Critical analysis for nuclear data of thermal neutron capture cross section (σ_0) and the resonance integral (I_0) for the reaction ^{69}Ga(n,γ)^{70}Ga and ^{71}Ga(n,γ)^{72}Ga from library based on neutron activation measurements

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Introduction

Gallium is considering as an important material in nuclear reactor techniques. Having a very low melting point and a very high boiling point, gallium becomes a promissory element among various candidates for liquid-metallic coolant [1]. Accordingly, the data of thermal neutron cross sections and resonance integrals for gallium are important in nuclear reactor research. Nuclear data of gallium is also requested in theoretical and experimental studies on nuclear science and technology concerning interaction of material with neutron. The usefulness of several recent evaluation works on cross section data as major sources of information is unquestionable. In this work, the reaction cross sections were evaluated using different nuclear reactions models and are tabulated. Also the present status of experimental data for neutron capture cross sections is still inadequate both in quality and quantity. Therefore, it is important to perform precise measurements of capture cross sections for this nuclide. The aim of this work is to evaluate the thermal neutron cross - sections for 2200 m/s neutrons and resonance integrals for ^{69}Ga(n,γ)^{70}Ga and ^{71}Ga(n,γ)^{72}Ga reactions by activation method with neutron source. The results of evaluation were obtained, using cadmium ratios, relative to the reference values of 197 Au with σ_0 = 98.659±0.09 barn and I_0 = 1550±28 barn [2].

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TABLE I: Parameters of the neutron flux monitor wires and nuclear data used for data evaluation.

Monitors	Radioisotope	$T_{1/2}$	σ_0(barn)	g	s_0	G_{th}	G_{epi}
Co	^{60}Co	5.271Y	37.18	1.00	1.738	1.00	1.00
Au	^{198}Au	2.695D	98.65	1.00	17.22	1.00	1.00

TABLE II: Data evaluation.

Isotope	λ	$G\varepsilon$	θ (KeV)	BR	t_{co}(h)	t_{coo}(h)	σ(b)
^{197}Au	2.97×10^{-6}	3%	411.802	95.6%	15	3	99
^{59}Co	4.2×10^{-9}	3%	1332.5	65%	10	3	37

Analysis and results

The neutron flux will be monitored using ^{197}Au(n,γ)^{198}Au(T1/2 =2.6948 d, decay gamma energy=411.802 KeV, with intensity 95.62%) and ^{59}Co(n,γ)^{60}Co, standard cross section of ^{197}Au(n,γ)^{198}Au and ^{59}Co(n,γ)^{60}Co by the ENDF/B-7.1 will be used for normalization. ^{59}Co and ^{197}Au have different sensitivities to thermal and epithermal neutrons, these wires are appropriate to determine the thermal and the epithermal fractions of neutron flux. Parameters of the neutron flux monitor wires and nuclear data used for data evaluation is shown in table 1, table 2 and table 3. The effective cross section σ is defined by equating the reaction rate R to the product of σ and n_0, where n_0 is the

TABLE III: Data evaluation.

Isotope	ϕ	t_{irr}(h)	Counts	Counts/sec
^{197}Au	10^{12}n/cm^2.sec	0.0167	37517550.93	694.76
^{59}Co	10^{12}n/cm^2.sec	2	4028165.20	111.89

TABLE IV: Thermal neutron cross-section and resonance integral for ^{69}Ga(n,γ)^{70}Ga.

reference	σ_0	I_0
this work	1.68	16.79
Ref 4	1.69±0.08	16.52±1.48
ENDF/B-VII	1.73024	16.1061
JEFF 3.0	1.6784	16.3755
JENDL 3.3	2.20095	18.1133

TABLE V: Thermal neutron cross-section and resonance integral for ^{70}Ga(n,γ)^{71}Ga.

reference	σ_0	I_0
this work	4.55	33.43
Ref 4	4.45±0.25	33.09±2.97
ENDF/B-VII	4.73114	33.6604
JEFF 3.0	4.7124	34.5299
JENDL 3.3	3.71011	32.0957

neutron flux in the Westcott's [3] convention with the neutron density n, including thermal and epithermal neutrons, and with the velocity of neutron $\nu_0 = 2,200m/s$,(thermal neutrons, 0.025 eV) so that, the reaction rate can be expressed as

$$R = nv_0\sigma \tag{1}$$

The relation between the the effective cross section σ and σ_0 can be expressed as

$$\sigma = \sigma_0(g + rs) \tag{2}$$

where σ_0 is the cross section for 2,200m/s neutrons g is a function of temperature and r is epithermal index in westcott's convention, s is a function of neutron temperature and resonance integral, s is defined by $s_0(T/T_0)^{1/2}$ then eqn no 2 can be expressed as

$$\sigma = \sigma_0[gG_{th} + r(T/T_0)^{1/2}s_0G_{epi}] \tag{3}$$

where T is the neutron temperature and T_0 is 293.6 K. The quantity $r(T/T_0)^{1/2}$ gives the fraction of the epithermal neutron in the neutron spectrum. The parameters in the eqn no 3 are summarized in table 1, table 2 and table 3 together with the nuclear data. The value of g, G_{th} and G_{epi} are taken as unity in the following analysis in current target conditions. Then s_0 is defined by

$$s_0 = \frac{2I_0'}{\sqrt{(\pi)}\sigma_0} \tag{4}$$

where I_0' is the reduced resonance integral, G_{th} and G_{epi} is the self-shielding co-efficients for thermal and epithermal neutrons. By substituting eqn no 3 in to 1, we get a simplified form,

$$(R/\sigma_0)_{monitor} = (\phi_1 + \phi_2.s_0)_{monitor} \tag{5}$$

for the irradiation without Cd capsule

$$(R'/\sigma_0)_{monitor} = (\phi_1' + \phi_2'.s_0)_{monitor} \tag{6}$$

The reaction rates R and R' were obtained from peak counts of gamma rays from the monitors ^{60}Co and ^{198}Au. Here ϕ_1 and ϕ_1' are the neutron fluxes in thermal region, ϕ_2 and ϕ_2' are neutron fluxes in epithermal region. The slope of R/σ_0 as a function of s_0 gives the values of ϕ_2 and ϕ_2'. The s_0 for the unknown element (present case Ga) can be measured by,

$$(s_0)_{unknown} = -\frac{\phi1 - \phi1'(\frac{R}{R'})}{\phi2 - \phi2'(\frac{R}{R'})} \tag{7}$$

The resonance integral I_0 can be determined by

$$I_0 = I_0' + 0.45\sigma_0 \tag{8}$$

where I_0' is the reduced resonance integral it will obtained from eqn no 4. The details will be presented.

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