Fusion Studies for ^{6}Li+ ^{82}Se, ^{51}V Systems using In Beam Gamm-ray Spectroscopy

H. Kumawat[1],* V.V. Parkar[1], V. Jha[1], B.J. Roy[1], Y. Sawant[1], P.C. Rout[1], E.T. Mirgule[1], S.V. Suryanarayana[1], B.K. Nayak[1], A. Saxena[1], S. Kailas[1,2], T. Trivedi[3], S. Bhattacharya[3], and Y. Mishra[3]
[1]*Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai - 400085, INDIA*
[2]*UM-DAE Centre for Excellence in Basic Sciences, Mumbai - 400098, INDIA and*
[3]*Guru Ghasidas Vishwavidyalaya, Bilaspur - 495009, INDIA*

Introduction

Complete fusion cross-section for weakly bound nuclei are suppressed above coulomb barrier compared to one Dimensional Barrier Penetration Model and coupled channel calculations. The suppression is partially understood in terms of loss of flux due to projectile breakup before fusion and/or due several partial fusion channels. Several experiments and theoretical calculations are carried out in recent past and systematic study [1] suggests a universal suppression of complete fusion along mass. Though, few experimental data [2] suggests much lower suppression factor at lower mass region and others suggest slight lower suppression [3] . In view of this we have measured fusion cross-sections for ^{6}Li+^{82}Se and ^{6}Li+^{51}V systems using InBeam γ-spectroscopy method. Preliminary results are presented here along with statistical model calculations using PACE[4].

Experimental details

The experiment was carried out with a ^{6}Li^{3+} beam delivered by 14UD BARC-TIFR Pelletron-Linac accelerator facility, Mumbai at bombarding energies from 16 to 35 MeV. The beam impinged on targets of $\sim$720μg/cm^2, self-supported natural Vanadium (^{51}V $\sim$99.75%) and $\sim$1.2 mg/cm^2 ^{82}Se enrich (99.7%) evaporated on 80 μg/cm^2 Al backing. The In-beam γ-spectroscopy measurements were carried out with HPGe detector placed $\sim$15 cm from the target outside of the thin walled Al-chamber. Two surface barrier detectors were placed at 20° and 25° on opposite sides of the target. Beam current was measured at beam dump located few meters away from target. The characteristic γ-lines from the evaporation residues are measured.

*Electronic address: harphool@barc.gov.in

Analysis and Results

The evaporation residues from different complete and incomplete fusion channels emit characteristic γ-lines. The cross-section can be obtained from the yield of the γ-lines populating to ground state. The observed ground state lines are given in Table I. The fusion cross-sections can be calculated using equation 1 in case of monitor yield and with equation 2 by use of the integral beam current. Fig. 1 shows observed γ-ray spectra for ^{6}Li + ^{82}Se, ^{51}V at 30 MeV depicting several identified lines.

$$\sigma_\gamma(J) = \frac{Y_\gamma(J) d\Omega_M}{Y_M \varepsilon_\gamma} \sigma_M \quad (1)$$

$$\sigma_\gamma(J) = \frac{Y_\gamma(J)}{N_I N_T \varepsilon_\gamma} \quad (2)$$

where ε_γ is the absolute efficiency of the detector, N$_I$ is total beam particles and N$_T$ is target atoms/cm^2, Y$_\gamma$ and Y$_M$ are yield of gamma lines and elastic ^{6}Li at monitor detector, $\sigma_\gamma(J)$ is cross-section for the transition, σ_M is the Rutherford cross-section at the monitor angle and dΩ_M is solid angle of the monitor detector.

For ^{6}Li + ^{82}Se system 2n, 3n and 4n channels are adding to more than 90% of the CF

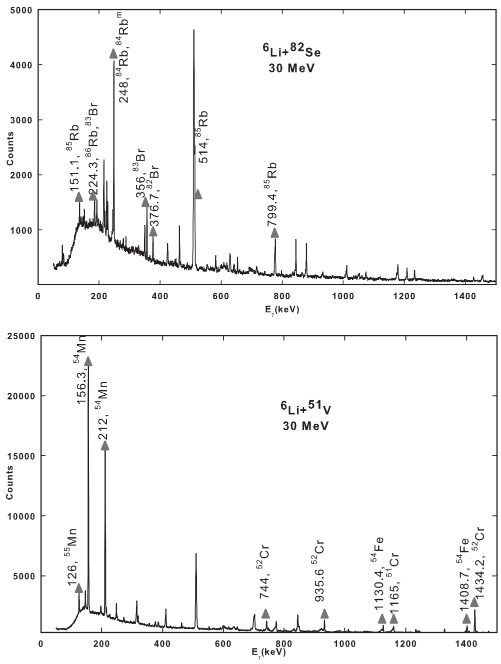

FIG. 1: Online line gamma-ray spectra for ^{6}Li + ^{82}Se, ^{51}V systems at 30MeV beam energy.

corss-section. ^{85}Kr and ^{83}Br are ICF channels for α and deuteron fusion followed by neutron evaporation. Contribution from CF is very less for these channels as per PACE calculations. Fig. 2 shows ratio of various observed channels and compared with the PACE calculations. The 224.3 keV γ-line have contamination from the ^{83}Br lines which need to be subtracted (due to low statistics we have not done it here). In the case of ^{6}Li + ^{51}V system, ^{54}Mn and ^{52}Cr are having contribution from α and deuteron fusion followed by neutron evaporation.

Conclusions

We have measured the complete and incomplete fusion cross-section for ^{6}Li+^{82}Se and ^{6}Li+^{51}V systems. Preliminary results are compared with the PACE calculated values.

References

[1] H. Kumawat *et al.* Phys. Rev. **C 86**, 024607 (2012).

TABLE I: List of measured Evaporation Residues (ER) either from CF or ICF/transfer(TR) reactions and the gamma line energy for the ground state transition.

Reaction	ER	E_γ (keV)
^{82}Se(^{6}Li,2n)	^{86}Rb	224.3
^{82}Se(^{6}Li,3n)	^{85}Rb	514.1, 151
^{82}Se(^{6}Li,4n)	^{84}Rb	247.5
^{82}Se(^{6}Li,*)	^{85}Kr	1931.6
^{82}Se(^{6}Li,*)	^{84}Kr	881.6
^{82}Se(^{6}Li,*)	^{83}Br	356.6
^{82}Se(^{6}Li,*n)	^{82}Br	376.7
^{51}V(^{6}Li,2n)	^{55}Fe	1316.4, 931.3, 1408.4, 411.9
^{51}V(^{6}Li,3n)	^{54}Fe	1408.7
^{51}V(^{6}Li,*)	^{55}Mn	126, 984
^{51}V(^{6}Li,*)	^{54}Mn	156.2
^{51}V(^{6}Li,*)	^{53}Mn	1441
^{51}V(^{6}Li,*)	^{52}Cr	1434.2
^{51}V(^{6}Li,*)	^{51}Cr	1165, 1481

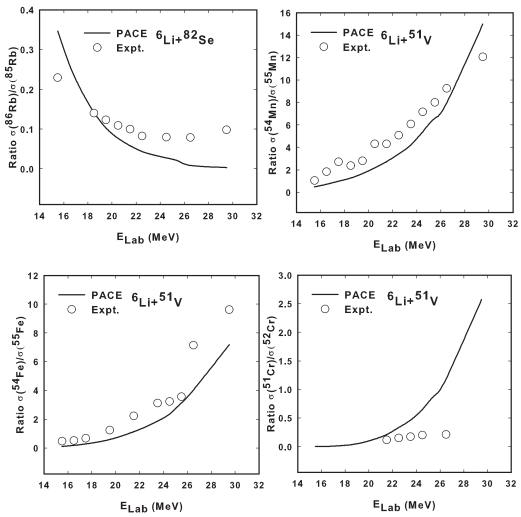

FIG. 2: Ratio of different reaction channels for ^{6}Li + ^{82}Se, ^{51}V systems.

[2] Md.M. Shaikh *et al.* Phys. Rev. **C 90**, 024615 (2014).

[3] S.P. Hu *et al.* Phys. Rev. **C 91**, 044619 (2015).

[4] A. Gavron Phys. Rev. **C 21**, 230 (1980).