Incomplete fusion and transfer cross sections in ^{7}Li+^{144,152}Sm reactions

P. K. Rath[1],* S. Santra[2], N. L. Singh[1], B. K. Nayak[2], K. Mahata[2], R. Palit[3], K. Ramachandran[2], S. K. Pandit[2], A. Parihari[1], A. Pal[2], R. Chakrabarti[2], S. Appannababu[1], and Sushil K. Sharma[3]
[1]*Department of Physics, The Maharaja Sayajirao University of Baroda, Vadodara - 390002, INDIA*
[2]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA and*
[3]*Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai - 400005, India*

Introduction

Recently we have measured the complete fusion (CF) cross section for ^{7}Li+^{144,152}Sm reactions [1]. CF cross-sections calculated by different models at above barrier energies shows that the measured values are suppressed by $\sim 10-25\%$. The suppression factors were found to be smaller compared to the ones measured earlier for ^{6}Li+^{144,152}Sm reactions[2] indicating the effect of higher projectile breakup threshold for ^{7}Li compared to ^{6}Li. The reason for the CF suppression is attributed to the loss of incident flux due to the breakup of ^{7}Li ($\rightarrow \alpha + t$) prior to the fusion. In such a situation, one of the breakup fragments (α or t) may get captured by the target leading to incomplete fusion (ICF) or partial fusion or breakup fusion. So, the ICF cross section has a direct link to the suppression of CF cross sections. In fact the cross sections for CF+ICF for several reactions have been found to match with the coupled-channel calculations without breakup coupling. So, it would be interesting to investigate the experimental ICF cross section for the present (^{7}Li+^{144,152}Sm) reactions to complement and understand the suppression in the CF cross sections measured earlier[1].

In this paper, we present the ICF cross sections for some of the evaporation residues with reasonable half lives for possible off-line γ-counting measurement. In addition, the cross sections for some of the evaporation residues formed by transfer reactions are also presented.

Measurement and Results

The ^{7}Li beam of 25 − 60 nA from BARC-TIFR Pelletron-Linac accelerator facility has been used for the irradiation of the ^{144,152}Sm targets ($\sim 450-680$ μg/cm^2 with 2.2 mg/cm^2 Aluminium backing) for several hours at each of the measured energies in the range of 20−40 MeV and in steps of 1 − 2 MeV. The yield of evaporation residue (ER) formed due to ICF or transfer reactions are then measured by counting the characteristic γ particles emitted from the corresponding ERs using the HPGe detector. The list of ERs (that have been measured with reasonable cross sections) along with their spectroscopic information is given in Table 1. Cross sections are estimated using the procedure and expression as described in Ref. [2].

Unlike the case of ^{7}Li+^{144}Sm reaction, no ER corresponding to the ICF channels in ^{7}Li+^{152}Sm reaction has been observed either because of their large half lives or they are stable. The estimated cross sections for each of the above ERs are shown in Fig. 1. Solid circle, diamond and square symbols in Fig. 1(a) correspond to ^{146}Eu, ^{145}Eu and ^{147}Gd respectively. In case of ^{145}Eu, there is contamination from 1p stripping transfer reaction ^{144}Sm(^{7}Li,^{6}He). However, on the basis of the Q-value of this reaction (−6.66 MeV), it is less likely to contribute to the formation of ^{145}Eu residue. Similarly the stars in

*Electronic address: ssantra@barc.gov.in

TABLE I: List of observed evaporation residue channels in ^{7}Li+^{144,152}Sm reactions, and the corresponding radiation decay data.

Reactions	ER	$T_{1/2}$	E_γ(keV)	I_γ (%)
^{144}Sm(^{3}H,1n)	^{146}Eu	4.59 d	430.3 747.1	4.72 99
^{144}Sm(^{3}H,2n) / ^{144}Sm(^{7}Li,^{6}He)	^{145}Eu	5.93 d	542.5 893.7	4.5 66
^{144}Sm(^{4}He,1n)	^{147}Gd	38.06 h	229.3 765.8 929.0	58 10.4 18.4
^{152}Sm(^{7}Li,^{8}Be)	^{151}Pm	28.4 h	340.1	23

Fig. 1(b) correspond to the $1p$ pickup transfer reaction i.e., ^{152}Sm(^{7}Li,^{8}Be). The solid line corresponds to the result of coupled reaction channels (CRC) calculations for $1p$ pickup reaction using FRESCO[3]. Microscopic double-folded potentials are used for elastic as well as transfer channels. Only the ground state and first two low-lying excited states of ^{151}Pm are coupled for the transfer calculations. Spectroscopic factors are taken from the literature. The calculated transfer cross sections are found to under-predict the measured data indicating that either the inclusion of higher excited states or an increase in spectroscopic factors of the present states is needed.

Cross sections for the CF measured earlier[1] are also shown (as hollow circles) in the figure to compare with the present ICF data. It is observed that the sum total of the cross sections for the ERs corresponding to t-capture and α-capture, though a lower limit, will make a large fraction of the CF cross section. It indicates that projectile breakup is playing a crucial role in reducing the CF cross sections at the measured energies as well as providing a substantial cross section for ICF.

One of the authors (P.K.Rath) acknowledges the financial support of CSIR (09/114/0178/2011/EMR-I) in carrying out these investigations.

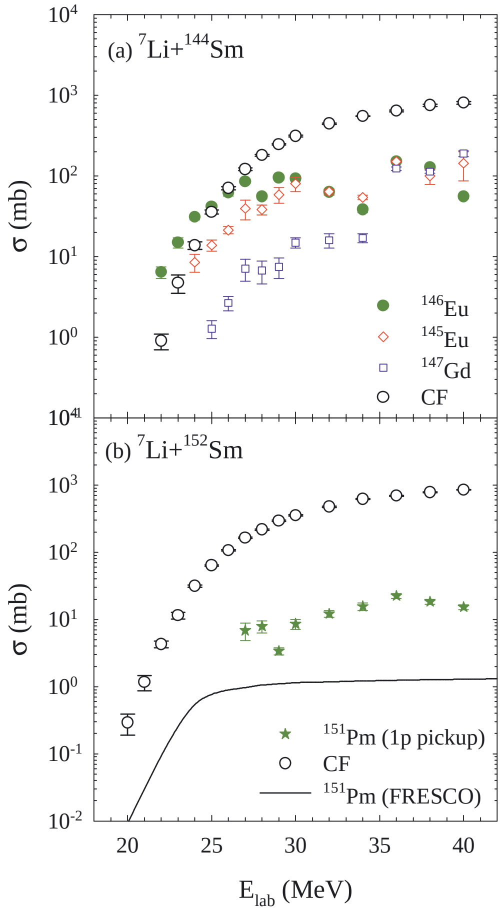

FIG. 1: Measured cross sections for different ICF and transfer channels along with the CF cross sections (hollow circles) for (a) ^{7}Li+^{144}Sm and (b) ^{7}Li+^{152}Sm reactions. Solid line corresponds to the CRC calculation for $1p$ pickup reaction using FRESCO.

References

[1] P. K. Rath *et al.* DAE Symp. on Nucl. Phys. **56**, 544 (2011); **57**, 518 (2012); Submitted to Phys. Rev. C, 2013.

[2] P. K. Rath *et al.*, Comput. Phys. Rev. C **79**, R051601 (2009).

[3] I. J. Thompson, Comput. Phys. Rep. **7**, 167 (1988).