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Measurement of the Intensity and Spectra of the Neutron from Reaction $^{3}T(d,n)^{4}He$ by Low Energy Ion Accelerator

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Abstract We have measured the neutron beams and spectra at several points around a neutron source generated in $^{3}T(d, n)^{4}He$, using the fluorine-film activation method by a detector sample with threshold energy of 10 MeV in order to diminish the influence of neutrons scattered from the surrounding objects on condition that the space for target installation is limited.
Key words neutron source, radio-activation method, threshold detector

Introduction

The great leader Comrade **Kim Jong Il** said as follows.

"**Now is the age of science and technology, which is the basis of economic progress.**" ("**KIM JONG IL** SELECTED WORKS" Vol. 10 P. 22)

Accelerator neutron source, which bombards a tritium target with the deuterium ion beam to get neutron, strictly speaking, cannot be a spherical source, thus the correct determination of the angle distribution character of neutron beam in finite sources except for a dot source is very important in estimating the intensity character of the accelerator neutron source.

Reaction (n, 2n), inelastic reaction and several reactions of (n, p), (n, α)are taken place only when the neutron energy exceeds a definite one. In many cases the products of such reactions are radioactive nuclei, and we can determine the flux and energy spectrum of neutron by measuring the radioactivity. Thus a material activated only by neutron over a definite energy is called threshold detector.

In general, a various detectors and measuring methods are applied to detect the neutron[2－5]. The reaction (n, 2n) is used to measure the energy and flux of neutron in the range of 9 MeV. Now the threshold detectors of using LiF or $^{63}Cu(n, 2n)^{62}Cu$[1] are numerous, but there is no instance of using fluorine resin.

1. Measurement of the Neutron Strength by the Fluorine Radio-Activation Method in $^{3}T(d, n)^{4}He$ Reaction

As a detector sample for the measurement of neutron beam, we chose fluorine resin, which has threshold energy of 10.8MeV for (n, 2n) reaction. In general, the influence of coexistence element is very important in radio-activation method, which raises an optimization problem.

Fluorine resin can have any size, any weight and any shape. And fluorine has only one isotope in nature and the product nucleus to be measured has a long half-life, which are quite suitable for the measurement of induction radioactivity. Carbon in fluorine resin also reacts with fast neutron but has no sensitivity to the generated 14MeV neutron because its threshold energy is 20.8MeV high.

The half-life of the nuclides produced from other reactions exception for reaction (n, 2n) by fluorine and 14 MeV neutron is about several tens of second, thus a reasonable selection of rest time can minimize the influence on product nucleus with the short half-life.

The fluorine resin sample used in experiment has a disc type of 6mm in thickness and 20mm in diameter and its mass is 3.806g.

The voltage and current was set to 150kV and 400 μA respectively to measure neutron beam and the samples were placed at the points 15cm away from target. We chose the four points and performed measurements.

The neutron beam, Φ is as follows.

$$\Phi = \frac{A\lambda S_{\text{ph-e}} e^{\lambda t_{\text{rest}}} e^{\mu_{\text{Al}} X_{\text{Al}} + \mu_{\text{sample}} X_{\text{sample}}}}{N_0 M \gamma \sigma \varepsilon_{\text{detect}} \varepsilon_{\text{ph-e}} \Omega K (1 - e^{\lambda t_{\text{irr}}})(1 - e^{\lambda t_{\text{meas}}})} x \tag{1}$$

where A is an atom quantity, λ is a decay constant, $S_{\text{ph-e}}$ is the area of photo electric peak, t_{rest} is a rest time, μ_{sample} and μ_{Al} are absorption coefficients in sample and aluminium shielding chamber of the scintillator. X_{Al} and X_{sample} are thicknesses of shielding chamber and sample, N_0 is the Avogadro number, M is the mass of sample, γ is the content of the chemical element to be consider in sample, σ is the cross section of reaction, $\varepsilon_{\text{detect}}$ is the record coefficient of scinrillator, $\varepsilon_{\text{ph-e}}$ is the record coefficient of photo electricity, Ω is a solid angle, K is a decay portion, t_{irr} is the irradiation time and t_{meas} is the measurement time.

The efficiencies of photo electricity and counter were determined with the standard sources, ^{60}Co, ^{107}Cs, ^{22}Na and an absorption in sample itself was disregarded. The area of photo-electron peak was calculated using CoBell method and the neutron beams were obtained at each measure point.

We determined a function of neutron beam according to angle θ, $\Phi(\theta)$ with four points.

In a sphere coordinates, it can be said that the neutron beam is constant according to angle φ and is changed continuously only by angle θ, so that $\Phi(\theta)$ can be written.

$$\Phi(\theta) = a_3\theta^3 + a_2\theta^2 + a_1\theta + a_0 \tag{2}$$

Calculations of a_3, a_2, a_1, a_0 by Lagranju interpolation polynomial expression give us $a_3 = -0.513\Phi_0(180^\circ)$, $a_2 = -2.272\Phi_0(180^\circ)$, $a_1 = -3.82\Phi_0(180^\circ)$, $a_0 = 2\Phi_0(180^\circ)$, thus

$$\Phi(\theta) = -0.413\Phi_0\theta^3 + 2.272\Phi_0\theta^2 - 3.82\Phi_0\theta + 2\Phi_0 \tag{3}$$

which means that the neutron beam from a source changes according to angle θ.

Consequently the neutron intensity on the surface of sphere of radius R is an integration of (3) over the whole surface of the sphere, that is, $Q_0 = 1.012 \cdot 10^{10} \cdot \text{s}^{-1}$.

The relative error δ calculated by interpolation method is 9.9% , thus the neutron intensity is $Q = (1.01 \pm 0.10) \cdot 10^{10} \cdot \text{s}^{-1}$.

2. Measurement of the 14MeV Fast Neutron Spectra by the Reaction $^{3}T(d, n)^{4}He$

We measured the fast neutron spectra by means of recoil proton scintillation spectrometer with a selector of signal shape. The reactivity of target ^{3}T was $5.5 \cdot 10^{11}$ Bq and the target $Ti-^{3}T$ had a diameter of 40mm.

The fast neutron sensor was installed at the point 10cm away from the target located at center and the spectra were measured at the angles, 0°, 45° and 90° with an incident direction angle as a standard angle 0°(Fig. 1－4).

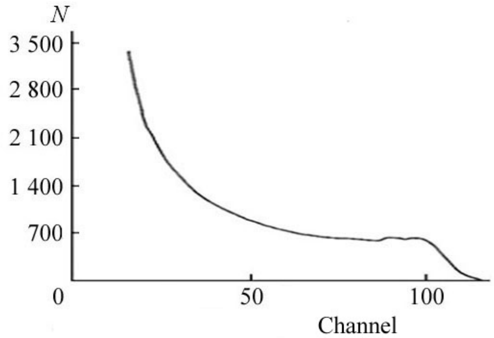

Fig. 1. Apparatus spectrum of 14MeV neutron by (d, t)reaction

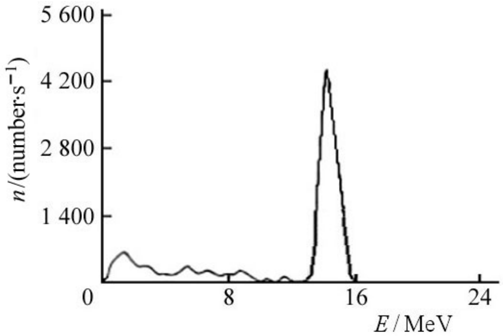

Fig. 2. Energy spectrum($\theta = 90^{\circ}$)of 14MeV neutron by (d, t)reaction

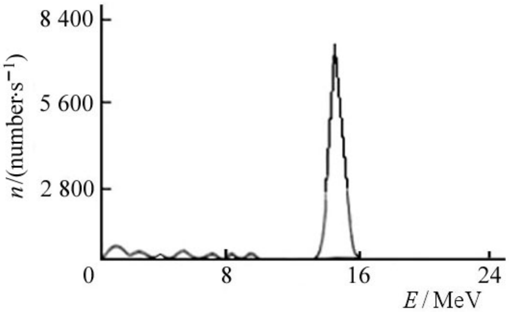

Fig. 3. Energy spectrum($\theta = 45^{\circ}$)of 14MeV neutron by (d, t)reaction

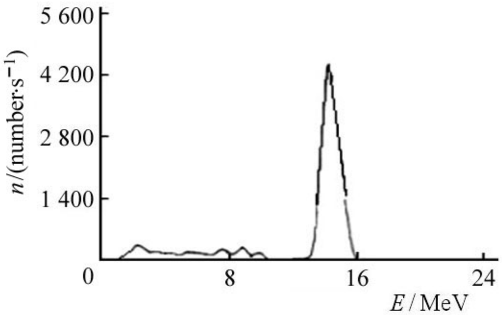

Fig. 4. Energy spectrum($\theta = 0^{\circ}$)of 14MeV neutron by (d, t)reaction

In this experiment, the neutron beam's strength was restricted to 4 500/cm^{2} from the consideration of an overload of measurement apparatus. Figures show that the 14MeV monochrome neutron was obtained at the angle $\theta = 90^{\circ}$, which are different little by little according to angle. Our results are coincident with reference [3].

Conclusion

^{19}F exists in nature state and its coexistence element has no effect on measurement. Using the fluorine resin that is convenient for manufacture of detector sample as a threshold detector, we have determined the integral intensity of the neutron emitted from $^{3}T(d, n)^{4}He$ reaction and measured the 14MeV neutron spectra.

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