sections, respectively; ε is full energy peak efficiency of the measured characteristic gamma ray; I_γ is gamma-ray intensity; η is abundance of the target nuclide; M is mass of sample; $D = e^{-\lambda t_1} + e^{-\lambda t_2}$ is counting correction factor (where t_1, t_2 are time intervals from the end of the irradiation to the start and finish of counting, respectively); A is atomic weight; C is measured full-energy peak area; $F=f_s f_c f_g$ is total correction factor of the activity (where f_s, f_c and f_g are the correction factors for the self-absorption in the sample for a given gamma energy and the sum effect of cascade gamma rays in the investigated nuclide as well as the counting geometry, respectively); and K is neutron fluctuation factor.

$$K = \sum_{i=1}^{L} [\Phi_i (1 - e^{-\lambda \Delta t_i}) e^{-\lambda T_i}] / (\Phi s)$$

Where L is number of time intervals, into which the irradiation time is divided; Δt_i is duration of the ith irradiation time; λ is decay constant; T_i is time interval from the end of the Δt_i to the end of irradiation; Φ_i is neutron fluence averaged over the sample in Δt_i; Φ is neutron fluence averaged over the sample in the total irradiation time T, S is factor $1-e^{-\lambda T}$.

The measured cross section for the ^{114}Cd(n, 2n) ^{113m}Cd reaction in this work is shown in Table 2.

Table 2 The measured cross sections

Reaction	E_n / MeV	σ / mb
^{114}Cd(n, 2n) ^{113m}Cd	14.7±0.3	432±41
^{93}Nb(n, 2n) ^{92m}Nb	14.7±0.3	458.2±9.2

The errors reported in this work are from counting statistics, standard cross section, detector efficiency, neutron energy, weight of samples, self-absorption of gamma ray, etc.

Reference

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[2] WANG Yongchang et al., High Energy Phys & Nucl Phys. 1990, 14(10): 923

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Measurement of Thermal Neutron Capture Cross Section

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【abstract】 *The thermal neutron capture cross sections of $^{71}Ga(n,\gamma)^{72}Ga$, $^{94}Zr(n,\gamma)^{95}Zr$ and $^{191}Ir(n,\gamma)^{192}Ir^{m1+g,m2}$ reactions were measured by using activation method and compared with other measured data. Meanwhile the half-life of ^{72}Ga was also measured. The samples were irradiated with the neutron in the thermal column of heavy water reactor of China Institute of Atomic Energy. The activities of the reaction products were measured by well-calibrated Ge(Li) detector.*

Introduction

The thermal neutron capture cross sections of ^{71}Ga(n,γ)^{72}Ga, ^{94}Zr(n,γ)^{95}Zr and ^{191}Ir(n,γ)^{192}Ir$^{m1+g,m2}$ reactions are very important for evaluating the radiation damage of the material, especially for the metal Ir. The very accurate capture cross section is needed for Ir metal due to its larger capture cross section and longer half-life($T_{1/2}$=241 a). All measurements of other laboratories were performed before 1978, and there are large discrepancies among them. So new measurements are needed.

In present work, we measured the thermal neutron capture cross sections of $^{71}Ga(n,\gamma)^{72}Ga$, $^{94}Zr(n,\gamma)^{95}Zr$ and $^{191}Ir(n,\gamma)^{192}Ir^{m1+g,m2}$ reactions. The activation method was used and $^{197}Au(n,\gamma)^{198}Au$ reaction was taken as reference reaction.

1 Experiment Procedures

The experiments were performed in the thermal column of heavy water reactor of China Institute of Atomic Energy. The $^{197}Au(n,\gamma)^{198}Au$ reaction was taken as reaction to determine the absolute neutron fluence. The samples of $^{191}Ir(n,\gamma)^{192}Ir^{m2}$ reaction were irradiated in 1992 and its cooling time is 5a. The other measurements were performed in December 1997. Natural metal Ir and Zr plates were machined into the samples with 20 mm in diameter. The ^{71}Ga samples made of Ga_2O_3 powder were pressed into disks of 20 mm in diameter, 1 mm in thickness. The weight correction of Ga_2O_3 powder were made due to its little water-absorption in air.

After irradiation, the activities of the residual nuclei were measured with well-calibrated Ge(Li) detector. The decay data of the residual nuclei were taken from the reference [1] and listed in Table 1.

Table 1 Decay data of reaction products and standard cross-section

Reactions	$T_{1/2}$	E_γ/keV	I_γ/%	Standard cross section / b
$^{71}Ga(n,\gamma)^{72}Ga$	13.95 h	834.0	95.63±0.07	
$^{94}Zr(n,\gamma)^{95}Zr$	64.02 d	724.2	44.17±0.13	
$^{191}Ir(n,\gamma)^{192}Ir^{m1+g,}$	73.831 d	468.1 316.5	47.83±0.17 82.81±0.21	
$^{191}Ir(n,\gamma)^{192}Ir^{m2}$	241 a	316.5	82.81±0.21	
$^{197}Au(n,\gamma)^{198}Au$	2.6498 d	411.8	95.57±0.48	98.65±0.09

2 Results and Discussion

(1) The samples made of Ga_2O_3 powder were irradiated for 4 times. After the corrections of the weight and self-absorption in the ^{71}Ga sample, the final result is the average of the four measurements and listed in Table 2, with the other data taken from the reference BNL-325, (1971 and 1984). Present measurements are in agreement with recommended data by BNL-325 in the error bar.

Table 2 The cross-section of $^{71}Ga(n,\gamma)^{72}Ga$ reaction

Time	Author	Cross section / b
1947	L.Seren	3.36±0.67
1952	H.Pomerance	4.9±0.4
1959	Y.Starisski	4.0±0.7
1960	W.S.Lyon	6.18±0.62
1971	T.B.Ryres	4.71±0.27
1975	G.Gleason	4.40±0.20
1978	R.E.Heft	4.74±0.10
1984	L.Koester	3.69±0.10
1981	BNL-325	4.71±0.23
1998	Present work	4.62±0.09

In present work, the half-life of ^{72}Ga was also measured. The measurements were performed in 2 times. By means of the non-linear least squares method, the final result of the half-life of ^{72}Ga is:

$$T_{1/2}=13.95\pm0.05 \text{ h}.$$

(2) Present measurements and other data for $^{191}Ir(n,\gamma)^{192}Ir^{m1+g,m2}$ reactions are listed in Table 3.

Table 3 The cross-section of $^{191}Ir(n,\gamma)^{192}Ir^{m1+g,m2}$ reactions

Time	Author	m_1+g (b)	m_2 (b)
1947	L.Seren	1000±200	
1963	B.Keish	910±90	
1963	G.Harbottl		0.38±0.24
1964	H.Arinu	1200±300	
1968	B.Sims	1120±25 1166±26	
1978	R.E.Heft	922±13	
1984	BNL-325	954±10	0.16±0.07
1998	Present work	855±13	0.14±0.06

There is only one datum for $^{191}Ir(n,\gamma)^{192}Ir^{m2}$ reaction measured by G.Harbottle in 1963 before present work. In his experiment, the cross section of $^{191}Ir(n,\gamma)^{192}Ir^{m1+g}Ir$ was used as the reference cross section to determine the neuron fluence, and the half-life was 600 a. If 954 b (evaluated by BNL-325) as reference cross section and 241 a as half-life are used

the datum 0.38±0.24 b would be changed becomes to 0.15±0.07 b, which is consistent with present measurement.

Present measurement of the cross section for the m_1+g state is about 10% lower than the data measured by other laboratories (BNL-325, 1971 and 1984).

(3) Present measurements and other data(BNL-325, 1971 and 1984) for $^{94}Zr(n,\gamma)^{95}Zr$ reaction are listed in Table 4. The present result is in agreement with the data of BNL-325 in the range of measured errors.

Reference

[1] Richard B.Firestone,Virginia S.Shirley. Table of Isotopes eighth Edition, March 1996

Table 4 The cross-section of $^{94}Zr(n,\gamma)^{95}Zr$ reaction

Time	Author	Cross section / b
1952	H.Pomerance	0.08±0.04
1955	W.A.Brooksbank	0.06±0.01
1960	W.S.Lyon	0.075
1970	M.D.Ricabarra	0.063±0.008
1971	R.H.Fulmer	0.052±0.003
1973	D.C.Santry	0.0475±0.0024
1978	R.Kundberg	0.052
1978	R.E.Heft	0.055±0.002
1982	J.M.Wyrick	0.0494±0.0017
1971	BNL-325	0.056±0.004
1981	BNL-325	0.0499±0.0024
1998	Present work	0.053±0.002

Chain Yields from 19.1 MeV Neutron-induced Fission of ^{235}U

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【**abstract**】*Chain yields for 35 mass chains were determined for the fission of ^{235}U induced by 19.1MeV neutrons for the first time. Absolute fission rate was monitored with a double fission chamber; fission product activities were measured by HPGe γ-ray spectrometry. Threshold detector method was used to measured the neutron spectrum in order to estimate the fission events induced by break-up neutrons and scattering neutrons from the environment. A mass distribution curve has been obtained.*

Introduction

The fission product mass distribution of ^{235}U has been extensively investigated, for some fission induced by monoenergic neutrons, but no more than 19 MeV neutron [1],[2]. In the present work, the chain yield of ^{235}U fission induced by 19.1 MeV neutrons was measured by means of γ-ray spectrometry.

1 Experiment

The experiment was carried out at the 2×1.7 MeV Tandem ,CIAE. The 19.1 MeV neutron was produced by $T(d,n)^4He$ reaction. The Tritium-Ti target, which was used to produce neutrons by the bombardment with the deuteron beam, was of the size Φ10 mm and 5.2 mg/cm^2 in thickness. The deuteron beam energy was 3 MeV. The neutron spectrum was measured by threshold detector method in order to estimate the fission events induced by the background neutrons from the $T(d,np)^3H$ reaction and from the scattering by the environment. The ratio of background neutron fission events to 19.1 MeV neutron fission events was estimated to be 0.574:1.

The sample used in the irradiation were Φ16 mm disks of uranium metal of about 2 g, the abundance of Uranium isotopes is 90.2% for ^{235}U, 1.1% for ^{234}U, 0.3% for ^{236}U and 8.4% for ^{238}U. The uranium disks were sealed in a pure Al foil of 0.2 mm thickness. The sample, which was sandwiched between two standardized thin samples to monitor the fission rate absolutely[3], was mounted in a double fission chamber. The standardized thin samples were made of the same uranium as the thick ones. The double