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Measurement of Resonance Parameters of Dy Isotopes

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Introduction

The electron linear accelerator facility at the Rensselaer Polytechnic Institute (RPI) was used to explore neutron interactions with Dysprosium in the energy region from 10 eV to 1 keV. The neutron capture experiments were performed by the TOF method. The neutron capture measurements were made at 25 m with a 16-segment sodium iodide multiplicity detector. High pure isotopic samples of ^{161}Dy, ^{162}Dy, ^{163}Dy, ^{164}Dy as well as one natural dysprosium sample with thickness of 0.508 mm were prepared for this measurement. Resonance parameters were extracted from the data using the multilevel R-matrix Bayesian code SAMMY [1].

Dysprosium can play an important role in a reactor system in many different capacities. Dysprosium has a very large thermal neutron absorption cross section. The ability to absorb neutrons readily without swelling or contracting over time as well as its high melting point make dysprosium alloyed with special stainless steels attractive for control in nuclear reactor [2]. Dysprosium is also a fission product from the thermal fission of ^{235}U, ^{233}U, and ^{239}Pu. The accumulation of fission products in the reactor core increase with the burn-up of the nuclear fuel and the poison effect become more important. In addition, dysprosium is difficult to separate from minor actinides such as americium, curium, and other higher fission products. If spent nuclear fuel is to be reprocessed and it is desired to burn up the minor actinide burning core [3]. Therefore, it is necessary to understand dysprosium's effect on the neutron population over all energy regions in a nuclear reactor system, whether it is in the capacity of a fission product poison or a neutron absorbing control rod.

Experimental Procedure

This is the first experiment to use high-purity Dy isotopes of ^{161}Dy, ^{162}Dy, ^{163}Dy, ^{164}Dy. Table 1 lists the isotopic content of the dysprosium samples used in this experiment.

The electron beam impinges on a water-cooled tantalum target where electrons interact and produce bremsstrahlung, which generates photoneutrons. The resulting neutrons are moderated and collimatede as they travel through a long evacuated flight tube to the sample and detector. The neutron energy for a detected event is determined using the TOF method.

Table 1. Isotopic composition of Dysprosium isotopes.

Properties/Sample		^{161}Dy	^{162}Dy	^{163}Dy	^{164}Dy
Isotopic Composition [%]	^{156}Dy	0.02	<0.01	<0.01	<0.01
	^{158}Dy	0.02	<0.01	<0.01	<0.02
	^{160}Dy	0.35	0.08	0.03	0.02
	^{161}Dy	95.66	1.24	0.36	0.15
	^{162}Dy	2.53	96.17	1.23	0.35
	^{163}Dy	0.9	1.79	96.86	1.03
	^{164}Dy	0.56	0.72	1.52	98.45

When an incident neutron is captured in the sample, a compound nucleus in an excited state is formed.

The compound nucleus then de-excites to the ground state with the subsequent emission of gamma rays. The detection of these gamma rays allows one to measure the fraction of neutrons of a given energy that are captured if the incident neutron flux is known. This fraction of captures is known as the capture yield. Thus, for a uniform thickness sample and a parallel neutron beam incident perpendicularly to this sample, the capture yield is defined as the number of detected capture gamma rays divided by the product of the detector efficiency times the number of incident neutrons. Mathematically speaking, the capture yield is defined as the number of captures per incident neutron. In time of flight measurements the capture yield, Y_i in TOF channel i was calculated by

$$Y_i = \frac{C_i - B_i}{K\phi_{smi}}$$

where

C_i=dead-time-corrected and monitor-normalized count rate of the sample measurement

B_i=dead-time-corrected and monitor-normalized background counting rate

K=detector efficiency and flux normalization factor

Φ_{smi}=smoothed, background-substacted, and monitor-normalized neutron flux shape

The incident neutron flux shape was determined with the use of a thick $^{10}B_4C$ sample that is mounted on the sample changer. The measured flux shape is usually normalized directly to a saturated capture resonance. This capture yield and its associated statistical uncertainty provided input to the SAMMY data analysis code that extracted the neutron resonance parameters. A more detailed description of the present measurement and analysis is given in REF[4].

Results and Conclusions

The Resonance parameters, neutron width Γ_n, radiation width Γ_γ, and resonance energy E_0, were extracted from the capture using the SAMMY version 8 multilevel R-matrix Bayesian code. ^{161}Dy was observed new resonance as shown in Figure 1.

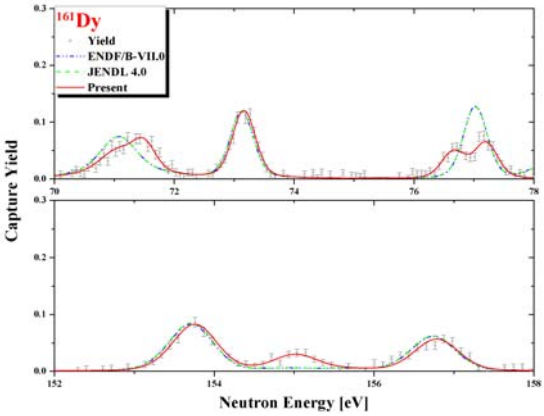

Figure 1. Comparison with evaluated value of ENDF/B-VII.0 and JENDL 4.0 for ^{161}Dy

In this study, new resonance and discarded are determined by the standard of 2σ of uncertainty. As the consequence, there are 19 new resonances introduced that were not include in ENDF/B-VII.0. Twenty resonances present in ENDF/B-VII.0 have been discarded because whether or not they exist is beyond the present measurement. The present results are compared with other evaluated values of ENDF/B-VII.0 and JENDL 4.0. The details of resonance parameters for Dy isotopes are obtained and will be reported in the paper.

References

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