MEASUREMENT AND ANALYSIS OF $^{165}Ho(n,\gamma)^{166m}Ho$ REACTION CROSS SECTION

Xia Yijun, Wang Chunhao, Long Xianguan, Yang Jingfu
He Fuging, Yang Zhihua, Peng Xiufeng ,Liu Mantian
Luo Xiaobing

Institute of Nuclear Science and Technology,Sichuan University
Chengdu 610064 P. R. China

Lu Hanlin

Institute of Atomic Energy, P. O. Box 275(3), Beijing 102413
P, R. China

Abstract: The cross sections of the $^{165}Ho(n,r)^{166m}Ho$ reaction have been studied in the energy range from 29 to 1100 kev , using Au as a standard. The upper limits of the reaction cross section in the energy region were estimated. The capture cross section of Ho to 1200 y isomeric state has been determined at 676 ± 114 kev neutron energy. The result is 2.92 ± 0.60 mb.

Introduction

Along with the development of fusion research, more capture cross section data for the generation of long-lived radionuclides are needed for estimation of radioactive waste and selection of materials leading to low-level activities. $^{165}Ho(n,r)^{166m}Ho$ reaction is one of the important reactions. Up to now, There were no reliable cross sections for the $^{165}Ho(n,\gamma)^{166m}Ho$ reaction reported in literature.

Experiment

The detailed description of experimental measurement is given in Ref(1). Therefore, only a brief description is given here.

The proton beam collimated to a diameter of < 8 mm was incident on the target producing neutron. The target cooling was achieved by compressed air. The sample of Ho was prepared by pressing 99.9% pure Ho_2O_3 powder into a thin disk. The diameter of Ho and Au samples were 20 mm. The purity of the Au samples were 99.999%.

Two irradiation runs were carried out. In the first run,the samples were sandwiched between two glod foils with thickness o.1mm and were wrapped in 0.3 mm thickness cadmium foils. A group of samples mounted on the surface of Al ring (88 mm daimeter) centered at the neutron source were irradiated simultaneously at 0° , 30° , 60° , 90° , and 120° degrees with respect to the incident proton beam. Therefore neutrons between 29 and 230 KeV were produced by the $^7Li(p,n)^7Be$ reaction, and 215 and 1100 KeV by the $T(p,n)^3He$ reaction. The proton beam currents were generally 8 to 14 μA and the durations of irradiation was 70 hours.

In the second run, the cross section of the $^{165}Ho(n,\gamma)^{166m}Ho$ reaction has been measured at 676±114keV neutron energy. Neutrons were produced via the $T(p,n)^3He$ reaction. The protom beam currents were 16 to 20 uA and the durations of irradiation was 110 hours. Ho sample was placed at 0 degree with respect to the incident proton beam. The distance betbetween the samples and target was 10 mm. In this way, the total neutron flux on the sample was 18 times larger than the first run experiment.

In order to detect the induced γ-ray activity of the samples under study and the corresponding gold reference foils , an ORTEC GEM-30195

HPGe detector was used for the γ-ray spectrum mersurement in a low background environment. The energy resolution (FWHM) of the detector was 2.1 kev at the 1332 keV ^{60}Co peak. The photopeak efficiency of the detector system was calibrated with the ^{241}Am, ^{109}Cd, ^{57}Co, ^{54}Mn, ^{65}Zn, ^{152}Eu, ^{60}Co and ^{22}Na standard sources at different source to detector distance. The coincidence sum effect at short source to detector distance was considered.

Analysis and results

The decay parameters of the reaction product in ^{165}Ho(n,γ) ^{166m}Ho reaction are given in Table 1.

Table 1. Decay parameters of the produced nuclide in the ^{165}Ho(n,γ) ^{166m} Ho reaction

products	Half-life (years)	-ray energy (kev)	absolute intensity (%)
^{166m}Ho	1200	184.4	73.9
		711.7	59.3
		810.3	63.3

The cross section for ^{165}Ho(n,γ) ^{166m}Ho reaction can be determined by measurimg the characteristic γ-rays of 184.4, 711.7 and 810.3 keV in the decay of ^{166m}Ho. Because there are two peaks with energies of 185 (^{235}U, ^{226}Ra) and 810.8 (^{58}Co contamination) keV respectively in the background spectrum. In the calculation of the cross sections, γ-rays with energy 711.7 keV was chosen as the characteristic γ-ray for reaction product ^{166m}Ho.

In the first run, the samples were cooled for 2 months after irradiation, then to analyse each samples. The distance of sample to surface of the detector was 1.2mm. The counting time of -ray spectrum was about 153 to 216 hours. however, the net counts corresponding the 711.7kev peak were less than the lower detecting limit of the detector system which presented by the following formula:

$$L_D = 2K\sqrt{2N_b}$$

Where N_b is the background counts correponding the 711.7kev peak, and K is the confidence factor. Thus, we did not detect any characteristic γ-ray of product nuclide ^{166m}Ho in these samples.

Nevertheless,from the lower detect limit we can determing the lower limit of the nuclide ^{166m}Ho activity for the samples by the following formula:

$$A_D = \frac{2.83\,k\sqrt{N_b}}{a \cdot \varepsilon \cdot T_b}$$

Where a is absolute intensity of γ-ray, ε is the detecting efficiency of the γ-ray and T_b is the caunting time. From the lower limit of the nuclide activity for the samples, the upper limits of the reaction cross section were estimated as 68 to 150 mb in the energy range from 29 to 1100 kev.

In the second run, the sample was cooled for 57 days, and the counting time of the γ- ray spectrum was 432 hours. The net counts corresponding 711.7 kev peak was 705. Then the cross section rate relative to that of gold at the neutron energy of 676kev can be determined. The cross section has been converted to absolute cross section using the gold cross section recommended by ENDF/B-VI. The result is 2.92 ± 0.60 mb.

The main uncertainties came from the statistics of the activity measurement, the glod cross section, the decay scheme, absolute activity determination, various correction etc. The main error are listed in Table 2.

Table 2. Error sources

Error source	Error (%)
Au standard cross section	3.5
Error in decay scheme	4.0
HPGe detector efficiency	< 1.5
Statistics	19.6
Irradiation history	< 2.0
Correction for neutron scattering and attenuation	1.0
background	1.0
Gamma self absorption in the sample	1.0
Weighing error of sample	0.5
Total error	20.5

Note that our result is only preliminary . The further analysis will be considered .

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REFERENCES

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