Energy Calibration for Neutron Capture Resonance of Natural Sm by Using 46-MeV Electron Linear Accelerator

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Abstract

Energy calibration is important to identify accurate neutron capture resonance energy in the neutron TOF (Time-of-Flight) experiment. In present study, the accurate neutron capture resonance energies of natural Sm were measuredby using a 46-MeV electron linear accelerator (linac) at the Research Reactor Institute, Kyoto University(KURRI). The BGO spectrometer were adopted for measurement the prompt capture gamma-ray of the sample. To obtain energy calibration curve, resonance energy of a gold sample used as standard resonance energy Mughabghab's data (From neutron resonance parameters data). Previous data (by Mughabghab) of natural Sm sample have been compared with the present result.

Key word Energy calibration, Neutron, Capture, Resonance, Natural Sm, TOF

I. INTRODUCTION

Today, data of neutron capture resonance parameters gives very useful information to a field of study of Nuclear Physics, Nuclear Engineering, Nucleosynthesis and Radiation Therapy. This kind of data information is important accurate data base. Specially, Radiation Therapy and Nuclear Physics are great important accurate data base of neutron capture resonance energy forto understand nuclear structure and to research boron neutron capture therapy. Energy calibration is important to identify accurate neutron capture resonance energy in the neutron TOF (Time-of-Flight) experiment. In present study used Sm is one of the most important standard energy calibration samples with gold. Therefore, to find accurate neutron capture resonance of Sm for energy calibration is mean to get accurate data of the neutron resonance parameters. In present study, the neutron capture resonance energies of natural Sm were identified by using a 46-MeV electron linear accelerator (linac) at the Research Reactor Institute, Kyoto University (KURRI). The BGO spectrometer were adopted for measurement the prompt capture gamma-ray of the sample To obtain energy calibration curve, resonance energy of a gold sample used as standard resonance energy Mughabghab's data (Neutron resonance parameters data). Previous data (by Mughabghab) of natural Sm sample have been compared with the present result.

II. EXPERIMENTS

A. Experimental Arrangement

Energy calibration for neutron capture resonance of natural Sm measurement has been carriedout by the neutron TOF methed using the 46-MeV electron linac and the total energy absorption detector assembled with BGO scintillatiors at the KURRI. The experimental arrangement is shown in Fig. 1. The flight path used in the experiment is in the direction of 135 deg to the KURRI linac electron beam. Bursts of pulsed neutrons from the water-cooled tantalum target strike the capture

sample placed at a distance of 12.7±0.02m from the neutron source. The neutron and gamma-ray collimation system is mainly composed of B4C, Pd, Li2CO3, and borated paraffin and is tapered from~12 ㎝ in diameter at the entrance of the flight tube to 1.8×1.8㎝ at the BGO assembly. The capture sample, which was put on the sample holder, was placed at the center of the BGO assembly. A Pd shadow shielding bar (5×5㎝ and 10㎝ long) was put in front of the photoneutron target to reduce the intense gamma-flash produced at the Ta target. The neutron beam intensity during the experiment was monitored with a BF3 proportional counter inserted into the TOF neutron beam, as seen in Fig. 1.

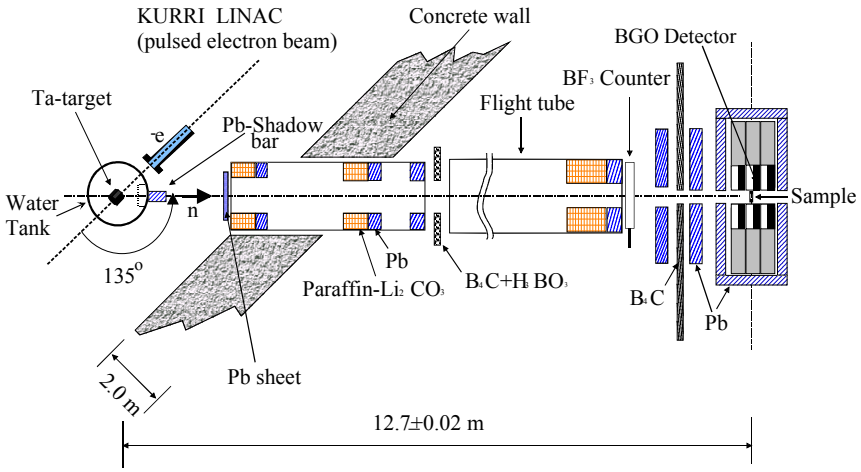

Figure 1. Experimental arrangement for the energy calibration for neutron capture resonance of natural Sm

B. Pulsed Neutron Source

A photoneutron target of Ta has been adopted as an intense pulsed neutron source for the neutron TOF measurement. The water-cooled Ta target is made of 12 sheets of Ta plate, 5㎝ in diameter, and the effective thickness is ~3㎝. The housing of the target is made of titanium. This target was set at the center of a water tank, 30㎝ in diameter and 35㎝ high and having a wall thickness of 0.8㎝, as a fast neutron moderator. The water tank has a re-entrant hole of 10㎝ in depth and 10㎝ in diameter to extract low-energy neutron.

C. BGO Assembly for Prompt Capture Gamma-Ray Measurement

Prompt capture gamma rays were detected with the BGO assembly as a total energy absorption detector in the TOF measurement. The BGO assembly consists of 12 scintillation bricks 5×5×7.5㎤ each. The total volume of the BGO scintillators is 2.25l. Each BGO scintillator was arranged to have the utmost absorption of the capture gamma ray form the sample. A through-hole of 1.8×1.8㎠ in section is made in the BGO assembly. A collimated neutron beamis led through the hole to the captures sample, which is placed at the center of the BGO assembly. Moreover, the BGO assembly is installed in a house made of lead bricks of 5 to 10㎝ thickness to shield against background radiation from the surroundings. The inside of the though hole was covered with 6LiF tiles 3㎜ thickness to absorb neutrons scattered by the capture sample.

D. Sample

Two kinds of samples were used in the energy calibration for neutron capture resonance of natural Sm.

The parameters of the samples are summarized in table 1.

Table 1. Physical of the Samples used in the Energy calibration

Sample	Sm	197Au
Physical form	Metal plate	Metal plate
Purity (%)	99.8	99.99
Isotopic composition (%)		
144Sm	3.1	Natural Gold (100%)
148Sm	11.3	
147Sm	15.0	
149Sm	13.8	
150Sm	7.4	
152Sm	26.7	
154Sm	22.7	
Thickness of sample		
(㎜)	0.5	0.1
(atom/kb)	1.807	5.931
(g/㎠)	0.385	1.941
Size (㎝)	1.8×1.8	1.8×1.8

E. Data analysis

a) Time of flight Method

The kinetic energy of a neutron is given by, in non relativistic case,

$$E_n = \frac{1}{2} M_n v^2 = \frac{1}{2} M_n \left(\frac{L}{T} \right)^2 \quad (1)$$

Where Mn is the rest mass of neutron, L the flight path, and T the TOF of the neutron. A more practical equation is given as

$$E_n[MeV] = \left(\frac{72.29 \times L}{T[n\sec]} \right)^2 \quad (2)$$

b) Energy calibration

From equation (2), the relation between the neutron TOF and the neutron capture resonance E (eV) is given as

$$a \times channel + b = \frac{72.29 \times L}{\sqrt{E}} \quad (3)$$

Where L (m) is the flight path (12.7 m) and E is the incident neutron energy (eV).

As standard resonance energy Mughabghab's data (Neutron resonance parameters data) used gold sampleemployed to obtain energy calibration curve. Used gold's standard resonance energy Mughabghab's data and measured channel data are shown in table. 2.

Table 2. Measured channel data and Gold's standard resonance energy Mughabghab data

Measured channel data (channel)	Gold' s standard resonance energy Mughabghab data (eV)
3296.70±0.6	4.906
939.82±0.2	60.25
823.70±0.1	78.43
705.40±0.1566	107.0
592.95±0.1131	151.2
570.90±0.4330	164.9
470.67±0.0857	240.3
450.67±0.1346	261.9
426.50±0.1155	293.1

IV. CONCLUSION

Using 46-MeV electronlinear accelerator, linac TOF methed and a total energy absorption detector composed of BGO scintillators. The energy calibration for neutron capture resonance of natural Sm has been measured. Natural Sm sample's resonance parameters energy region are 0.872 eV to 348.7 eV in present study. The current measurement of the energy calibration for neutron capture resonance of natural Sm was compared standard resonance energy Mughabghab data of Sm. Compared data were show in Table. 3. Standard resonance energy Mughabghab data and measured current data seem to be in good agreement within the experimental error. However, some standard resonance energy Mughabghab data have difference of resonance parameter values from the measured current data. Specially, in the standard resonance energy Mughabghab data region of 6.428 eV, 17.14 eV, 26.08 eV, 44.26 eV, 185.2 eV and 261.1 eV have high difference. To obtainmore precise the standard resonance energy, standard resonance energy

Mughabghab data must be changedthe measured current data. No data energy regions will be calculated using.

Table 3. The comparison list of neutron capture resonances of Natural Sm for Previous and present results

Natural Sm Sample	Resonance parametersa(eV)	Measurement datab(eV)	Error(eV)	Ratio [a/b](%)
149Sm	0.872	0.875	0.000	0.997
147Sm	3.397	3.406	0.001	0.997
149Sm	4.94	4.945	0.001	0.999
149Sm	6.428	6.459	0.005	0.995
149Sm	12	12.022	0.005	0.998
149Sm	14.89	14.916	0.004	0.998
149Sm	17.14	17.186	0.007	0.997
147Sm	18.36	18.380	0.005	0.999
150Sm	20.64	20.621	0.005	1.001
149Sm	25.26	25.305	0.007	0.998
Natural Sm Sample	Resonance parametersa (eV)	Measurement datab(eV)	Error (eV)	Ratio [a/b](%)
149Sm	26.08	26.163	0.011	0.997
147Sm	27.16	27.199	0.011	0.998
147Sm	29.76	29.830	0.008	0.998
149Sm	30.82	30.870	0.010	0.998
147Sm	32.14	32.163	0.007	0.999
149Sm	33.94	33.983	0.014	0.999
147Sm	39.7	39.776	0.018	0.998
149Sm	41.33	41.337	0.013	1.000
149Sm	44.26	44.378	0.011	0.997
149Sm	45.05	45.111	0.026	0.999
150Sm	48.14	48.022	0.018	1.002
147Sm	49.36	49.426	0.016	0.999
149Sm	51.62	51.702	0.012	0.998
149Sm	57.47	-	-	-
147Sm	58.09	-	-	-
149Sm	59.69	59.755	0.016	0.999
149Sm	62.11	62.153	0.018	0.999
149Sm	64.81	64.911	0.019	0.998
149Sm	68.3	68.448	0.028	0.998
149Sm	70.75	70.888	0.028	0.998
149Sm	73.11	73.180	0.021	0.999
149Sm	74.69	74.693	0.039	1.000
149Sm	75.4	75.432	0.098	1.000
147Sm	83.6	83.769	0.030	0.998
152Sm	87.7	87.691	0.030	1.000
149Sm	90.85	91.023	0.043	0.998
154Sm	93	93.031	0.036	1.000
147Sm	102.69	102.600	0.041	1.001
149Sm	104	-	-	-
149Sm	104.9	-	-	-
147Sm	107.1	107.084	0.033	1.000
149, 150Sm	111.3	111.189	0.045	1.001
149Sm	115.2	115.096	0.068	1.001
149Sm	119.5	119.399	0.092	1.001
147Sm	123.71	123.664	0.065	1.000
149Sm	125.3	125.245	0.050	1.000

149Sm	134.1	133.985	0.059	1.001
150Sm	139.9	140.011	0.056	0.999
152Sm	154.1	154.120	0.049	1.000
147Sm	163.62	163.520	0.101	1.001
149, 152Sm	185.2	184.670	0.264	1.003
149Sm	214.7	214.810	0.288	0.999
Natural Sm Sample	Resonance parametersa (eV)	Measurement datab(eV)	Error (eV)	Ratio [a/b](%)
152Sm	237	236.977	0.241	1.000
152Sm	261.1	262.032	0.304	0.996
152Sm	314.7	314.731	0.898	1.000
152Sm	327.2	326.556	0.177	1.002
149Sm	346	-	-	-
149Sm	348.7	-	-	-

a : The data of resonance parameters from Mughabghab
b : The data from present result

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