Measurement of neutron energy spectrum from ^{241} Am-Be source using CR-39 track detector

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Introduction

Neutrons in the energy intreval 1 - 20 MeV, are prominent in a large variety of applications such as imaging, therapies. Unlike the energy measurements of ionizing radiations, such as charged particles and electromagnetic radiations, direct measurement of neutron energy is difficult. Energy measurements of neutrons are generally carried out using time of flight technique from which the velocity of the netron is converted into energy. This method is involved due to complex electronics and required safety measures on transporting the neutron beam from the source to the target with sufficient beam path. Here, we report the development of an innovative method for the direct measurement of neutron energy spectra, using CR-39 SSNTD as a passive detector. Neutons produced from Am-Be source is used for the measurement. 5.48MeV α particle from the ^{241}Am source undergo fusion with ^{9}Be to form the compound nucleus of ^{13}C at an excitation energy of around 14.4 MeV. Depending on the thickness of Be the excitation energy of ^{13}C may vary from 10.6 MeV to 14.4 MeV. Neutron from such resonance populate various states of ^{12}C depending on the structure of states. The expected neutron spectrum from Am-Be were measured using CR-39 detector from University of Calicut The neutron energy spectrum thus obtained analyzed using the simulated spectrum from nuclear reaction code EMPIRE 3.2[1], Alpha straggling and tunneling affected to spectrum is also taken in to consideration. Detailes of the measurement and analysis is described in the following sections.

Experimental setup

CR-39 track detector sheets with 1x1cm of thickness of 250μm, were irradiated using Am-Be neutron source at the University of calicut, Kerala, having a minimum emission of $5.5\text{x}10^{5}$ neutrons/sec. Irradiation was performed in air for a duration of 1.5 hours. The irradiated samples were then chemically etched in 6 N NaOH at 60°C for 6 hours. The detectors were then washed with distilled water and dried in dry air after etching. These etched detectors were then examined at a magnification of 40X using an optical microscope equipped with a 8 MP camera. Each 2-D track images are saved to use it in the TRIAC II[2] program code, TRIAC II is based on a segmentation method that groups image pixels according to their intensity value (brightness) to determine track parameters including diameter, major axis, minor axis,and angle.

To count tracks created on the surface of the CR-39 detector and measure their length of the major axis, minor axis, orientation and brightness of each elliptical track, a computer programme code was written and built in Matlab. This programme code is named as TRIAC II. The counting and calculations take only a few seconds with more precisely and accuracy compared to traditional (manual) method with personal counting depending on eyes and measuring scale. Different images of different tracks when exposed detectors to neutron source were taken.

Using a calibration graph, the recoiled proton energy related to each track was determined from the track diameter. The calibration graph is taken from the work of Matiullah Tufail M et al.[3], N. Sinenian et al. [4], and Antony Joseph et al[5]. The recoiled proton energy is then determined from the function as:

$$E_p = (0.0295956*(d^2)) + (-1.16821*d)+12.674$$

where d is the track diameter. Then the corresponding neutron energy is calculated using the equation

$$E_P = E_n \cos^2\theta$$

Where θ is the recoil angle,and E_n is the energy of the incident neutron.

Result and Discussion

The CR 39 track detector image shows a significant number of tracks. the TRIAC II programme is quite efficient in terms of time consumed counting,. The neutron energy corresponding to each track was estimated and the neutron spectrum was measured. The spectrum shows a broad peak between 2.0 MeV to 4.5 MeV peaking at 3.6 MeV along with two smaller peaks at 6.5 and 8.5 MeV. The tracks caused by scattered and secondary neutrons of low energy (<1.5 MeV) is lost on etching. This leads to loss of information about the low energy of neutrons produced. However, there are limited contribution of low energy neutrons in this region. The spectrum obtained from the track detector is compared with the normalized spectrum obtained from EMPIRE 3.2, Both the spectra agree in general but differ in detail mainly at the broad peak near 2.5 and 4.5 MeV in CR-39 which appears as a broad single peak at 3 MeV in EMPIRE 3.2. However, the peaks at 6.5MeV are almost in the same place for both CR-39 and EMPIRE 3.2 spectra. Fig.1 Shows the compared energy spectrum obtained from CR 39 track detector and EMPIRE 3.2 code. Corections for scattering loss of alpha energies due to atomic collisions with Am and Be atoms enroute to the abosrption by Be is aso accounted. Further, it is to be noted that, the loss of information over low energy region of neutron spectra is compensated by the device, developed by the group, for meaurement of low energy neutrons upto 1.0 MeV with high precision, using Si-B and Si/Li nanostrucutres [6]. Thus the combination will work as a system for measureing neutron detectors over wide range of neutron energies.

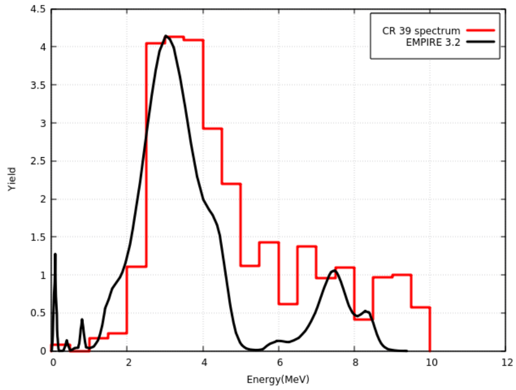

Fig. 1 Neutron energy spectrum from CR39 detector and EMPIRE 3.2

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