Fusion in ^{7}Li + ^{197}Au at sub-barrier energies

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Introduction:

Reaction studies with weakly bound stable nuclei like ^{6,7}Li, ^{9}Be are a topic of current interest [1]. These nuclei with well defined cluster structure and small separation energies have a large breakup probability. It is therefore possible to study the influence of direct reactions on fusion process. The excitation function measurements at deep sub-barrier energies for ^{7}Li + ^{198}Pt reaction have shown the importance of internal re-organisation on the dynamic path towards fusion [2]. The recent results with ^{8}He, nucleus with the largest neutron-to-proton ratio, on ^{197}Au target, indicate that the sub-barrier total reaction cross section is completely dominated by direct reactions, in the form of one- and two-neutron stripping [3]. We have therefore carried out a simultaneous measurement of direct and compound nuclear process in ^{7}Li + ^{197}Au reaction over the energy range $0.6 \leq E/V_b \leq 1.5$. Most of the residues from fusion (Pb isotopes) and from direct reactions, namely, breakup-fusion of α particle (Tl isotopes) and neutron transfer reactions have long half-lives (12 min to 3 days) and can be measured by off-line gamma counting.

Experimental Details:

The experiment was performed at Pelletron LINAC facility, Mumbai. Self supporting rolled ^{197}Au foils (~ 1.5−1.65 mg/cm^2) were irradiated with ^{7}Li beam of energies 23−44 MeV. A ~3 mg/cm^2 Al catcher foil was used behind the target to stop the residues. In order to optimize the beam time, two cascaded targets were used with catcher foil itself acting as an energy degrader. During irradiation the beam current was recorded at regular preset intervals. The irradiated target and the catcher foil together were kept at a distance of ~ 10 cm from an efficiency calibrated HPGe detector for offline counting. The HPGe detector was covered with thin Ni+Cd foils and was placed inside 10 cm thick lead cave, to reduce the background. Data was recorded using CAMAC based acquisition system, LAMPS and a standard pulser was used for dead time correction. For measurement of weaker reaction channels, data was also collected in close geometry with sample directly mounted on the detector face (~2.5 cm from the crystal).

Data Analysis and Results:

Table 1 lists the characteristic γ-rays of different reaction products together with their half-lives.

Table 1: Characteristic γ-rays and half-lives

Residue	Eγ (keV)	$T_{1/2}$
^{201}Pb	331.15	9.33 hrs
^{200}Pb	257.19, 268.36	21.5 hrs
^{199}Pb	353.39, 720.24, 1135.04	90 min
^{198}Au	411.8	2.695 days

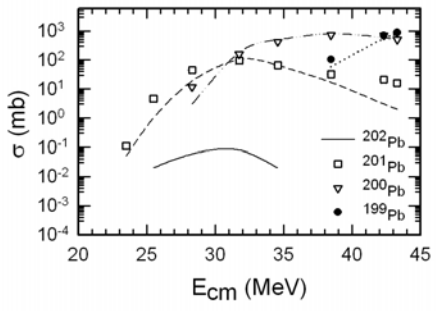

Fig. 1: Measured excitation function for residues from compound nuclear decay in ^{7}Li + ^{197}Au (symbols) reaction together with statistical model calculations (lines). Errors are smaller than symbol size.

The half-lives of various γ-rays were followed for unambiguous identification. The evaporation residue ^{202}Pb (2n channel), being stable cannot be detected. However, the contribution from this decay channel is expected to be negligible in the energy region of interest. Figure 1 shows the measured excitation function for residues arising from the compound nuclear fusion in ^{7}Li + ^{197}Au together with statistical model calculations. The statistical model calculations were performed with PACE2 [4] employing Ignatyuk level density prescription and are in good agreement with experimental data. The compound nuclear angular momentum distribution was taken from CCFUS [5].

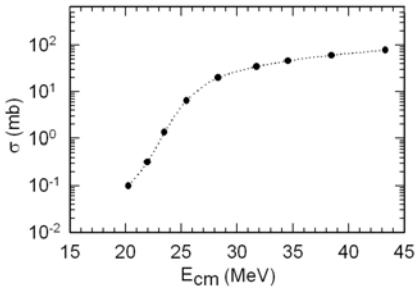

Fig. 2: Measured excitation function for 1n transfer (^{198}Au) reaction. The dotted line is to guide the eye.

The excitation function of *1n*-transfer process is shown in Figure 2. The contribution of other direct reaction component, namely, breakup fusion is not so straight forward. In this system, d/t capture leads to stable isotopes of Hg and could not be measured in the present experiment. On the other hand, α capture leads to Tl isotopes, which can also be produced by decay of Pb isotopes, i.e. evaporation residues. Analysis of the breakup fusion data from α capture is in progress.

The total compound nuclear fusion cross-section was obtained by summing the partial residue cross-sections and is shown in Figure 3. A one dimensional barrier penetration calculation using CCFUS is also shown for comparison, where enhancement below the barrier is clearly visible. Calculations taking into account couplings to n-transfer and breakup-fusion channel will be presented.

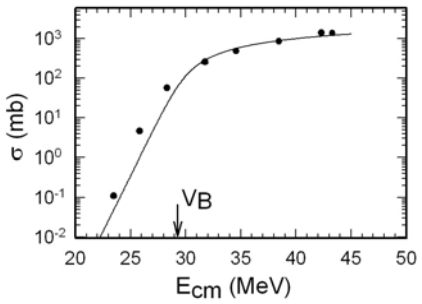

Fig. 3: Excitation function for compound nuclear fusion in ^{7}Li+^{197}Au. The solid line is CCFUS (1D- BPM) calculation.

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References:

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