3.22 Measurements of Thermal Neutron Capture Cross Section and Resonance Integral of ^{129}I

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Abstract: The thermal neutron capture cross sections(σ_0) and resonance integrals(I_0) of ^{129}I were measured to obtain the fundamental data for the transmutation of ^{129}I(one of fission products), by the neutron capture. The amount of target nucleus was determined from the specific activity and the weight of the target. Gamma-rays from the produced nuclei, ^{130}I and ^{130m}I, were measured by a high purity Ge detector to deduce the amount of ^{130}I and ^{130m}I. Results obtained are as follows:

For formation of ^{130m}I; σ_0^{2+} = 17.5 ± 0.8 (b), I_0^{2+} = 17.9 ± 0.9(b),

For formation of ^{130}I; σ_0^{5+} = 12.6 ± 0.5 (b), I_0^{5+} = 15.5 ± 0.9(b).

The thermal neutron capture cross sections and resonance integrals of ^{129}I were measured to obtain the fundamental data for the nuclear transmutation of ^{129}I(one of long-lived fission products) through the reaction $^{129}I(n,\gamma)^{130}I$.

The standardized solution, supplied from The Amersham, of ^{129}I contained in polyethylene tubes were irradiated by neutrons from the Rikkyo University Reactor. The amount of activity in the targets were about 2500 Bq for the targets within a Cd shield and 250 Bq for the targets without the Cd shield. The precise value of the amount of nucleus of each target was determined from the specific activity, 42.12 kBq/g, and the weight of solution in the target. The weight were measured by a Mettler's micro-balance. The neutron irradiation of the samples were carried out within a Cd shield tube or without the Cd shield. The neutron fluxes were monitored by two kinds of flux monitors, Co/Al and Au/Al. The thermal neutron flux at the irradiation position was 4.6 x 10^{11} n/cm^{2}s and the Westcott's epithermal index $r\sqrt{T/T_0}$ 0.038. Gamma-rays from produced nuclei, ^{130}I and ^{130m}I, were measured by a high purity Ge detector. In the gamma-ray spectra obtained, peaks of gamma-rays from ^{130}I and ^{130m}I were observed at the energies of 536 keV, 586 keV, 668 keV, 739 keV, 1157 keV and 1614 keV. Decay of the gamma-ray peaks were followed. The average values of half-lives of decay of the peaks were 8.786 ± 0.012 min for the 2+ state and 12.338 ± 0.008 hours for the 5+ state. These values were close to the values reported[1)] previously for these states, respectively.

The area of gamma-ray peaks of the spectra were analyzed with the following equation,

$$Y_i = \varepsilon_i \left[b_{2i} W_2 + b_{5i} W_5 \right]$$

where, Y_i : Area of gamma peak of energy i

ε_i : detection efficiency of gamma-ray of energy i

b_{2i}: emission rate of gamma-ray of energy i due to ^{130m}I

b_{5i}: emission rate of gamma-ray of energy i due to ^{130}I.

The factors W_2 and W_5 are expressed as follows,

$$W_2 = R_2 \frac{N_0}{\lambda_2} (1 - \exp(-\lambda_2 T_{irr}))(\exp(-\lambda_2 T_1) - \exp(-\lambda_2 T_2))$$

where, N_0: Number of the target nucleus

λ_2, λ_5: decay constants of ^{130m}I and ^{130}I, respectively

R_2, R_5: reaction rates for formation of ^{130m}I and ^{130}I, respectively

T_{irr}: irradiation time

T_1: start time of the measurement

T_2: stop time of measurement

b_{it}: isomeric transition probability(83%).

When the neutron is well thermalized, the reaction rate(R) can be combined with the effective cross section($\hat{\sigma}$) as follows,

$$R = nv_0\hat{\sigma}$$

where, nv_0 is the neutron flux including the thermal and epithermal components. The v_0 is the velocity of 2,200 m/s.

The effective cross section is expressed according to the Westcott convention with the thermal neutron capture cross section(σ_0) with the following relation.

$$\hat{\sigma} = \sigma_0(gG_{th} + r\sqrt{T/T_0}\, s_0 G_{epi})$$

where σ_0 is the cross section for 2,200 m/s neutron, g the deviation from the 1/v law, and $r\sqrt{T/T_0}$ the epithermal index.

The s_0 is related to the resonance integral(I'_0) above the 1/v component, and is

$$s_0 = \frac{2}{\sqrt{\pi}} \frac{I'_0}{\sigma_0} .$$

In this experiment, the parameter gG_{th} can be set as 1. With a simple calculation[2]), the relation between the reaction rate and the thermal neutron cross section was deduced as follows,

$$\frac{R}{\sigma_0} = \phi_1 + \phi_2 s_0 G_{epi}$$ for irradiation without the Cd shield

and $$\frac{R'}{\sigma_0} = \phi'_1 + \phi'_2 s_0 G_{epi}$$ for irradiation within the Cd shield.

The values of neutron fluxes $\phi_1^{(')}$ and $\phi_2^{(')}$ were determined by flux monitors(Co/Al and Au/Al). The reaction rates obtained for both irradiations are combined to the value s_0G_{epi} as follows;

$$s_0G_{epi} = -\frac{\phi_1 - \phi'_1(R/R')}{\phi_2 - \phi'_2(R/R')}.$$

By using this value and the relation of R/σ_0, the value of σ_0 can be obtained. The value of resonance integral(I_0) is also obtained from a relation of

$$I_0 = I'_0 + 0.045\sigma_0 .$$

Results obtained in this experiment are

$\sigma_0^{2+} = 17.5 \pm 0.8$ (b), $I_0^{2+} = 17.9 \pm 0.9$ (b) for ^{130m}I formation,

$\sigma_0^{5+} = 12.6 \pm 0.5$ (b), $I_0^{5+} = 15.5 \pm 0.9$ (b) for ^{130}I formation.

The present value of the cross sections are close to the value reported by Block et al[3]. However, their value is only a combined value of ^{130}I and ^{130m}I formation. The value of the resonance integral is 10% larger than the value reported previously[4], which does not include the contribution of isomeric transition. Our measurement includes this effects.

References:

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