Fission cross sections for $^{6,7}Li+^{235}U$

A. Parihari[1], S. Santra[2], N. L. Singh[1], K. Mahata[2], P.K. Rath[1], K. Ramachandran[2], Sushil K. Sharma[3], B. K. Nayak[2], S. Kailas[2]

[1]*Department of Physics, Maharaja Sayajirao University of Baroda, Vadodara - 390002, INDIA*

[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*

[3]*DNAP, Tata Institute of Fundamental Research, Mumbai - 400005, INDIA*

** email: anamikaparihari.87@gmail.com*

Introduction

The study of nuclear reaction mechanisms involving weakly bound stable heavy ions has been very interesting due to the observation of many new non-conventional behaviors compared to those involving tightly bound projectiles. Fusion suppression at above barrier energies, absence of threshold anomaly in the real part of the optical potential and production of large alpha particles are some of the important features associated with the above reactions. These observations are known to be largely due to the effect of projectile breakup on other channels. Study of fission involving weakly bound projectiles is another avenue. Effect of projectile breakup has also been discussed in many studies. However, there are very few work in the literature that explain the reaction mechanisms involved in the breakup affected fission observables. Freiesleben et al. in their study on $^{6,7}Li+^{232}Th,^{238}U$ have done a systematic study on fission fragment angular distribution and found characteristic differences between ^{6}Li and ^{7}Li induced reactions. They have also mentioned the possibility of projectile breakup and its effect on fission. In the present work we have performed a similar study but for different systems $^{6,7}Li+^{235}U$ to see if their conclusions differ for a target having a large g.s. spin. The reactions with ^{235}U as a target are known [2] to have different fission anisotropy as compared to the one having zero g.s. spin. In that case the characteristics observed for $^{6,7}Li+^{238}U$ may not be same as for the present case. With this motivation we made the fission measurements for $^{6,7}Li+^{235}U$ systems. Presented in this paper are the measurements, results of the analysis and anisotropy calculations.

Measurements

The fission fragment angular distribution for $^{6,7}Li + ^{235}U$ reaction have been measured at the 14UD BARC-TIFR pelletron facility, Mumbai using $^{6,7}Li$ beam of average current 35 nA. Beam energies between 26 MeV to 44 MeV in step of 2 MeV have been used. Target of ^{235}U of thickness 1.6mg/cm^2 was prepared by electro-deposition on backing of 4 µinch Ni-Cu foil. The target were carefully centered in a scattering chamber where four solid state detectors mounted at a distance of ~20 cm from the target centre with fixed angular separation of 20^0 and additional two detectors served as monitors were used to detect the fission fragments.

Analysis

The differential fission cross sections were calculated, using the relation

$$W(\theta_{cm}) = \frac{d\sigma_{fiss}}{d\Omega}(\theta) = \frac{Y_{fiss}(\theta)}{Y_{Ruth}(\theta_{Ruth})} \times \frac{d\sigma_{Ruth}}{d\Omega}(\theta_{Ruth}) \times \frac{d\Omega_{Ruth}}{2d\Omega_{fiss}}$$

Where Y's and Ω's are the yields and the solid angles of fission and monitor (Ruth) detectors.

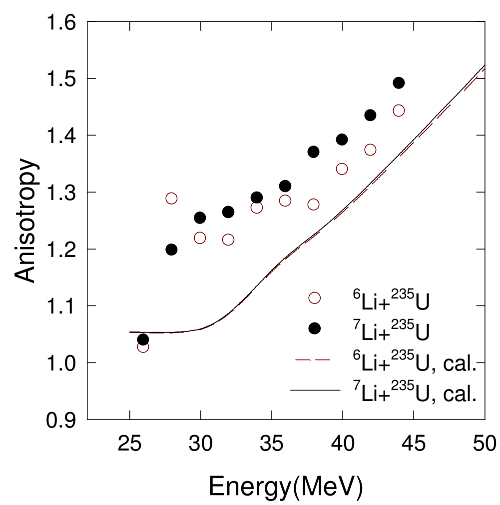

Fig. 1: Energy dependence of the fission fragment angular anisotropy for $^{6,7}Li+^{235}U$ reactions.

The experimental differential cross section were fitted with the exact expression of *W(θ)* [3], from the saddle point model. From the fit of the $W(\theta)$ one can obtain the fission anisotropy, $A=W(180^o)/W(90^o)$, as shown in Fig.1. It can be observed that the anisotropy values for ^{7}Li are higher compared to ^{6}Li as observed in Ref.[1]. This was expected because a compound nucleus having $1n$ more is supposed to have more later-chance fission and thus increasing the value of the anisotropy *'A'*.

The fission fragment anisotropy was calculated by standard saddle point statistical (SSPS) model using the relation $A=1+\langle l^2\rangle/4K_0^2$, where K_0^2 is the variance of K (projection of the total angular momentum on the symmetry axis of the fissioning system) distribution and $\langle l^2\rangle$ is the mean square spin of the compound nucleus. The values of $\langle l^2\rangle$ were derived by fitting the experimental fusion cross sections (obtained by integrating the fission angular distributions) with the coupled-channels calculations by CCFULL[4]. The values for K_0^2 ($=J_{eff}T/\hbar^2$, where J_{eff} is the effective moment of inertia and T is the temperature of the compound nucleus) were obtained from the standard relations for T with excitation energy and level density as described in Ref. [5]. The anisotropy results for ^{6,7}Li+^{235}U are shown in Fig.1 as dotted and solid lines respectively. It can be observed that the calculated values are smaller than the experimental ones, even at higher energies. Secondly, though the theoretical anisotropies for both the systems are almost same, the experimental values for ^{7}Li are slightly higher than ^{6}Li. The large difference between the experiment and theory in A-values at energies around the barrier is known to be due to the effect of coupling of different reaction channels to the entrance channel.

The fitted $W(\theta)$ values were integrated to get the total cross section at energies E_{lab}=26-44 MeV. The experimental total fission cross sections for ^{6,7}Li and ^{235}U are displayed in Fig. 2. It can be observed that at low energies the integrated fission cross section for ^{6}Li induced reaction is much higher than those for ^{7}Li induced reactions and at very high energies their values are almost same. This can be understood in terms of larger breakup fragment induced fission for ^{6}Li than ^{7}Li. Since ^{6}Li has a lower breakup threshold (1.48 MeV) compared to the one for ^{7}Li (2.47 MeV), breakup probability is much higher for the former. In order to quantify the contribution from breakup fragment induced fission one needs to measure the coincidence between fission fragments and light charged particles like *p, d, t* and α.

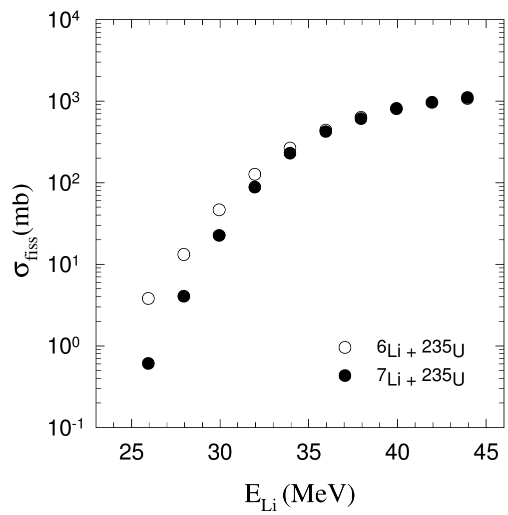

Fig. 2: Angle integrated fission cross sections for ^{6,7}Li+^{235}U at different energies.

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