Thick target energy integrated neutron fluence from heavy ion reactions at 5-6 MeV/u

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Introduction

Neutron fluence integrated over the energy range is an important parameter for measurement of directional distribution of neutron field in any accelerator. Here we study the effect of various parameters such as the specific energy, excitation energy, neutron separation energy and the mass of the projectile on the neutron fluence.

Another important parameter in the study is the slope of the angular distribution since a model will have to care of not just the total counts but also its angular distribution. Previous studies have indicated that the slope of the distribution does not follow a systematic trend with the projectile energy.

Experiment

The experiments were carried out at the BARC-TIFR Pelletron Linac Accelerator Facility at TIFR. The arrangement consisted of a thick Al target and a BF_3 detector in conjunction with moderator placed at 1.0 meter distance at angles 0°, 30°, 60° and 90° with respect to the beam direction. The instrument is calibrated using an Am-Be neutron source of known strength to provide a neutron count rate. The time integration facility of the instrument is used to obtain the total counts. This is normalized to unit incident projectile using the current integrator reading.

Neutron angular distribution was measured for 60 and 67.5 MeV ^{12}C, 57.3 and 65 MeV ^{13}C, 80 and 100 MeV ^{16}O, 69 and 90 MeV ^{18}O, 50 and 54.1 MeV ^{10}B and 50.8 and 55 MeV ^{11}B projectiles incident on thick Al target. The slopes of the angular distribution curves are analyzed and attempts have been made to develop some empirical formalism relating these slopes with projectile energy and excitation energy. The results of the study will help formulate an empirical expression to predict the neutron yield in terms of the few variables.

Results and discussions

The measured angular distribution of neutron counts from reaction induced by six projectiles at 5 MeV/u is given in figure 1.

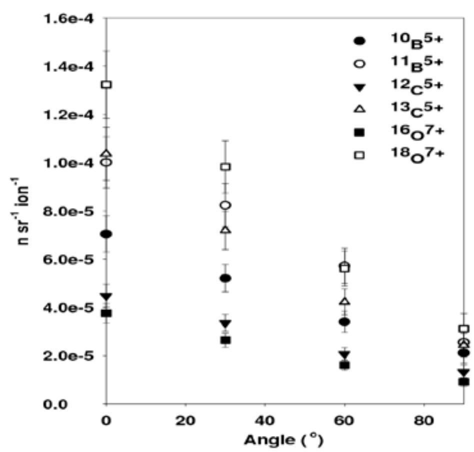

Fig. 1 The angular distribution of neutron fluence from various heavy ion projectiles of 5 MeV/u incident on a thick Al target.

The results plotted in figure 1 show no systematic trend of neutron distribution with projectile mass or total incident energy. Neutron yield distribution shows a decreasing trend with increasing mass for projectiles with N=Z. But no such systematic behavior is observed for the projectile with excess neutrons.

In figure 2 we have plotted neutron angular distribution from reactions induced by the same six projectiles where same excitation energy is given to the system by two different isotopes of a given element. It can be seen that while the yield from neutron rich projectiles is higher than that from the isotope with N=Z, neutron yield does not follow any particular pattern with respect to the projectile mass. Thus, while ^{18}O appears to emit more neutrons as compared to ^{11}B, ^{13}C shows lesser yield as compared to ^{10}B. However, if the neutron rich isotopes are considered, the yield increases with increasing mass number. Evidently, the mass and neutron excess alone are not sufficient to explain the results obtained here.

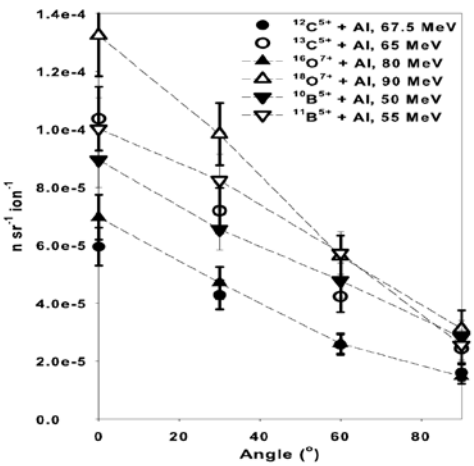

Fig. 2 Neutron angular distribution for the same excitation energy for ^{12}C and ^{13}C projectiles.

Table 1: The neutron separation energy in the compound nucleus formed by various projectiles used in this study with Al target.

Projectile	Neutron Separation Energy (MeV)	n sr^{-1} ion^{-1} at 5 MeV/u at 0^{o}	N_{tot}	S
^{10}B	8.8	7.1e-5	3.3e-4	0.71
^{11}B	11.8	1.0e-4	5.1e-4	0.67
^{12}C	13.1	4.5e-5	2.1e-4	0.73
^{13}C	7.8	1.0e-4	4.1e-4	0.86
^{16}O	12.1	3.7e-5	1.5e-4	0.83
^{18}O	11.3	1.3e-4	5.5e-4	0.82

The data are now analyzed in terms of neutron separation energy which is given in table 1. From the table it can be seen that ^{13}C has the lowest neutron separation energy which could explain the highest yield observed. However, the highest neutron separation energy for the ^{12}C projectile does not explain the neutron yield from it. Similarly, ^{11}B with higher neutron separation energy gives higher neutron yield as compared to ^{10}B which has lower neutron separation energy. We have also compared the yield distribution with the formalism of Nandy et al (eqn. 1) [1] with fixed values of N_{total} and S values and also keeping them as free parameters. These comparisons are shown in fig. 3. Values of N_{total} and S obtained from free parameter fit are also given in Table 1.

$$N(\theta)=\frac{N_{tot}}{2\pi}\left(\frac{1+S^2}{1+e^{-S\pi}}\right)\exp(-S\theta) \qquad (1)$$

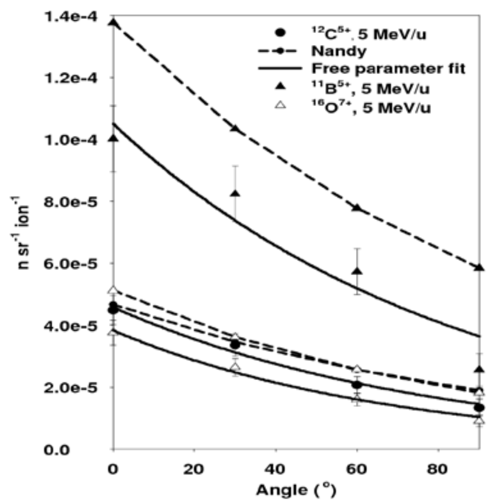

Fig. 3 Comparison of measured distribution with formalism of Nandy *et al.* for the systems shown.

Conclusions

The neutron yield measured by a moderated BF_3 proportional counter from various heavy ion induced reaction from a thick Al target is reported here. The data is analyzed in terms of excitation energy, projectile mass and the neutron separation energy. The neutron yield distribution shows a decreasing trend with increasing mass for projectiles where N=Z but do not show the same trend for projectiles with N > Z. The empirical formalisms used in this study appears to predict the yield reasonably well.

References

1. Nandy *et al.*, Nucl. Instr. Meth. Phys. Res. A. **576**, 380 (2007)