF/B-V data. Significant differences between calculated and measured results are observed.

INTRODUCTION

Li_2O is an important candidate for a tritium breeding material in fusion reactors. A series of experiments(1-3) has been performed in the FNS facility at JAERI. In this work, the leakage spectrum measurements with Li_2O slabs are analyzed to examine the adequacy of fast neutron cross sections in the ENDF/B-V file.

ANALYSIS OF EXPERIMENT

Monte Carlo code MCNP(4) was employed for the analysis with data from the ENDF/B-V (RMCCSlaa)(4). Figure 1 shows the experimental setup. The Li_2O assembly was constructed as a small cylinder of 31.4 cm radius. The thickness was varied as 5.06, 20.24, or 40.48 cm. The Li_2O blocks were sealed in a 0.2 mm thick stainless steel can. The atomic density of the center region of the cylinder was slightly different from that of the remainder. In modeling the geometry, the Li_2O cylinder was divided into two regions: the inside of a coaxial cylinder of 18-cm radius (Region I) and the outside (Region II) of it, and different atomic compositions were assigned to these regions.

A point isotropic neutron source was assumed in the calculation at 20 cm distance from the assembly. The measured spectrum of source neutrons at 0° was assumed at every emitting angle. Point detectors were placed at a distance of 7 m from the rear surface of the assembly at 0^0, 12.2^0, 24.9^0, 41.8^0, and 66.8^0.

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Calculated spectra for the 5-cm thick case are compared with experimental results in Fig. 2. The calculated results agree well in general with the experiment. A peak corresponding to the second level of ^{7}Li (n, n' T) reactions is well predicted. This peak was not apparent when the ENDF/B-IV cross-section data were used(1). A better agreement is obtained between the calculation and the experiment with the ENDF/B-V data as compared to results(1) obtained by BERMUDA with the ENDF/B-IV data.

Neutron spectra of both the calculation and the experiment were integrated over energy to obtain fluxes over energy ranges 0.48-5 MeV, 5-10 MeV, 10-20 MeV and whole energy range 0.45-20 MeV. These fluxes will be referred to as low-, intermediate-, high-energy and total flux, respectively. The estimated systematic errors in the experimental values are -2% to 5%(1). The statistical errors in the partial fluxes are highest at 66.8° in the 40.48 cm case for both the calculation and the experiment. However, the values are less than several % even in the worst case. The obtained partial fluxes are compared in Table I as ratios of calculated values to experimental ones. The following are pointed out from this comparison: 1) The high-energy flux at 66.8° is greatly underestimated in the thin (5 cm) assembly case; 2) The high-energy flux is generally over-predicted by ENDF/B-V except at 66.8°, and the degree of overestimation increases as the Li_2O thickness is increased; 3) The intermediate-energy flux tends to be underpredicted by ENDF/B-V for the thinner slab; 4) The low-energy flux is well-predicted except at large angles of the thick-slab case.

Regarding observations (1) and (2) above for the 5.04 cm case, differential elastic scattering cross sections of Li or O at ~15.2 MeV (source neutron peak energy) seem to be underestimated at 66.8° and overestimated at 24.9°. The neutron emission cross section for secondary neutrons in the 5-10 MeV range for Li, O or Fe may be underestimated from observation (3) above. The reason for the overestimation of the high-energy flux at 0° is as follows: Blocks were made of Li_2O bricks packed in stainless steel cans. A slight gap between the can and the Li_2O bricks was homogenized in the process of atomic density estimation, so the heterogeniety in the detailed geometry was not considered in the calculation.

Consider the extreme case, where the whole void is gathered at the end of the Li_2O block. Neutrons at 0° pass the Li_2O blocks at the center part, and do not pass the void region. As the total volume of the void was estimated to be 5~6% of the block, this case gives 5~6% higher density than the homogenized density along the 0° neutron path.

The Li_2O density in Region I (center region) of the assembly was increased by 5% and the calculations were repeated for the 40 cm thick cases. Table II shows results of the ratio (C/E values) for these cases. The calculated value for the high-energy flux at 0° agrees this time well with the experimental value. However,

TABLE I Ratios of Calculated to Experimental Fluxes

Thickness (cm)	Angle	Low Energy (0.4<En<5MeV)	Intermediate (5<En<10MeV)	High Energy (10MeV<En)	Total (0.48MeV<En)
	0°	0.970	1.14	1.097	1.083
	12.2°	N	N	N	N
5.06	24.9°	1.114	0.856	1.176	1.155
	41.8°	1.073	0.848	1.054	1.054
	66.8°	1.056	0.792	0.689	0.873
	0°	1.068	1.059	1.187	1.175
	12.2°	1.086	0.994	1.185	1.147
20.24	24.9°	1.051	0.976	1.203	1.121
	41.8°	1.178	1.056	1.069	1.119
	66.8°	1.082	1.098	0.890	1.047
	0°	1.018	1.053	1.298	1.236
	12.2°	0.980	1.025	1.228	1.126
40.48	24.9°	1.120	1.097	1.326	1.196
	41.8°	1.273	1.180	1.388	1.285
	66.8°	1.335	1.404	1.311	1.343

TABLE II Ratios of Calculated To Experimental Flux Calculated with 5% Increase In Li_2O Density in Region I with 40.48 cm Thickness

Angle	Low Energy (0.48<En<5Mev)	Intermediate (5<En<10MeV)	High Energy (10MeV<En)	Total (0.48MeV<En)
0°	0.979	0.950	1.068	1.046
12.2°	0.950	0.949	1.102	1.029
24.9°	1.086	0.965	1.229	1.123
41.8°	1.227	1.006	1.342	1.216
66.8°	1.218	1.226	1.426	1.244

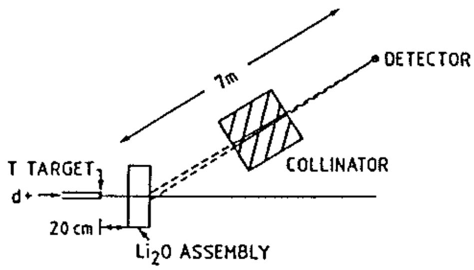

FIGURE 1 Experimental setup.

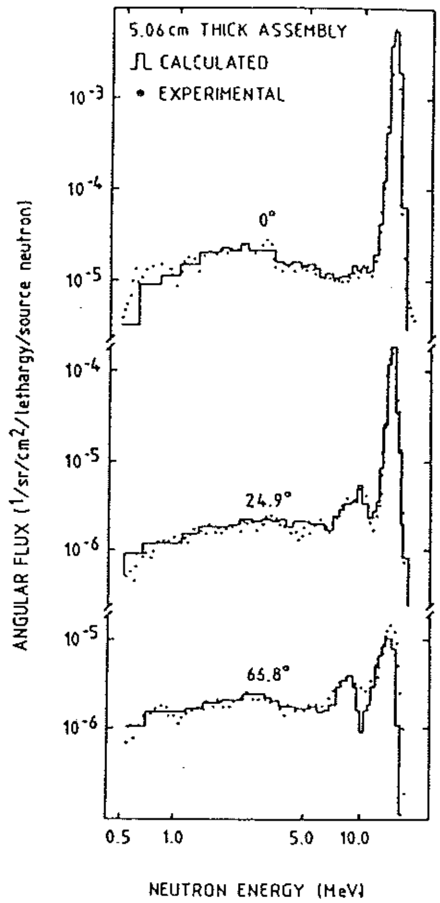

FIGURE 2 Comparison of angular flux for 5.06 cm assembly between the calculation and the experiment.

the overestimation by the calculation is seen as the angle is increased. So cross sections of total and elastic scattering of Li, O, and Fe around 15.2 MeV which is source neutron energy should be reevaluated in more detail.

Low energy fluxes are underestimated by the calculation with increased density. These fluxes were well predicted in the original calculations. The low-energy neutrons made multiple collisions in the assembly and the homogeneous model simulated the physical process well. At large angles, the lower-energy fluxes were overestimated in both models, although statistical errors were large in both the experimental and calculational results.

CONCLUSIONS

1) Differential elastic cross sections of Li or O in the energy range of 10 to 15.2 MeV appear to be overestimated at 24.9° and underestimated at 66.8°; 2) The total and elastic scattering cross sections of Li, O, and Fe lead to discrepancies between experimental and calculational results in the range of 10 to 15.2 MeV; 3) Neutron emission cross section at ~15 MeV for Li, O, or Fe seem to be underestimated for 5-10 MeV secondary neutrons; 4) Neutron emission cross section at ~15 MeV was considered to be adequate for secondary neutrons in the 0.48-5 MeV range.

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