Measurement of Neutron Capture Cross Sections of ^{139}La, ^{152}Sm and ^{191,193}Ir at 55 and 144keV

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Introduction

Precise radiactive neutron capture cross sections are important need for:

- Researches on fundamental nuclear physics,
- Calculation and/or simulation of neutron transport,
- Design of reactors and nuclear power facilities,
- Nuclear Safety analysis,
- Study on Nuclear astrophysics,
- Applications of nuclear technologies,

Introduction (cont.)

In this work, we performed the measurements of capture cross section of ^{139}La, ^{152}Sm and ^{191,193}Ir at 55keV and 144keV by means of the activation method on the filtered neutron beams of the research reactor of VAEC.

Methods

The filtered neutron beams

The neutron filter technique has been applied to create the mono-energy neutron beams of 55keV and 144keV. The filter composition and beams characteristics is given in the following Table and Figures.

Table 1 *The properties of the filtered neutron beams*

Neutron energy (keV)	Filter combination	Flux density ($n/cm^2/s$)	FWHM
55	98cmSi + 35g/cm^{2}S + 0.2g/cm^{2}B^{10}	5.61 x 10^5	8keV
144	98cmSi +1cmTi + 0.2g/cm^{2}B^{10}	2.14 x 10^6	22keV

Methods (cont.)

The filtered neutron beams

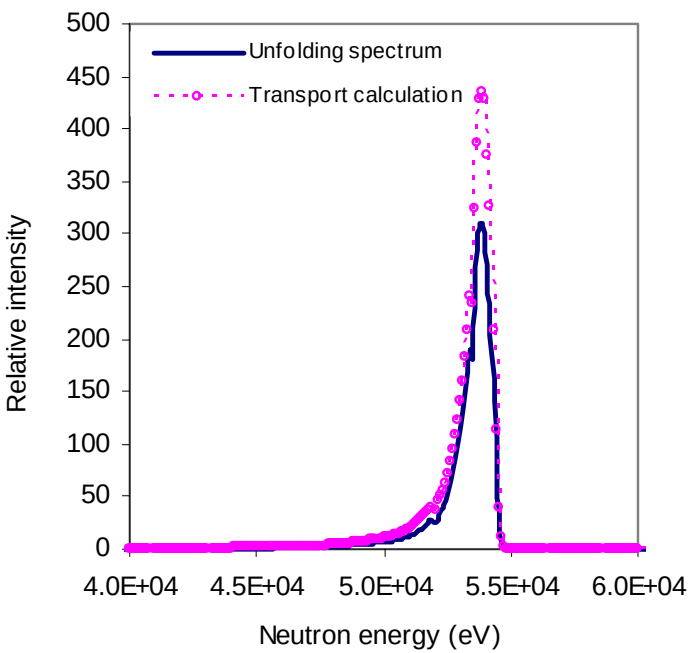

Fig. 1 Neutron spectrum of the 55keV filtered beam

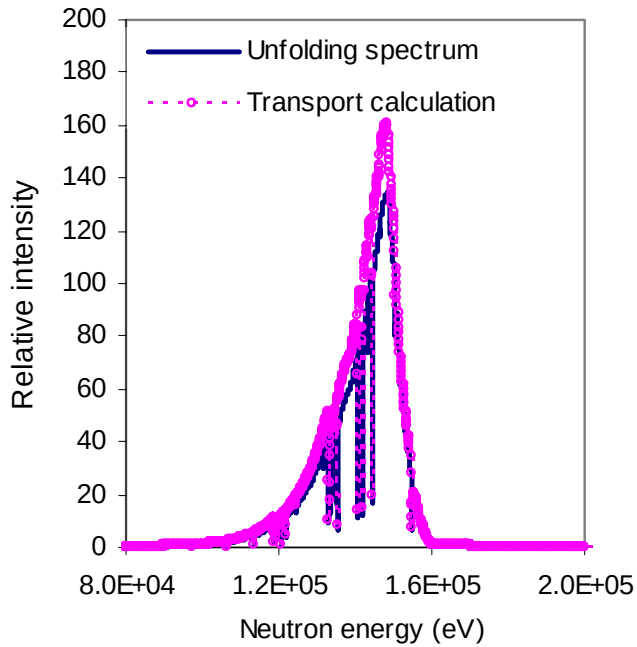

Fig. 2 Neutron spectrum of the 144keV filtered beam

Methods (cont.)

Data Processing

The reaction rate, R, of samples is defined as follows:

$$R = N\int \phi(E)\sigma_a(E)dE \qquad R = N < \sigma_a > \Phi$$

$<\sigma_a>$ and $<\Phi>$ are defined as following

$$< \sigma_a >= \int \sigma_a(E)\phi(E)dE \; / \int \phi(E)dE$$

$$\Phi = \int \phi(E)dE$$

N number of nuclei in sample
E neutron energy

σ_a(E) capture cross section
< > average Φ neutron flux

Methods (cont.)

Data Processing

- The radioactivity, A, of sample at the end of irradiation

$$A = R(1 - \exp(-\lambda t_1))$$

$$A = \frac{C f_c \lambda}{\varepsilon_\gamma I_\gamma \exp(-\lambda t_2)(1 - \exp(-\lambda t_3))}$$

λ decay constant

ε_γ detection efficiency

I_γ intensity of γ -ray

t_1 irradiating time

t_2 cooling time

t_3 measuring time

f_c correction factors

Methods (cont.)

Data Processing

- The average capture cross sections of the irradiated samples can be obtained by the following expressions

$$< \sigma_a >= \frac{C^x f(\lambda,t)^x f_c^x I_\gamma^{Au} \varepsilon_\gamma^{Au} N^{Au} < \sigma_a >^{Au}}{C^{Au} f(\lambda,t)^{Au} f_c^{Au} I_\gamma^x \varepsilon_\gamma^x N^x}$$

$$f(\lambda,t) = \frac{\lambda}{(1-\exp(-\lambda t_1))\exp(-\lambda t_2)(1-\exp(-\lambda t_3))}$$

Experiments

Reference Data

- The relevant decay data of product nuclei, used in this work, were extracted from Nudat 2.2 Database, http://www.nndc.bnl.gov/nudat2/ , and are given in Table 2.

***Table 2 D**ecay properties of the product nuclei*

Product nucleus	Half-life	γ-ray energy (keV)	Intensity per decay (%)
^{198}Au	2.6952±0.0002 d	411.8	95.6±0.1
^{140}La	1.6781±0.0003 d	487.02	45.5±0.6
^{153}Sm	46.50±0.21 h	103.2	29.3±0.1
^{192}Ir	73.827±0.013 d	316.5	82.7±0.2
^{194}Ir	19.28±0.13 h	328.45	13.1±1.7

Experiments (cont.)

Samples preparation and irradiation

- The samples were prepared from the natural oxide powders, 99.99% purity, of La_2O_3, Sm_2O_3 and IrO_2.
- Each sample was sandwiched between two gold disks for monitoring of neutron flux.
- Each Sample group were wrapped in a Cd cover with 0.5mm in thickness.
- The samples were irradiated on the filtered neutron beams of 55keV and 144keV (70hours irradiation time).
- The specific activities of the samples and the gold disks were measured with a calibrated high efficiency HPGe detector.

Experiments (cont.)

Correction factors

- The correction factors for the neutron self-shielding, multi-scattering and the effects of strong resonance capture of neutron in the samples were calculated by Monte-Carlo method.
- The data used for the correction calculation were taken from JENDL3.3 and ENDF/B-6.8.
- The calculated correction factors are given in Table 3.

Experiments (cont.)

Correction factors

Table 3 *Correction factors for multi-scattering, self-shielding and resonance capture of neutron in the samples*

Nuclides	55keV region			144keV region		
	Self-shielding	Multi-scattering	Resonance capture	Self-shielding	Multi-scattering	Resonance capture
Au-197	0.9985	0.9901	0.4269	0.9988	0.9929	0.5338
La-139	0.9962	0.9785	0.6227	0.9986	0.982	0.7531
Sm-152	0.9988	0.9856	0.2816	0.9991	0.9917	0.4890
Ir-191	0.9959	0.9782	0.4937	0.9968	0.9828	0.6593
Ir-193	0.9959	0.9774	0.5214	0.9968	0.9826	0.6944

Results

- The values of average neutron capture cross sections of ^{139}La, ^{152}Sm and ^{191,193}Ir at incident neutron energies of 55keV and 144keV have been measured in this work, and the results are given in Table 4 and figures 3-6.
- The uncertainties in the present measurements were 5-6.5%, mainly due to:
  - the statistical errors (0.1-2%),
  - the uncertainties of γ-ray detection efficiency (3.5%),
  - the reference cross section (~3%),
  - and the correction factors (~3%).

Results (cont.)

Table 4 The neutron capture cross sections of ^{139}La, ^{152}Sm and ^{191,193}Ir obtained in the present work

Average neutron energy [Energy range] (keV)	$\langle\sigma_a\rangle^{La\text{-}139}$ (mb)	$\langle\sigma_a\rangle^{Sm\text{-}152}$ (mb)	$\langle\sigma_a\rangle^{Ir\text{-}191}$ (mb)	$\langle\sigma_a\rangle^{Ir\text{-}193}$ (mb)
55 [51-59]	22.4 ± 1.2	345.5 ± 19.4	1016.5 ± 57.2	566.7 ± 32.6
144 [133-155]	12.01 ± 0.58	258.7 ± 14.5	514 ± 29.4	404.5 ± 22.8

Results (cont.)

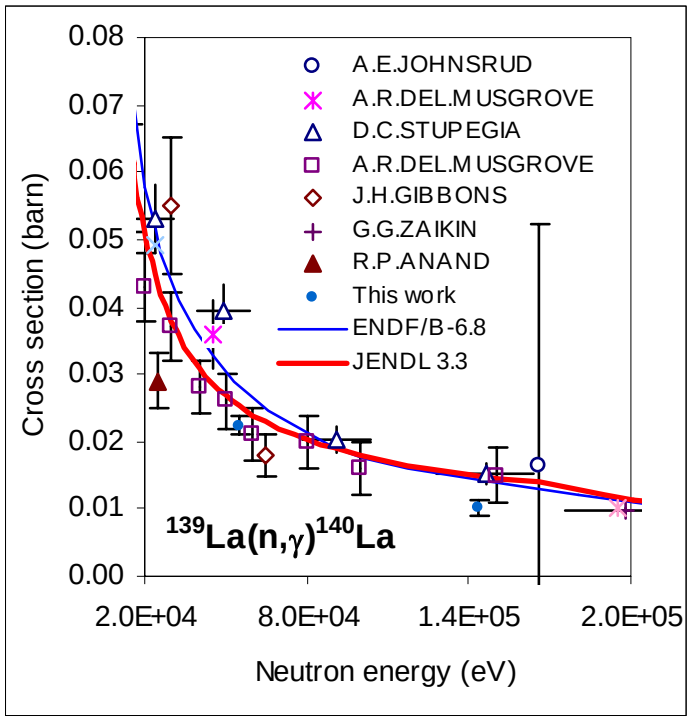

Fig. 3 Neutron capture cross section of ^{139}La in keV region

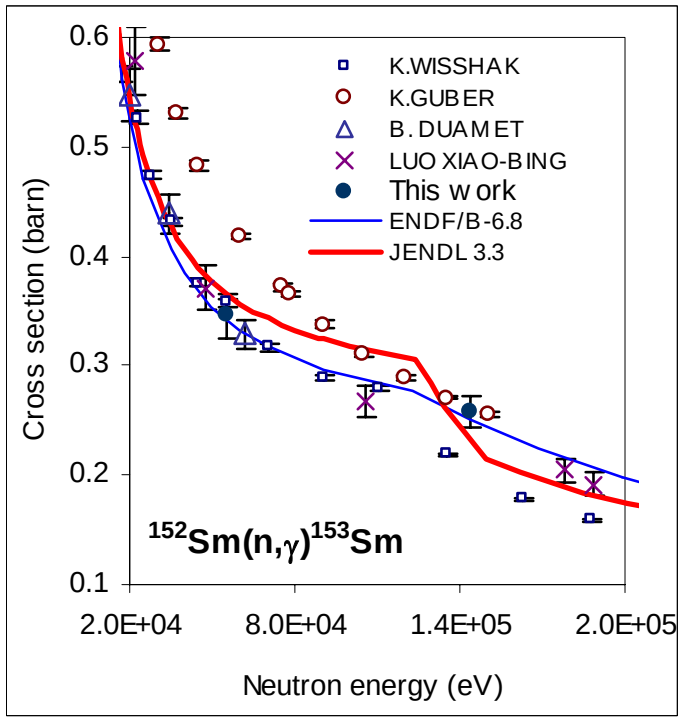

Fig. 4 Neutron capture cross section of ^{152}Sm in keV region

Results (cont.)

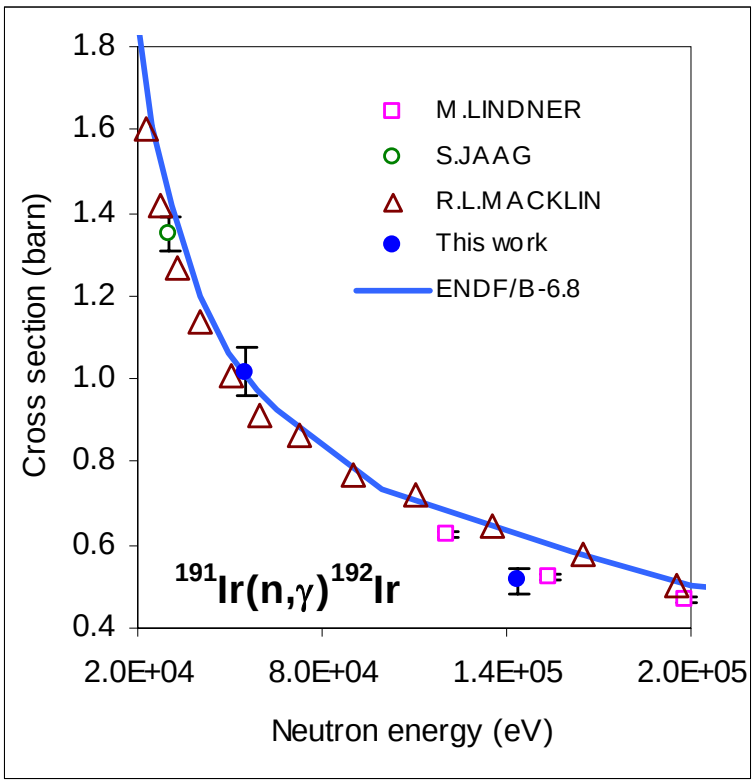

Fig. 5 Neutron capture cross section of ^{191}Ir in keV region

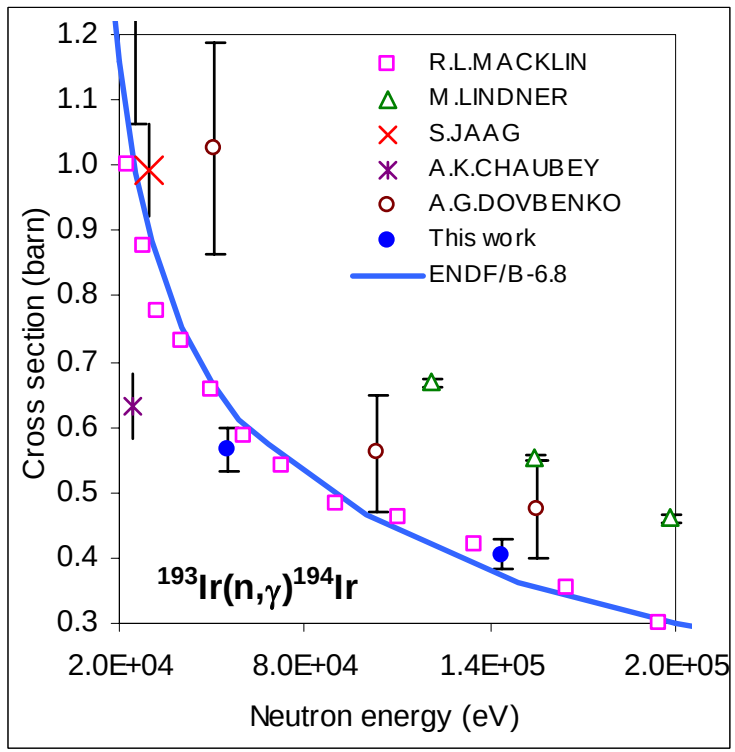

Fig. 6 Neutron capture cross section of ^{193}Ir in keV region

Conclusions

- The neutron capture cross section of ^{139}La, ^{152}Sm and ^{191,193}Ir at average incident neutron energies of 55keV and 144keV have been measured by means of the activation method, relative to the standard capture cross sections of ^{197}Au.
- The filtered neutron beams at the research reactor of the Nuclear Research Institute, Dalat Vietnam, were used in the present work.
- The uncertainties of the present results are 5-6.5%.
- The comparisons of the present results with the previous measured values and evaluation data from JENDL3.3 and ENDF/B 6.8 have been also performed.