Transfer reaction studies in $^{7}Li + ^{197}Au$

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Introduction:

Recently influence of direct reactions on fusion process around the barrier has drawn much attention. Particularly, in reactions with radioactive ion beams, the coupling to transfer channel results in large enhancement of fusion probability [1]. Further, the σ_{2n}/σ_{1n} ratio can provide information on structural correlations [2]. However, study of direct reactions at deep sub-barrier energy presents many experimental challenges and very little data exists at low energies. In cases where reaction products are beta unstable, off-line counting technique can be employed for measurement of low cross-section processes. This has been used successfully with RIB as well as weakly bound stable nuclei [3, 4]. The reactions with weakly bound stable nuclei (^{6,7}Li, ^{9}Be) are of great interest as they offer a direct comparison with halo nuclei. In this paper we present the transfer reaction cross-sections ^{7}Li+^{197}Au in near barrier region.

Experimental Details:

The experiment was performed using Pelletron LINAC facility, Mumbai. Self supporting rolled ^{197}Au foils were irradiated with ^{7}Li beam of energies 23−45 MeV. The fusion cross-section measured using offline spectroscopy method has been reported in Ref. [5]. Table 1 lists the gamma lines and half-lives for the 1n and 2n transfer reaction products.

Table 1: Characteristic γ-rays and half-lives for transfer reaction products

Nuclide	E_γ (keV)	$T_{1/2}$
^{198}Au (1n transfer)	411.8	2.695 days
^{199}Au (2n transfer)	158.28, 208.2	3.14 days

The gamma rays corresponding to ^{196}Au ($T_{1/2}$~6.17 days) or ^{198m}Au ($T_{1/2}$~2.27 days) were not observed in this experiment. In case of a d/t transfer, the products (Hg isotopes) are stable and could not be measured by present technique.

It should be mentioned that care has to be taken while extracting the 2n transfer cross-sections in offline counting. Both 158.28, 208.2 keV gamma rays are also produced in ^{199}Tl decay. The nucleus ^{199}Tl is populated via fusion evaporation channel namely, ^{199}Pb (5n evaporation), which decays to ^{199}Tl with a half life of 90 mins. In addition, the breakup-fusion can also lead to ^{199}Tl formation (e.g. ^{197}Au(α,2n)). However, ^{199}Tl has a half life of 7.42 hrs, which is significantly shorter than that of ^{199}Au. Therefore, for 2n transfer cross-section data was collected after 60 hours (~8 half-lives of ^{199}Tl) ensuring that gamma rays of interest are from ^{199}Au and contribution from the ^{199}Tl nucleus is negligible. Figure 1 shows typical decay plots of ^{199}Au at energies below and above the barrier, where the measured half life values are in excellent agreement with reference values as shown in Table 1.

The extracted 2n transfer cross sections are shown in Table 2, together with σ_{1n} [5].

Table 2: 1n and 2n transfer cross sections

E_{lab} (MeV)	σ_{1n} (mb)	σ_{2n} (mb)
45	78 (1)	11.4(1.1)
44	84(2)	13(0.9)
40	63(1)	12.1(0.5)
36	50.6(0.4)	10.3(0.3)
32.4	36.8(0.3)	7.8(0.2)
29	21.2(0.2)	2.9(0.3)
27	6.58(0.04)	0.54(0.03)
24.54	1.331(0.004)	0.06(0.01)
23	0.336(0.003)	0.02(0.005)
21.23	0.099(0.003)	--

It should also be mentioned that at very low energy (E_{cm}/V_B < 0.8), the 1n- transfer cross-section is larger than the fusion cross-section.

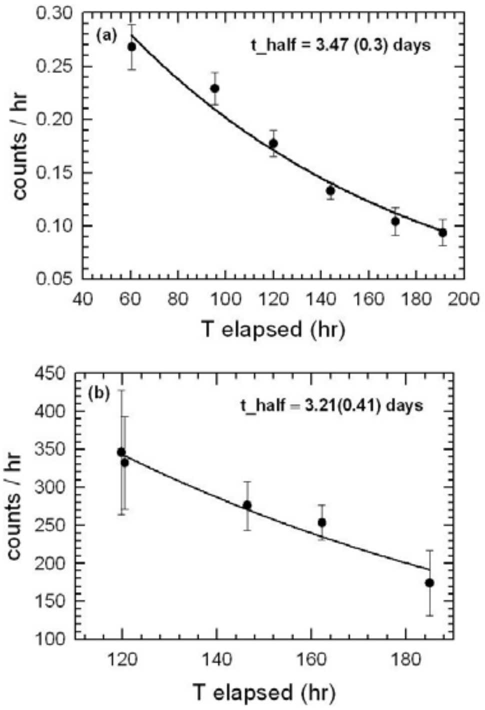

Figure 1: The decay plot of ^{199}Au at (a) 27MeV (below the barrier) and (b) 40MeV (above the barrier) for ^{7}Li+^{197}Au.

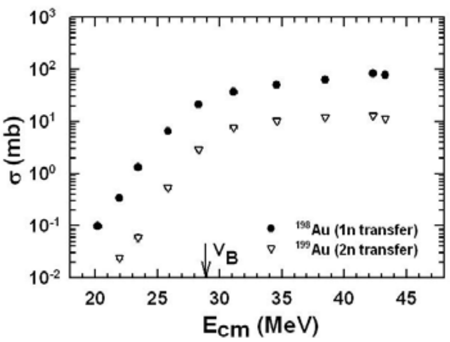

Figure 2: Transfer cross-sections for ^{7}Li+^{197}Au as a function of energy.

The transfer cross-sections (σ_{1n} and σ_{2n}) are plotted in Figure 2 as a function E_{cm}. Similar energy dependence has been reported in ^{6}He + ^{197}Au reaction for production of ^{198}Au [6]. They have suggested that the fall in transfer cross-section at lower energy may be understood in terms of the exponential dependence of the transfer form factor on turning point radius. However, for ^{6}He + ^{197}Au, the absolute magnitude of σ_{1n} is considerably large (>1 barn).

In case of ^{6,8}He, large Q value of 2n transfer leads to population of particle un-bound states in ^{199}Au and therefore is followed by neutron evaporation(s) [6]. Thus, the observed ^{198}Au cross-section contains contribution both from 1n and 2n transfer. However, this is not the case with ^{7}Li, since Q_{gg}=1.181 MeV for 2n transfer is smaller than neutron binding energy in ^{199}Au. For ^{7}Li, the ratio σ_{2n}/σ_{1n} varies only slowly with energy above the barrier, while it increases sharply for E <V_B.

Acknowledgement:

We would like to thank Mr. M.S. Pose for help during the experiment, Ms. Deepa Thapa for target preparation and the accelerator staff for smooth operation of machine.

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